



(51) International Patent Classification:

C03C 3/091 (2006.01) C03C 14/00 (2006.01)
C03C 4/02 (2006.01) H05K 5/00 (2006.01)

(21) International Application Number:

PCT/US2023/082809

(22) International Filing Date:

07 December 2023 (07.12.2023)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

63/433,119 16 December 2022 (16.12.2022) US

(71) Applicant: **CORNING INCORPORATED** [US/US]; 1 Riverfront Plaza, Corning, New York 14831 (US).

(72) Inventors: **FUTAGAMI, Mai L.**; 437 Potomac Drive, Lexington, Kentucky 40503 (US). **GUO, Xiaojun**; 37 Copper Woods, Pittsford, New York 14534 (US). **KUO, Po Hsuen**; 105 Woods Edge Drive, Painted Post, New York 14870 (US). **LOCKER, Sean Thomas Ralph**; 11 West Third Street, Apt. 412, Corning, New York 14830 (US).

SMITH, Liping Xiong; 6 Jacob Drive, Painted Post, New York 14870 (US).

(74) Agent: **MAGAZINER, Russell S.**; Corning Incorporated, Intellectual Property Department, SP-TI-03-1, Corning, New York 14831 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ,

(54) Title: GLASS ARTICLES AND NATIVELY COLORED GLASS HOUSINGS

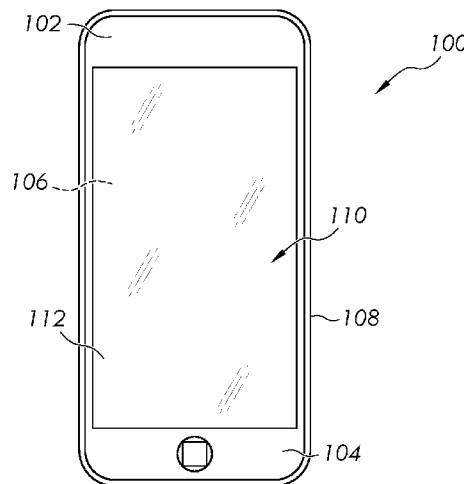


FIG. 1

(57) Abstract: Glass articles include a thickness defined between a first major surface and a second major surface opposite the first major surface. The glass article includes a plurality of particulates distributed throughout a volume of the glass article. A median of a maximum dimension of the plurality of particulates range from about 30 nanometers to about 500 micrometers. The plurality of particulates include a colorant. The glass article exhibits an absolute value of a CIE a* value of the glass article is about 0.3 or more, and an absolute of the CIE b* value of the glass article is about 0.2 or more. The glass article includes at least one alkali metal oxide.

RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

GLASS ARTICLES AND NATIVELY COLORED GLASS HOUSINGS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority under 35 U.S.C. § 119 of U.S. Provisional Application No. 63/433,119 filed December 16, 2022, the content of which is incorporated herein by reference in its entirety.

FIELD

[0002] The present disclosure relates generally to glass articles and natively colored glass housings and, more particularly, to glass articles and natively colored glass housings comprising a plurality of particulates.

BACKGROUND

[0003] Glass articles are commonly used, for example, in display devices, for example, liquid crystal displays (LCDs), electrophoretic displays (EPD), organic light-emitting diode displays (OLEDs), plasma display panels (PDPs), or the like. Glass articles can form part of a housing as well as covering the display.

[0004] Aluminosilicate glass articles may exhibit superior ion-exchangeability and drop performance. Various industries, including the consumer electronics industry, desire colored materials with the same or similar strength and fracture toughness properties as existing, non-colored, ion-exchange strengthened glasses. However, it was believed that there was a limit as to how much colorant or color saturation could be efficiently achieved without the formation of defects, such as unwanted clumps of colorants and/or agglomerations of unmelted raw materials in the glass. Accordingly, a need exists for an alternative colored glass article with a higher concentration of colorants and/or more saturated color having good strength, rich color, consistency of composition, toughness, and/or dielectric qualities to facilitate useability and communication, such as for use with consumer electronics.

SUMMARY

[0005] There are set forth herein glass articles and natively colored glass housings including the same that contain some types of particulates, but not others, such as those that may be unwanted, and where the articles and housings provide a rich, saturated color, which can be aesthetically pleasing. Providing the more saturated color can be achieved without noticeable visual defects associated with the particulates, for example, when a majority of the particulates (or a portion described

above) have a maximum dimension less than about 50 μm (e.g., less than about 40 μm). Since the particulates comprise colorants, the particulates enable higher amounts of colorant to be included in glass articles without noticeable visual defects to achieve colors that may not otherwise be possible with a natively colored glass article and/or natively colored glass housing.

[0006] Without wishing to be bound by theory, it is believed that traditional colorant approaches produce particles less than 50 nm (e.g., less than 30 nm), if any. For example, as described above, the length of silver particles is less than 40 nm with smaller maximum values provided. Likewise, gold particles for imparting color comprise nanometer scale maximum dimensions (e.g., less than 30 nm, less than 20 nm, from 1 nm to 20 nm). Indeed, it is believed that particulates of gold and silver larger than 50 nm would not be effect as colorants. Consequently, the particulates (and clusters thereof) described herein are of a different scale than would be achieved in traditional approaches.

[0007] On the other hand, large aggregates encountered in conventional approaches to increasing colorant concentration tend to about 100 μm or more, which can be noticeable with the naked eye and/or aesthetically unpleasing. In contrast, the particulates of the present disclosure can have a median of a maximum dimension of a particulate and/or a median of a maximum dimension of a cluster size that is 50 μm or less (e.g., 40 μm or less, from 10 μm to 40 μm , from 10 μm to 30 μm), and/or a distribution of the particulates or clusters of the present disclosure greater than 40 μm or more (e.g., 50 μm or more) can be less than 40% (e.g., less than 20%).

[0008] The inventors of the present application have discovered that particulates and/or clusters a corresponding maximum dimension (e.g., median of the corresponding maximum dimension or maximum value of the corresponding maximum dimension) from 30 nm to 50 μm (e.g., from 50 nm to 50 μm , 2 μm to 40 μm , etc.) may not be noticeable to the naked eye in combination with the saturated colors of the present disclosure. Without wishing to be bound by theory, it is believed that the particulates and/or clusters of particulates do not change the color of the glass article even though the particulates and/or clusters comprise the colorant. Further, particulates with a maximum dimension of less than or equal to 2 μm (e.g., from 30 nm to 2 μm , from 50 nm to 2 μm) may not be visible even with optical microscopy techniques. Consequently, glass articles with the particulates and/or clusters of particulates described herein can be made in a more cost-effective manner relative to

glass articles that are free of such particulates. For example, cheaper and/or less purified raw materials that result in such particulates and/or clusters can be used, and/or processing time associated with dissolving the raw materials can be reduced that can reduce costs and increase cycle time. Further, without wishing to be bound by theory, the particulates and/or clusters of the present disclosure may increase a toughness (e.g., fracture resistance) of the glass article, for example, by deflecting and/or arresting crack propagation that is incident on such structures.

[0009] The glass-based material of the glass article can provide good dimensional stability, good impact resistance, good crack resistance, good puncture resistance, and/or good flexural strength. The glass article can include a compressive stress region (e.g., be chemically strengthened), which can provide improved crack resistance, puncture resistance, impact resistance, and/or improved flexural strength. Minimizing the combination of R_2O , CaO , MgO , and ZnO in the glass composition may provide the resultant colored glass article with a desirable dielectric constant, for example when the colored glass article is used as a portion of a housing for an electronic device. Providing a dielectric constant for frequencies from 10 GHz to 60 GHz from 5.6 to 6.4 can allow wireless communication through the glass article.

[0010] Providing a natively colored glass housing with a colored glass article can eliminate the need for an additional layer to impart color to the housing, which can simplify assembly and provide a more consistent color. Consequently, the natively colored glass housing including the glass article can provide an aesthetically pleasing appearance (e.g., color) while simultaneously protecting an electronic device from damage and/or permitting wireless communication therethrough.

[0011] Some example aspects of the disclosure are described below with the understanding that any of the features of the various aspects may be used alone or in combination with one another.

[0012] Aspect 1. A glass article comprising:

a thickness defined between a first major surface and a second major surface opposite the first major surface; and

a plurality of particulates distributed throughout a volume of the glass article, the plurality of particulates comprising colorant, the plurality of particulates comprising a plurality of clusters, each cluster comprising one or more particulates of the plurality of particulates with adjacent pairs of particulates within 15 micrometers

of one another, and a median of a maximum dimension of the plurality of clusters is from about 2 μm to about 40 μm ,

wherein the glass article exhibits a CIE L^* value of about 50 or more, an absolute value of a CIE a^* value of the glass article is about 0.3 or more, and an absolute of the CIE b^* value of the glass article is about 0.2 or more, and the glass article comprises at least one alkali metal oxide.

[0013] Aspect 2. The glass article of aspect 1, wherein the colorant comprises chromium, cerium, cobalt, gold, silver, nickel, or combinations thereof.

[0014] Aspect 3. The glass article of any one of aspects 1-2, wherein a concentration of the colorant is about 50 ppm or more.

[0015] Aspect 4. The glass article of aspect 3, wherein the concentration of the colorant is from about 500 ppm to about 10,000 ppm.

[0016] Aspect 5. The glass article of any one of aspects 1-4, wherein the plurality of particulates comprise a median of an maximum dimension ranging from about 30 nm to about 40 μm .

[0017] Aspect 6. The glass article of any one of aspects 1-4, wherein a median of the maximum dimension of the plurality of particulates is from about 2 μm to about 30 μm .

[0018] Aspect 7. The glass article of any one of aspects 1-4, wherein 80% or more of a distribution of a maximum dimension of the plurality of particulates is from about 30 nm to about 50 μm .

[0019] Aspect 8. The glass article of any one of aspects 1-4, wherein 60% or more of a distribution of a maximum dimension of the plurality of particulates is from about 2 μm to about 40 μm .

[0020] Aspect 9. The glass article of any one of claims 7-8, wherein 5% or less of the distribution of the maximum dimension of the plurality of particulates is 100 μm or more.

[0021] Aspect 10. The glass article of any one of aspects 5-9, wherein a maximum value of the maximum dimension of the plurality of particulates is about 50 μm or less.

[0022] Aspect 11. The glass article of any one of claims 5-10, wherein the plurality of particulates further comprises a set of particulates with a maximum dimension from 30 nm to 2 μm .

[0023] Aspect 12. The glass article of any one of aspects 1-11, wherein a concentration of the plurality of particulates in the glass article is about 10 particulates per kilogram of the glass article or more.

[0024] Aspect 13. The glass article of aspect 12, wherein the concentration of the plurality of particulates in the glass article ranges from about 100 particulates per kilogram of the glass article to about 100 particulates per kilogram of the glass article.

[0025] Aspect 14. The glass article of any one of aspects 1-13, wherein 80% or more of a distribution of the maximum dimension of the plurality of clusters is from about 50 nm to about 50 μm .

[0026] Aspect 15. The glass article of aspect 14, wherein 60% or more of a distribution of the maximum dimension of the plurality of clusters is from about 2 μm to about 40 μm .

[0027] Aspect 16. The glass article of any one of aspects 14-15, wherein 5% or less of the distribution of the maximum dimension of the plurality of clusters is 100 μm or more.

[0028] Aspect 17. The glass article of any one of aspects 13-16, wherein a concentration of the plurality of clusters in the glass article is about 10 particulates per kilogram of the glass article or more.

[0029] Aspect 18. The glass article of aspect 17, wherein the concentration of the plurality of clusters in the glass article ranges from about 100 particulates per kilogram of the glass article to about 100 particulates per kilogram of the glass article.

[0030] Aspect 19. The glass article of any one of aspects 1-18, wherein the glass article comprises a CIE a^* value from about -15 to -1.

[0031] Aspect 20. The glass article of any one of aspects 1-19, wherein the CIE b^* value is from about 1.5 to about 5.

[0032] Aspect 21. The glass article of any one of aspects 1-20, wherein the CIE L^* value is from about 80 to 96.

[0033] Aspect 22. The glass article of any one of aspects 1-21, further comprising:

from about 50 mol% to about 75 mol% SiO_2 ;

from about 5 mol% to about 20 mol% Al_2O_3 ;

from about 15 mol% to about 20 mol% of the at least one alkali metal oxide;

and

at least one of B_2O_3 or P_2O_5 .

[0034] Aspect 23. The glass article of any one of aspects 1-21, wherein the glass article comprises, as a mol% of the glass article:

from 60 mol% to 65 mol% SiO₂;

from 12 mol% to 17 mol% Al₂O₃;

from 3 mol% to 6 mol% B₂O₃;

from 10 mol% to 16 mol% of at least one alkali metal oxide, alkali metal oxides including Li₂O, Na₂O, and K₂O;

from 3 mol% to 5 mol% CaO;

from 0 mol% to 1 mol% ZrO₂; and

from 0 mol% to 0.25 mol% SnO₂.

[0035] Aspect 24. The glass article of any one of aspects 1-23, wherein the glass article comprises a soda lime glass, an alkali aluminosilicate glass, an alkali containing borosilicate glass, or an alkali aluminoborosilicate glass.

[0036] Aspect 25. The glass article of any one of aspects 1-24, wherein the glass article comprises at least one crystalline phase.

[0037] Aspect 26. The glass article of aspect 25, wherein a crystallinity of the glass article is 10 wt% or less.

[0038] Aspect 27. The glass article of any one of aspects 1-26, further comprising a first compressive stress region extending to a first depth of compression from the first compressive stress region.

[0039] Aspect 28. The glass article of aspect 27, wherein a maximum compressive stress of the first compressive stress region is about 400 MegaPascals or more.

[0040] Aspect 29. The glass article of any one of aspects 1-28, wherein the glass article comprises a dielectric constant at frequencies from 10 GigaHertz to 60 GigaHertz of from about 5.6 to about 6.4.

[0041] Aspect 30. The glass article of any one of aspects 1-29, wherein the glass article exhibits a fracture toughness of 0.60 MPam^{1/2} or more, and a Young's modulus from about 50 GigaPascals to about 100 GigaPascals.

[0042] Aspect 31. A natively colored glass housing for an electronic device comprising:

the glass article of any one of aspects 1-30;

circuitry comprising an antenna that transmits signals within a range of 26 GHz to 40 GHz;

the glass article at least partially surrounding the circuitry; and

a structure formed as an integral portion of the glass article, wherein the structure comprises a perimeter demarcating a second thickness of the structure that differs from the thickness of the glass article by at least 150 μm ,

wherein the antenna is positioned and oriented such that the signals are transmitted through the structure of the glass sheet of the panel of the housing.

[0043] Aspect 32. A natively colored glass housing for a consumer electronic device, the housing comprising:

the glass article of any one of claims 1-30; and

a reflector layer disposed on the glass article, the reflector layer is opaque and has a CIE L^* value > 70 ,

wherein the thickness of the glass article is from about 30 micrometers to about 5 millimeters, a total transmittance of at least one 10 nm band within the wavelength range of 380 nm to 750 nm through the first thickness is from 3% to 80%.

[0044] Aspect 33. A consumer electronic product, comprising:

a housing comprising a front surface, a back surface, and side surfaces;

electrical components at least partially within the housing, the electrical components comprising a controller, a memory, and a display, the display at or adjacent the front surface of the housing; and

a cover substrate disposed over the display,

wherein at least one of a portion of the housing comprises the glass article of any one of aspects 1-30.

[0045] Throughout the disclosure, the drawings are used to emphasize certain aspects. As such, it should not be assumed that the relative size of different regions, portions, and substrates shown in the drawings are proportional to its actual relative size, unless explicitly indicated otherwise.

BRIEF DESCRIPTION OF THE DRAWINGS

[0046] The above and other features and advantages of aspects of the present disclosure are better understood when the following detailed description is read with reference to the accompanying drawings, in which:

[0047] **FIG. 1** is a schematic plan view of an example consumer electronic device according to aspects of the disclosure;

[0048] **FIG. 2** is a schematic perspective view of the example consumer electronic device of **FIG. 1**;

[0049] **FIG. 3** is a conceptual diagram from a back view of a communicating device, more specifically of a cellular phone, according to an aspect of the disclosure;

[0050] **FIG. 4** is a simplified conceptual view of the device of **FIG. 3** in a slightly exploded cross-section taken along line 4-4 of **FIG. 3**;

[0051] **FIG. 4A** shows an enlarged view **4A** of **FIG. 4**;

[0052] **FIG. 4B** shows an enlarged view **4B** of **FIG. 4**;

[0053] **FIG. 5** is a cross-sectional view of a natively colored glass housing including a glass article in accordance with aspects of the disclosure;

[0054] **FIG. 6** shows an enlarged view **6** of **FIG. 5**;

[0055] **FIG. 7** illustrates a flow chart of methods of making glass articles and/or natively colored glass housings in accordance with aspects of the disclosure;

[0056] **FIG. 8** illustrates a step in a method of making glass articles and/or natively colored glass housings comprising heating the glass article;

[0057] **FIG. 9** illustrates a step in a method of making glass articles and/or natively colored glass housings comprising ion exchange; and

[0058] **FIGS. 10-13** schematically represent clusters of particulates observed for example glass articles.

DETAILED DESCRIPTION

[0059] Aspects will now be described more fully hereinafter with reference to the accompanying drawings in which example aspects are shown. Whenever possible, the same reference numerals are used throughout the drawings to refer to the same or like parts.

[0060] **FIGS. 3-5** illustrate views of natively colored glass housings **322** or **500** including glass articles **511** that can be incorporated to consumer electronic products (e.g., display devices), for example, those shown in **FIGS. 1-4**. Unless otherwise noted, a discussion of features of aspects of one foldable apparatus can apply equally to corresponding features of any aspects of the disclosure. For example, identical part numbers throughout the disclosure can indicate that, in some aspects, the identified features are identical to one another and that the discussion of the identified feature of one aspect, unless otherwise noted, can apply equally to the identified feature of any of the other aspects of the disclosure.

[0061] Aspects of the disclosure can comprise a consumer electronic product. The consumer electronic product can comprise a front surface, a back surface, and side surfaces. The consumer electronic product can further comprise electrical

components at least partially within the housing. The electrical components can comprise a controller, a memory, and a display. The display can be at or adjacent to the front surface of the housing. The display can comprise liquid crystal display (LCD), an electrophoretic displays (EPD), an organic light-emitting diode (OLED) display, or a plasma display panel (PDP). The consumer electronic product can comprise a cover substrate disposed over the display. In aspects, at least one of a portion of the housing or the cover substrate comprises the foldable apparatus discussed throughout the disclosure. The consumer electronic product can comprise a portable electronic device, for example, a smartphone, a tablet, a wearable device, or a laptop.

[0062] The foldable apparatus disclosed herein may be incorporated into another article, for example, an article with a display (or display articles) (e.g., consumer electronics, including mobile phones, tablets, computers, navigation systems, wearable devices (e.g., watches), and the like), architectural articles, transportation articles (e.g., automotive, trains, aircraft, sea craft, etc.), appliance articles, or any article that may benefit from some transparency, scratch-resistance, abrasion resistance or a combination thereof. An exemplary article incorporating any of the foldable apparatus disclosed herein is shown in **FIGS. 1-2**. Specifically, **FIGS. 1-2** show a consumer electronic device **100** including a housing **102** having front **104**, back **106**, and side surfaces **108**. Although not shown, the consumer electronic device can comprise electrical components that are at least partially inside or entirely within the housing. For example, electrical components include at least a controller, a memory, and a display. As shown in **FIGS. 1-2**, the display **110** can be at or adjacent to the front surface of the housing **102**. The consumer electronic device can comprise a cover substrate **112** at or over the front surface of the housing **102** such that it is over the display **110**. In aspects, at least a portion of the housing **102** may include the glass article and/or the natively colored glass housing disclosed herein.

[0063] Referring to **FIGS. 3-4**, a communicating device **310** (i.e., electronic device with wireless signal communication capability; e.g., broadband communicating device, cellular phone, smartphone, control panel, console, dashboard, tablet, handheld computer, electronic tool) includes circuitry **312** (see **FIG. 4**). The consumer electronic device **100** shown in **FIGS. 1-2** is an example of the communicating device **310**. In aspects, the circuitry **312** includes an antenna **314**. The circuitry **312** may further include other components, for example a camera **316** (**FIG.**

3), printed circuit board, processor, memory, display **110** (**FIG. 3**), battery, connector port, and other componentry.

[0064] In aspects, the antenna **314** can comprise a patterned metal wire or layer, or other such device (e.g., transceiver, receiver, transmitter, antenna array, communication module) configured to transmit and/or receive communication signals at or over a frequency range. A surface area of the antenna is defined as an area within a perimeter **338** surrounding the antenna. In further aspects, the surface area of the antenna can be 25 cm² or less, 15 cm² or less, 10 cm² or less, 100 μm² or more, 1 mm² or more, 25 mm² or more, or 100 mm² or more. In further aspects, the antenna **314** can be configured for wireless communication (e.g., transmitting, receiving, operating, and/or otherwise communicating) with transmission of signals at a frequency of 100 MHz or more, 1 GHz or more, 10 GHz or more, 24 GHz or more, 24.25 GHz or more, GHz or more, 26 GHz or more, 28 GHz or more, 100 GHz or less, 60 GHz or less, 50 GHz or less, 47 GHz or less, or 40 GHz or less. For example, the antenna may operate in a frequency range from 26 GHz to 40 GHz or from 60 GHz to 80 GHz. Communication at a frequency greater than 26 GHz may be particularly benefited from the present disclosure because such signals may be more inhibited by transmission through solid materials, and may accordingly be improved greatly by use of a housing **102** incorporating the structure **326** described herein. As such, the antenna **314** can be positioned and/or oriented such that signals are transmitted through the structure **326** (e.g., directly facing the structure **326**, the structure **326** may overlay at least a portion of the antenna **314**). In further aspects, a minimum distance between the antenna **314** to a portion of the glass article defining the structure **326** can be 5 mm or less, 3 mm or less, 2 mm or less, or 0.6 mm or less. Alternatively, the antenna **314** and the portion of the glass article defining the structure **326** may be in direct contact or separated only by a thickness of the coating **328**.

[0065] In aspects, as shown in **FIGS. 3-4**, the communicating device **310** includes a housing **102** enclosing some or all of the circuitry **312**. The housing **102** may include a frame **320**, for example a metallic (e.g., aluminum, steel) sidewall, a natively colored glass housing **322** (e.g., back), and a display **110** (e.g., see **FIGS. 1-2**). The housing **102** may include alternative structures as well, for example a panel integral with frame forming a back with sidewalls within which circuitry **312** and

other components may be located, and/or such as having the housing **102** integrated with a keyboard, touch panel, or other features in addition to or instead of the display.

[0066] In aspects, as shown in **FIGS. 3-4**, the natively colored glass housing **322** may comprise (e.g., include, mostly consist of by weight or volume, be) a glass article **350**. The glass article **350** may be flat, may have curved edges, may be bowed, or otherwise. As shown in **FIG. 4**, The natively colored glass housing **322** may include layer(s) **328**, for example a scratch-resistant coating, an anti-reflective, or other coatings on a surface of the glass article **350** (e.g., first major surface **332**, second major surface **330** of the glass article **350**), and may further include decorative ink and/or other layers on a surface thereof as well. For example, the coating **328** on the second major surface **330** of the glass article can comprise any of the aspects and/or be the same as the reflector **501** discussed below with reference to **FIG. 5**. Conceivably, although not shown, the natively colored glass housing may simply consist of a sheet of glass, where layers, coatings, etc. are unneeded for the corresponding device.

[0067] In aspects, as shown in **FIG. 4**, the glass article **350** includes a structure **326**. The structure **326** may be an integral portion of the glass article **350** such that glass of the glass article **350** continuously extends throughout the glass article **350**, including defining the structure **326**. For example, the structure **326** may be a recess, trench, bump, plateau, or other feature formed in or on the glass article **350**. The glass article **350** may have more than one such structure **326**. Such a structure may be formed in many conceivable ways, for example, by etching away a portion of the glass article **350**, milling away a portion of the glass article **350**, pressing the glass of the glass article **350** in a mold, welding additional glass onto the glass article **350**. As such, glass forming the structure **326** may have the same composition as the glass of the glass article **350** outside of the structure **326**. The glass of the structure **326** may also share a common microstructure with the glass of the glass article **350** outside of the structure **326**, such as having the same types and distributions of crystals, for example if the glass is a glass-ceramic, and/or the same types and distributions of colorants. In aspects, as shown in **FIG. 4**, the structure **326** is formed as a recess relative to a major surface (e.g., second major surface **330**) of the glass article **350**. As used herein, the “major surfaces” of the glass article **350** sheet are sides of the sheet having the most surface area (e.g., front and back sides). A major surface may be surrounded by edges of a sheet that extend between the major

surfaces. For a more complex body, major surfaces may be surfaces thereof have areas defined by perimeters of edges, where the major surfaces have surface areas substantially greater than other surfaces of the body (e.g., sidewalls), for example at least 50% greater.

[0068] In aspects, as shown in **FIG. 4**, the glass article **350** comprises a thickness **337**, which is defined as an average distance between the second major surface **330** and the first major surface **332** opposite the first major surface excluding any portion of the glass article **350** including the structure **326** described above. In further aspects, the thickness **337** can be within one or more of the ranges discussed below for the thickness **517** with reference to **FIG. 5**. In further aspects, the thickness **337** can be substantially uniform across the second major surface **330** and/or more than 50% of the glass article can comprise a local thickness within 10% of the thickness **337**.

[0069] In aspects, as shown in **FIGS. 3-4**, the structure **326** comprises a perimeter **340** on a major surface (e.g., second major surface **330**) of the glass article **350**, where the perimeter **340** demarcates a second thickness **327** of the structure **326** that differs from the thickness **337**, for example, by 50 μm or more, by 100 μm or more, by 150 μm or more, by 200 μm or more, by 300 μm or more, by 500 μm or more (e.g., located at corner **336** as shown in **FIG. 4B**). For example, the second thickness **327** of the structure **326** may be 600 μm or less, 500 μm or less, or 400 μm or less, while the thickness **337** of the glass article **350** may be 600 μm or more, 700 μm or more, 800 μm or more (or any of the ranges described herein for the thickness **517**). Alternatively, although not shown, the second thickness **327** may be greater than the thickness **337** by 50 μm or more, by 100 μm or more, by 150 μm or more, by 200 μm or more, by 300 μm or more, by 500 μm or more. As shown in **FIGS. 3-4**, the perimeter **340** forms a closed loop on the major surface (e.g., second major surface **330**), where a shape of the perimeter **340** may be rectilinear, curved, or curvilinear and can comprise any shape (e.g., square, blocky, ziggurat-shaped with rectangular rows of diminishing length overlaying one another, triangular, oval, or even more complex geometries). For example, the perimeter **340** of the structure **326** may be shaped as a silhouette of a logo and/or registered trademark or other recognizable design or shape. As used herein, a surface area of the structure is defined as the surface area within the perimeter of the structure projected onto the first major surface of the glass article. In aspects, a surface area of the structure **326** may be 100

cm² or less, 50 cm² or less, 25 cm² or less, 25 μm² or more, 100 μm² or more, 1 mm² or more, 25 mm² or more, or 4 cm² or more. In aspects, the glass article can comprise a housing of a communicating device and the glass article may have more than one such structure, as shown in **FIG. 3**, where the structure **326** overlays the antenna **314** while another structure **342** forms a portion of a camera or sensor encasement (e.g., camera **316**). In further aspects, the structure **326 and/or 342** can overlay at least a portion and/or all of the surface area corresponding to the antenna **314** and/or the camera **316**.

[0070] Forming the structure **326 and/or 342** in a middle or interior portion of the glass article **350**, spaced inward from outside edges **344** of the glass article **350** (see, **FIG. 3**) may help mitigate structural weaknesses or stress concentrations of the glass article **350** that may be associated forming the structure **326 and/or 342**. Forming edges or corners **334 and/or 336** (see **FIGS. 4A-4B**) or the perimeter **340** of the structure **326** with a geometry that reduces concentration of stress at the edges or corners **334 and/or 336** may also help strengthen the glass article **350** when forming the structure **326**. Such a geometry may include rounding or dulling vertices or corners **334 and/or 336** of the structure **326**, as may be done through etching or localized melting/heating (e.g., with a laser). For example, the glass article **350** may smoothly transition between the thickness **337** and the second thickness **327** at corner **334 and/or 336** over a distance “**D**” (see **FIG. 4A**) from about 5 μm to 700 μm, from about 10 μm to about 500 μm, from about 20 μm to about 500 μm, from about 100 μm to about 500 μm, or any range or subrange therebetween, as measured in a direction perpendicular to a direction of the thickness **337**.

[0071] Throughout the disclosure, CIE color coordinates are with reference to the CIELAB 1976 color space established by the International Commission on Illumination (CIE). Unless otherwise indicated, CIE color coordinates are measured in transmission through the glass article using an F02 illuminant and an observer angle of 10°. The CIELAB 1976 color space expresses color as three values: L* for the lightness from black (0) to white (100), a* from green (-) to red (+), and b* from blue (-) to yellow (+).

[0072] **FIG. 5** illustrates a natively colored glass housings **500** comprising the glass article **511** and the reflector **501**. In aspects, the reflector **501** comprises an opaque material. As used herein, opaque means that an average transmittance in the wavelength range of 400 nm to 700 nm through a 1.0 mm thick piece of a material is

10% or less. The average transmittance in the wavelength range of 400 nm to 700 nm is calculated by measuring the transmittance of whole number wavelengths from about 400 nm to about 700 nm and averaging the measurements. In aspects, the reflector comprises a CIE L* value of about 70 or more. An exemplary material for the reflector is aluminum. In aspects, as shown in **FIG. 5**, the glass article **511** can be disposed on and/or contact a surface **503** of the reflector **501** can contact the glass article **511**. Providing the reflector can increase a perceived brightness of the glass article.

[0073] Unless otherwise indicated, transmittance data (total transmittance and diffuse transmittance) in the visible spectrum is measured with a Lambda 950 UV/Vis/NIR Spectrophotometer manufactured by PerkinElmer Inc. (Waltham, Massachusetts USA). The Lambda 950 apparatus was fitted with a 150 mm integrating sphere. Data was collected using an open beam baseline and a Spectralon® reference reflectance disk. For total transmittance (Total Tx), the sample is fixed at the integrating sphere entry point. The term “average transmittance,” as used herein with respect to the visible spectrum, refers to the average of transmittance measurements made within a given wavelength range with each whole numbered wavelength weighted equally. Unless otherwise indicated, as described herein, the “average transmittance” with respect to the visible spectrum is reported over the wavelength range from 380 nm to 750 nm (inclusive of endpoints). Unless otherwise specified, the average transmittance is indicated for article thicknesses from 0.4 mm to 5 mm, inclusive of endpoints. Unless otherwise specified, when average transmittance is indicated, this means that each thickness within the range of thicknesses from 0.4 mm to 5 mm has an average transmittance as specified. For example, colored glass articles having average transmittances of 10% to 92% over the wavelength range from 380 nm to 750 nm means that each thickness within the range of 0.4 mm to 5 mm (e.g., 0.6 mm, 0.9 mm, 2 mm, etc.) has an average transmittance in the range of 10% to 92% for the wavelength range from 380 nm to 750 nm.

[0074] As used herein, if a first layer and/or component is described as “disposed over” a second layer and/or component, other layers may or may not be present between the first layer and/or component and the second layer and/or component. Furthermore, as used herein, “disposed over” does not refer to a relative position with reference to gravity. For example, a first layer and/or component can be considered “disposed over” a second layer and/or component, for example, when the

first layer and/or component is positioned underneath, above, or to one side of a second layer and/or component. As used herein, a first layer and/or component described as “bonded to” a second layer and/or component means that the layers and/or components are bonded to each other, either by direct contact and/or bonding between the two layers and/or components or via an adhesive layer. As used herein, a first layer and/or component described as “contacting” or “in contact with” a second layer and/or components refers to direct contact and includes the situations where the layers and/or components are bonded to each other.

[0075] As shown in **FIG. 5**, the glass article **511** comprises a first major surface **513** and a second major surface **515** opposite the first major surface **513**. In aspects, as shown, the first major surface **513** and/or the second major surface **515** can comprise planar surfaces, although other shapes and designs are possible in other aspects. A thickness **517** of the glass article **511** is defined as an average distance between the first major surface **513** and the second major surface **515**. In aspects, the thickness **517** can be about 30 micrometers (μm) or more, about 50 μm or more, about 80 μm or more, about 90 μm or more, about 100 μm or more, about 150 μm or more, about 200 μm or more, about 400 μm or more, about 500 μm or more, about 600 μm or more, about 5 millimeters (mm) or less, about 3 mm or less, about 2 mm or less, about 1 mm or less, about 800 μm or less, about 700 μm or less, about 600 μm or less, about 550 μm or less, about 500 μm or less, or about 300 μm or less. In aspects, the thickness **517** can be in a range from about 30 μm to about 5 mm, from about 50 μm to about 3 mm, from about 80 μm to about 2 mm, from about 90 μm to about 1 mm, from about 100 μm to about 800 μm , from about 150 μm to about 700 μm , from about 200 μm to about 600 μm , from about 300 μm to about 550 μm , from about 400 μm to about 500 μm , or any range or subrange therebetween.

[0076] The glass article **511 and/or 350** comprises a glass-based material. In aspects, the glass-based material can comprise a pencil hardness of 8H or more, for example, 9H or more. As used herein, pencil hardness is measured using ASTM D 3363-20 with standard lead graded pencils. Throughout the disclosure, an elastic modulus (e.g., Young’s modulus) and/or a Poisson’s ratio is measured using ISO 527-1:2019. In aspects, the glass article **511 and/or 350** can comprise an elastic modulus in a range from about 40 GPa to about 140 GPa, from about 50 GPa to about 100 GPa, from about 60 GPa to about 80 GPa, or any range or subrange therebetween.

[0077] As used herein, “glass-based” includes both glasses and glass-ceramics, wherein glass-ceramics have one or more crystalline phases and an amorphous, residual glass phase. A glass-based material may comprise an amorphous material (e.g., glass) and optionally one or more crystalline materials (e.g., ceramic). Amorphous materials and glass-based materials may be strengthened. As used herein, the term “strengthened” may refer to a material that has been chemically strengthened, for example, through ion exchange of larger ions for smaller ions in the surface of the glass article, as discussed below. However, other strengthening methods, for example, thermal tempering, or utilizing a mismatch of the coefficient of thermal expansion between portions of the glass article to create compressive stress and central tension regions, may be utilized to form strengthened glass articles. Exemplary glass-based materials, which may be free of lithia or not, comprise soda lime glass, alkali aluminosilicate glass, alkali-containing borosilicate glass, alkali-containing aluminoborosilicate glass, alkali-containing phosphosilicate glass, and alkali-containing aluminophosphosilicate glass. In aspects, glass-based material can comprise an alkali-containing glass or an alkali-free glass, either of which may be free of lithia or not. In aspects, the glass material can be alkali-free and/or comprise a low content of alkali metals (e.g., R_2O of about 10 mol% or less, wherein R_2O comprises Li_2O , Na_2O , K_2O , or the more expansive list provided below). In one or more aspects, a glass-based material may comprise, in mole percent (mol%): SiO_2 in a range from about 40 mol% to about 80 mol%, Al_2O_3 in a range from about 5 mol% to about 30 mol%, B_2O_3 in a range from 0 mol% to about 10 mol%, ZrO_2 in a range from 0 mol% to about 5 mol%, P_2O_5 in a range from 0 mol% to about 15 mol%, TiO_2 in a range from 0 mol% to about 2 mol%, R_2O in a range from 0 mol% to about 20 mol%, and RO in a range from 0 mol% to about 15 mol%. As used herein, R_2O can refer to an alkali-metal oxide, including Li_2O , Na_2O , and K_2O . As used herein, RO can refer to MgO , CaO , SrO , BaO , and ZnO . In further aspects, the glass-based material may comprise (in mol%) from about 50 mol% to about 75 mol% SiO_2 , from about 5 mol% to about 20 mol% Al_2O_3 , from about 15 mol% to about 20 mol% of at least one alkali metal oxide (R_2O), and at least one of B_2O_3 or P_2O_5 . In further aspects, the glass-based material may comprise (in mol%) from 60 mol% to 65 mol% SiO_2 , from 12 mol% to 17 mol% Al_2O_3 , from 3 mol% to 6 mol% B_2O_3 , from 13 mol% to 20 mol% of at least one alkali metal oxide (R_2O), from 0.5 mol% to 4 mol% CaO , from 0 mol% to 1 mol% ZnO , from 0 mol% to 1 mol% ZrO_2 , and from 0.01 mol% to 0.25

mol% SnO_2 . In further aspects, the glass-based material may comprise (in mol%) from 60 mol% to 65 mol% SiO_2 , from 12 mol% to 17 mol% Al_2O_3 , from 3 mol% to 6 mol% B_2O_3 , from 10 mol% to 16 mol% of at least one alkali metal oxide (R_2O), from 3 mol% to 5 mol% CaO , from 0 mol% to 1 mol% ZrO_2 , and from 0 mol% to 0.25 mol% SnO_2 . In any of the aspects, the glass-based material can comprise from 0.2 mol% to 0.5 mol% ZrO_2 . In aspects, a glass-based material may optionally further comprise in a range from 0 mol% to about 2 mol% of each of Na_2SO_4 , NaCl , NaF , NaBr , K_2SO_4 , KCl , KF , KBr , As_2O_3 , Sb_2O_3 , SnO_2 , Fe_2O_3 , MnO , MnO_2 , MnO_3 , Mn_2O_3 , Mn_3O_4 , Mn_2O_7 . In aspects, the glass-based material can comprise a colorant selected from a group consisting of silver, gold, chromium, cobalt, nickel, cerium, copper, and combinations thereof. For example, the glass-based material can comprise titanium oxide, zirconia, iron oxide, cerium oxide, or combinations thereof. In further aspects, the glass-based material can comprise from 5 parts-per-million (ppm) to 15 ppm gold. In further aspects, a concentration of the colorant can be about 50 ppm or more, about 100 ppm or more, about 300 ppm or more, about 500 ppm or more, about 1,000 ppm or more, about 2,000 ppm or more, about 5,000 ppm or more, about 10,000 ppm or more, about 50,000 ppm or less, about 30,000 ppm or less, about 20,000 ppm or less, about 10,000 ppm or less, about 6,000 ppm or less, about 4,000 ppm or less, or about 2,000 ppm or less. In further aspects, a concentration of the colorant can range from about 50 ppm to about 50,000 ppm, from about 100 ppm to about 30,000 ppm, from about 300 ppm to about 20,000 ppm, from about 500 ppm to about 10,000 ppm, from about 1,000 ppm to about 6,000 ppm, from about 2,000 ppm to about 4,000 ppm, or any range or subrange therebetween.

[0078] Unless otherwise indicated, compositions are specified in mole percent (mol%). The terms “0 mol%” and “free,” when used to describe the concentration and/or absence of a particular constituent component in a glass composition, means that the constituent component is not present in the glass composition. The term “substantially free,” when used to describe the concentration and/or absence of a particular constituent component in a glass composition and the resultant colored glass article, means that the constituent component is not intentionally added to the glass composition and the resultant colored glass article. However, the glass composition and the resultant colored glass article may contain traces of the constituent component as a contaminant or tramp in amounts of less than 200 ppm unless specified otherwise herein. It is noted that the definition of “substantially free”

is exclusive of gold (Au) which may be intentionally added to the glass composition in relatively small amounts, for example and without limitation, amounts less than 200 ppm (or the equivalent in mol%) to achieve a desired color in the resultant colored glass article.

[0079] “Glass-ceramics” include materials produced through controlled crystallization of glass. In aspects, glass-ceramics have about 1% to about 99% crystallinity. Examples of suitable glass-ceramics may include $\text{Li}_2\text{O}-\text{Al}_2\text{O}_3-\text{SiO}_2$ system (i.e., LAS-System) glass-ceramics, $\text{MgO}-\text{Al}_2\text{O}_3-\text{SiO}_2$ system (i.e., MAS-System) glass-ceramics, $\text{ZnO} \times \text{Al}_2\text{O}_3 \times n\text{SiO}_2$ (i.e., ZAS system), and/or glass-ceramics that include a predominant crystal phase including β -quartz solid solution, β -spodumene, cordierite, petalite, and/or lithium disilicate. The glass-ceramic materials may be strengthened using the chemical strengthening processes. In one or more aspects, MAS-System glass-ceramic materials may be strengthened in Li_2SO_4 molten salt, whereby an exchange of 2Li^+ for Mg^{2+} can occur. In aspects, the glass article **511 and/or 350** can be a glass-ceramic comprising one or more crystalline phases. In further aspects, a total amount of the one or more crystalline phases, as a weight% (wt%) of the glass article **511 and/or 350**, can be about 10 wt% or less, about 8 wt% or less, about 6 wt% or less, about 4 wt% or less, about 4 wt% or less, about 2 wt% or less, about 1 wt% or less, about 0.1 wt% or more, about 0.5 wt% or more, or about 1 wt% or more.

[0080] The glass articles described herein may be described as aluminoborosilicate glass compositions and colored glass articles and comprise SiO_2 , Al_2O_3 , and B_2O_3 . Additionally, the glass articles described herein include one or more colorants in a colorant package to impart a desired color to the resultant colored glass article. The glass articles described herein also include alkali oxides (e.g., Li_2O and Na_2O) to enable the ion-exchangeability of the colored glass articles. In aspects, the glass articles described herein may further include other components to improve colorant retention and produce colored glass articles having the desired color. In aspects, the difference between R_2O and Al_2O_3 (i.e. R_2O (mol%) – Al_2O_3 (mol%)) in the glass articles described herein may be adjusted to produce a desired observable color (e.g., pink, purple, red, orange, or blue). In aspects, the viscosity of the glass composition may be adjusted to prevent devitrification of the glass composition.

[0081] SiO_2 is the primary glass former in the glass articles described herein and may function to stabilize the network structure of the colored glass articles. The

concentration of SiO₂ in the glass articles should be sufficiently high (e.g., 40 mol% or more) to enhance the chemical durability of the glass composition and, in particular, the resistance of the glass composition to degradation upon exposure to acidic solutions, basic solutions, and in water. The amount of SiO₂ may be limited (e.g., 80 mol% or less) to control the melting point of the glass composition, as the melting point of pure SiO₂ or high SiO₂ glasses is undesirably high. Thus, limiting the concentration of SiO₂ may aid in improving the meltability and the formability of the resultant colored glass article. In aspects, the glass article may comprise from 40 mol% to 80 mol% SiO₂ or from 50 mol% to 80 mol% SiO₂. In aspects, the glass article may comprise from about 45 mol% to about 67 mol% SiO₂ or from 53 mol% to 67 mol% SiO₂. In aspects, the concentration of SiO₂ in the glass article may be 40 mol% or more, 45 mol% or more, 50 mol% or more, 52 mol% or more, 53 mol% or more, 54 mol% or more, 55 mol% or more, 56 mol% or more, 57 mol% or more, 58 mol% or more, 60 mol% or more, 80 mol% or less, 75 mol% or less, 73 mol% or less, 71 mol% or less, 70 mol% or less, 68 mol% or less, 67 mol% or less, 66 mol% or less, 65 mol% or less, 64 mol% or less, 63 mol% or less, 62 mol% or less, 61 mol% or less, 60 mol% or less, or 59 mol% or less. In aspects, the concentration of SiO₂ in the glass article may be from 40 mol% to 70 mol%, 45 mol% to 70 mol%, from 50 mol% to about 68 mol%, from about 52 mol% to about 68 mol%, from about 53 mol% to about 67 mol%, from about 54 mol% to about 67 mol%, from about 55 mol% to about 66 mol%, from about 56 mol% to about 65 mol%, from about 57 mol% to about 65 mol%, from about 58 mol% to about 65 mol%, from about 60 mol% to about 65 mol%, from about 60 mol% to about 64 mol%, from about 60 mol% to about 63 mol%, from about 60 mol% to about 62 mol%, or any range or subrange therebetween.

[0082] Like SiO₂, Al₂O₃ may also stabilize the glass network and additionally provides improved mechanical properties and chemical durability to the glass article. The amount of Al₂O₃ may also be tailored to control the viscosity of the glass composition. Al₂O₃ may be included such that the resultant glass article has the desired fracture toughness (e.g., 0.7 MPa·m^{1/2} or more). However, if the amount of Al₂O₃ is too high (e.g., 25 mol% or more), the viscosity of the glass melt may increase, thereby diminishing the formability of the glass article. In aspects, if the amount of Al₂O₃ is too high, the solubility of one or more colorants of the colorant package in the glass melt may decrease, resulting in the formation of undesirable

crystal phases in the glass. For example and without limitation, when the colorant package includes Cr_2O_3 , the solubility of Cr_2O_3 in the glass melt may decrease with increasing Al_2O_3 concentrations (e.g., concentrations of 17.5 mol% or more), leading to the precipitation of undesirable crystal phases. Without wishing to be bound by theory, it is hypothesized that similar behavior may occur with colorants other than Cr_2O_3 . Accordingly, in aspects, the glass com article may comprise from 7 mol% to 25 mol% Al_2O_3 , from 7 mol% to 20 mol% Al_2O_3 , or from 8 mol% to 20 mol% Al_2O_3 . In aspects, the glass article may comprise from 10 mol% to 20 mol% Al_2O_3 , from 10 mol% to about 17.5 mol% Al_2O_3 , or from 12 mol% to about 17.25 mol% Al_2O_3 . In aspects, the glass article may comprise from 11 mol% to 19 mol% Al_2O_3 or from 14 mol% to 17 mol% Al_2O_3 . In aspects, the concentration of Al_2O_3 in the glass article may be 7 mol% or more, 8 mol% or more, 9 mol% or more, 10 mol% or more, 11 mol% or more, 12 mol% or more, 12.5 mol% or more, 13 mol% or more, 13.5 mol% or more, 14 mol% or more, 14.5 mol% or more, 15 mol% or more, 15.5 mol% or more, 16 mol% or more, 25 mol% or less, 23 mol% or less, 20 mol% or less, 19 mol% or less, 18 mol% or less, 17.5 mol% or less, 17.25 mol% or less, 17 mol% or less, 16.75 mol% or less, or 16 mol% or less. In aspects, the concentration of Al_2O_3 in the glass article may be from 7 mol% to 25 mol%, from 7 mol% to 23 mol%, from 8 mol% to 20 mol%, from 9 mol% to 19 mol%, from 10 mol% to 18 mol%, from 11 mol% to 17.5 mol%, from 12 mol% to 17.25 mol%, from 13 mol% to 17 mol%, from 14 mol% to 16.75 mol%, from 14.5 mol% to 16 mol%, or any range or subrange therebetween.

[0083] B_2O_3 decreases the melting point of the glass composition, which may improve retention of certain colorants in the glass, for example and without limitation, Au. B_2O_3 may also improve the damage resistance of the resultant colored glass article. In addition, B_2O_3 may be added to reduce the formation of non-bridging oxygen, the presence of which may reduce fracture toughness. The concentration of B_2O_3 should be sufficiently high (e.g., 1 mol% or more) to reduce the melting point of the glass composition, improve the formability, and increase the fracture toughness of the colored glass article. However, if B_2O_3 is too high (e.g., 15 mol% or more), the annealing point and strain point may decrease, which increases stress relaxation and reduces the overall strength of the colored glass article. In aspects, the glass article may comprise from 1 mol% to 15 mol% B_2O_3 , from 1 mol% to 10 mol% B_2O_3 , from 3 mol% to 10 mol% B_2O_3 , or from 3.5 mol% to 9 mol% B_2O_3 . In aspects, the glass

article may comprise from 2 mol% to 12 mol% B_2O_3 or from 2 mol% to 8 mol% B_2O_3 . In aspects, the concentration of B_2O_3 in the glass article may be 1 mol% or more, 2 mol% or more, 3 mol% or more, 3.5 mol% or more, 4 mol% or more, 4.5 mol% or more, 5 mol% or more, 5.5 mol% or more, 15 mol% or less, 12 mol% or less, 10 mol% or less, 9 mol% or less, 8 mol% or less, 7.5 mol% or less, 7 mol% or less, 6.5 mol% or less, or 6 mol% or less. In aspects, the concentration of B_2O_3 in the glass article may be from 1 mol% to 15 mol%, from 2 mol% to 12 mol%, from 3 mol% to 10 mol%, from 3.5 mol% to 9 mol%, from 4 mol% to 8 mol%, from 4.5 mol% to 7.5 mol%, from 5 mol% to 7 mol%, from 5.5 mol% to 6.5 mol%, or any range or subrange therebetween.

[0084] As described hereinabove, the glass articles may contain alkali oxides (e.g., Li_2O , Na_2O , and K_2O) to enable the ion-exchangeability of the glass articles.

[0085] Li_2O aids in the ion-exchangeability of the glass article and also reduces the softening point of the glass composition, thereby increasing the formability of the glass articles. The addition of Li_2O facilitates the exchange of both Na^+ and K^+ cations into the glass for strengthening the glass and also facilitates producing a relatively high surface compressive stress and relatively deep depth of compression, improving the mechanical characteristics of the resultant colored glass article. In addition, Li_2O decreases the melting point of the glass composition, which may improve retention of colorants in the glass, for example and without limitation, Au. The concentration of Li_2O in the glass articles should be sufficiently high (e.g., 1 mol% or more) to reduce the melting point of the glass composition and achieve the desired maximum central tension (e.g., 40 MPa or more) following ion exchange. However, if the amount of Li_2O is too high (e.g., greater than 20 mol%), the liquidus temperature may increase, thereby diminishing the manufacturability of the colored glass article. In aspects, the glass article may comprise from 1 mol% to 20 mol% Li_2O or from 1 mol% to 20 mol% Li_2O . In aspects, the glass article may comprise from 3 mol% to 18 mol% Li_2O , from 7 mol% to 18 mol% Li_2O , from 8.8 mol% to 14 mol% Li_2O , or from 9 mol% to 13.5 mol% Li_2O . In aspects, the concentration of Li_2O in the glass article may be 1 mol% or more, 3 mol% or more, 5 mol% or more, 7 mol% or more, 7.5 mol% or more, 8 mol% or more, 8.5 mol% or more, 8.8 mol% or more, 9 mol% or more, 9.2 mol% or more, 9.4 mol% or more, 9.6 mol% or more, 9.8 mol% or more, 10 mol% or more, 11 mol% or more, 11.5 mol% or more, 12 mol% or more, 20 mol% or less, 18 mol% or less, 17 mol% or less, 16 mol% or less, 15 mol% or less,

14 mol% or less, 13.5 mol% or less, 13 mol% or less, 12.5 mol% or less, 12 mol% or less, 11.5 mol% or less, or 11 mol% or less. In aspects, the concentration of Li_2O in the glass article may be from 1 mol% to 20 mol%, from 3 mol% to 18 mol%, from 5 mol% to 17 mol%, from 7 mol% to 16 mol%, from 7.5 mol% to 15 mol%, from 8 mol% to 14 mol%, from 8.5 mol% to 13.5 mol%, from 8.8 mol% to 13 mol%, from 9 mol% to 12.5 mol%, from 9.2 mol% to 12.5 mol%, from 9.4 mol% to 12 mol%, from 9.6 mol% to 12 mol%, from 9.8 mol% to 11.5 mol%, from 10 mol% to 11 mol%, or any range or subrange therebetween.

[0086] Na_2O improves diffusivity of alkali ions in the glass and thereby reduces ion-exchange time and helps achieve the desired surface compressive stress (e.g., 300 MPa or more). The addition of Na_2O also facilitates the exchange of K^+ cations into the glass for strengthening and improving the mechanical characteristics of the resultant colored glass article. Na_2O also improves the formability of the colored glass article. In addition, Na_2O decreases the melting point of the glass composition, which may improve retention of certain colorants in the glass, for example, Au. However, if too much Na_2O is added to the glass composition, the melting point may be too low. In aspects, the concentration of Li_2O present in the glass article may be greater than the concentration of Na_2O present in the glass article. In aspects, the glass article may comprise greater than 0 mol%, from 0.01 mol% to 15 mol% Na_2O , from 0.5 mol% to 15 mol% Na_2O , or from 1 mol% to 15 mol% Na_2O . In aspects, the glass article may comprise from 1 mol% to 12 mol% Na_2O or from 2 mol% to 10 mol% Na_2O . In aspects, the glass article may comprise from 0.01 mol% to 4 mol% Na_2O . In aspects, the glass article may comprise from 1.5 mol% to 8 mol% Na_2O or from 2 mol% to 7.5 mol% Na_2O . In aspects, the concentration of Na_2O in the glass article may be greater than 0 mol%, 0.01 mol% or more, 0.5 mol% or more, 1 mol% or more, 1.5 mol% or more, 2 mol% or more, 2.5 mol% or more, 3 mol% or more, 3.5 mol% or more, 4 mol% or more, 4.5 mol% or more, 15 mol% or less, 12 mol% or less, 10 mol% or less, 9 mol% or less, 8.5 mol% or less, 8 mol% or less, 7.5 mol% or less, 7 mol% or less, 6.5 mol% or less, 6 mol% or less, 5.5 mol% or less, 5 mol% or less, 4.5 mol% or less, or 4 mol% or less. In aspects, the concentration of Na_2O in the glass article may be from greater than 0 mol% to 15 mol%, from 0.01 mol% to 12 mol%, from 0.5 mol% to 12 mol%, from 1 mol% to 10 mol%, from 1.5 mol% to 9 mol%, from 2 mol% to 8.5 mol%, from 2.5 mol% to 8 mol%, from 3 mol% to 7.5 mol%, from 3.5 mol% to 7 mol%, from 4 mol% to 6.5 mol%, from 4.5

mol% to 6 mol%, or any range or subrange therebetween. In aspects, the concentration of Na₂O in the glass article may be from 0.5 mol% to 10 mol%, from 1 mol% to 9 mol%, from 1 mol% to 8 mol%, from 1 mol% to 7 mol%, from 1 mol% to 6.5 mol%, from 1 mol% to 6 mol%, from 1 mol% to 5.5 mol%, from 1 mol% to 5 mol%, from 1.5 mol% to 4.5 mol%, from 2 mol% to 4 mol%, or any range or subrange therebetween.

[0087] K₂O, when included, promotes ion-exchange and may increase the depth of compression and decrease the melting point to improve the formability of the colored glass article. However, adding too much K₂O may cause the surface compressive stress and melting point to be too low. Accordingly, in aspects, the amount of K₂O added to the glass composition may be limited. In aspects, the glass article may optionally comprise from greater than 0 mol% to 3 mol% K₂O, from greater than 0 mol% to 1 mol% K₂O, from 0.01 mol% to 1 mol% K₂O, or from 0.1 mol% to 1 mol% K₂O. In aspects, the glass article may optionally comprise from 0.1 mol% to 0.5 mol% K₂O. In aspects, the concentration of K₂O in the glass article may be greater than 0 mol%, 0.01 mol% or more, 0.1 mol% or more, 0.2 mol% or more, 0.25 mol% or more, 0.3 mol% or more, 0.4 mol% or more, 0.5 mol% or more, 3 mol% or less, 2.5 mol% or less, 2 mol% or less, 1.5 mol% or less, 1 mol% or less, 0.75 mol% or less, 0.5 mol% or less, or 0.25 mol% or less. In aspects, the concentration of K₂O in the glass article may be from greater 0 mol% to 3 mol%, from 0.01 mol% to 2.5 mol%, from 0.1 mol% to 2 mol%, from 0.2 mol% to 1.5 mol%, from 0.25 mol% to 1 mol%, from 0.3 mol% to 0.75 mol%, from 0.4 mol% to 0.5 mol%, or any range or subrange therebetween.

[0088] R₂O, as used herein, is the sum (in mol%) of Li₂O, Na₂O, and K₂O present in the glass article (i.e., $R_2O = Li_2O \text{ (mol\%)} + Na_2O \text{ (mol\%)} + K_2O \text{ (mol\%)}$). Like B₂O₃, the alkali oxides aid in decreasing the softening point and molding temperature of the glass composition, thereby offsetting the increase in the softening point and molding temperature of the glass composition due to higher amounts of SiO₂ in the glass composition, for example. The softening point and molding temperature may be further reduced by including combinations of alkali oxides (e.g., two or more alkali oxides) in the glass composition, a phenomenon referred to as the “mixed alkali effect.” However, it has been found that if the amount of alkali oxide is too high, the average coefficient of thermal expansion of the glass composition increases to greater than $100 \times 10^{-7}/^{\circ}\text{C}$, which may be undesirable. In aspects, the

concentration of R_2O in the glass article can be from 1 mol% to 35 mol%, from 6 mol% to 25 mol%, or from 8 mol% to 23 mol%. In aspects, the concentration of R_2O in the glass article can be 2 mol% or more, 4 mol% or more, 6 mol% or more, 8 mol% or more, 10 mol% or more, 10.3 mol% or more, 11 mol% or more, 12 mol% or more, 13 mol% or more, 14 mol% or more, 35 mol% or less, 30 mol% or less, 25 mol% or less, 23 mol% or less, 22 mol% or less, 21 mol% or less, 20 mol% or less, 19 mol% or less, 18 mol% or less, 17 mol% or less, 16 mol% or less, or 15 mol% or less. In aspects, the concentration of R_2O in the glass article can range from 2 mol% to 35 mol%, from 4 mol% to 30 mol%, from 6 mol% to 25 mol%, from 8 mol% to 23 mol%, from 8 mol% to 22 mol%, from 10 mol% to 21 mol%, from 10.3 mol% to 20 mol%, from 11 mol% to 19 mol%, from 12 mol% to 18 mol%, from 13 mol% to 17 mol%, from 14 mol% to 16 mol%, or any range or subrange therebetween.

[0089] In aspects, a difference between R_2O and Al_2O_3 (i.e. R_2O (mol%) – Al_2O_3 (mol%)) in the glass article may be adjusted to produce a desired observable color (e.g., pink, purple, red, orange, or blue). The analyzed R_2O – Al_2O_3 of the glass article, along with the added colorant package, may correlate with the observable color of the colored glass article after an optional heat treatment, as discussed herein. In aspects, R_2O – Al_2O_3 in the glass article may be from -5 mol% to 7 mol% or from -3 mol% to 2 mol%. In aspects, R_2O – Al_2O_3 in the glass article may be from -3 mol% to 6 mol% or from -1 mol% to 5 mol%. In aspects, R_2O – Al_2O_3 in the glass article may be from -5 mol% to 1.5 mol% or from -3 mol% to 1.5 mol%. In aspects, R_2O – Al_2O_3 in the glass article may be from 1.5 mol% to 7 mol% or from 1.5 mol% to 5 mol%. In aspects, R_2O – Al_2O_3 in the glass article may be -5 mol% or more, -4 mol% or more, -3 mol% or more, -2.5 mol% or more, -2 mol% or more, -1.5 mol% or more, 0.2 mol% or more, 0.5 mol% or more, 1 mol% or more, 1.5 mol% or more, 2 mol% or more, 7 mol% or less, 6.5 mol% or less, 6 mol% or less, 5.5 mol% or less, 5 mol% or less, 4.5 mol% or less, 4 mol% or less, 3.5 mol% or less, 3 mol% or less, 2.5 mol% or less, 2 mol% or less, 1.5 mol% or less, 1 mol% or less, or 0.5 mol% or less. In aspects, R_2O – Al_2O_3 in the glass article may be from -5 mol% to 7 mol%, from -4 mol% to 6.5 mol%, from -3 mol% to 6 mol%, from -2.5 mol% to 5.5 mol% from -2 mol% to 5 mol%, from -1.5 mol% to 4.5 mol%, from 0.2 mol% to 4 mol%, from 0.5 mol% to 3.5 mol%, from 1 mol% to 3 mol%, from 1.5 mol% to 2.5 mol%, or any range or subrange therebetween.

[0090] In aspects, the glass articles described herein further include MgO and/or ZnO to improve retention of colorants in the glass, such as Au or the like, for example, by lowering the melting point of the glass composition. Decreasing the melting point of the glass composition may help improve colorant retention because the glass compositions may be melted at relatively lower temperatures and the evaporation of colorants from the glass, such as gold, may be reduced. Without wishing to be bound by theory, it is also believed that partially replacing Li₂O and/or Na₂O with MgO and/or ZnO may also help improve retention of the colorants. Specifically, Li₂O and/or Na₂O is included in the batch glass composition as lithium carbonate and sodium carbonate, respectively. Upon melting the glass composition, carbonate gas is released from the glass composition. Colorants such as Au escape from the glass composition within the carbonate gas. Therefore, the improved colorant retention may be due to the reduced amount of carbonate. Further, it is believed that MgO and/or ZnO may improve the solubility of some colorants in the glass (e.g., Cr₂O₃), thereby avoiding the formation of undesirable crystal phases (e.g., Cr-spinel crystals) and expanding the color gamut that may be achieved by the resultant colored glass articles. As used herein, “color gamut” refers to the pallet of colors that may be achieved by the colored glass articles within the CIELAB color space. For example, in aspects where the colorant includes Cr₂O₃, the sum of MgO and ZnO present in the glass article (i.e., MgO (mol%) + ZnO (mol%)) may be from greater than 0 mol% to 6 mol% or 4.5 mol% or less. Without wishing to be bound by theory, it is hypothesized that similar behavior may occur with colorants other than Au and Cr₂O₃. In aspects, the sum (in mol%) of MgO and ZnO present in the glass article (i.e., MgO (mol%) + ZnO (mol%)) may be greater than 0 mol%, 0.1 mol% or more, 0.5 mol% or more, 1 mol% or more, 1.5 mol% or more, 2 mol% or more, 2.5 mol% or more, 3 mol% or more, 3.5 mol% or more, 7 mol% or less, 6 mol% or less, 5.5 mol% or less, 5 mol% or less, 4.5 mol% or less, 4.25 mol% or less, or 4 mol% or less. In aspects, the sum of MgO and ZnO in the glass may be from greater than 0 mol% to 8 mol%, from 0.1 mol% to 7 mol%, from 0.1 mol% to 6 mol%, from 0.5 mol% to 6 mol%, from 1 mol% to 5.5 mol%, from 1.5 mol% to 5 mol%, from 2 mol% to 4.5 mol%, from 2.5 mol% to 4.25 mol%, from 3 mol% to 4 mol%, or any range or subrange therebetween.

[0091] In addition to improving colorant retention, MgO lowers the viscosity of the glass compositions, which enhances the formability, the strain point, and the

Young's modulus, and may improve ion-exchangeability. However, when too much MgO is added to the glass composition, the diffusivity of sodium and potassium ions in the glass composition decreases which, in turn, adversely impacts the ion-exchange performance (i.e., the ability to ion-exchange) of the resultant colored glass article. In aspects, the glass article may comprise from greater than 0 mol% to 8 mol% MgO or from 0 mol% to 4.5 mol% MgO. In aspects, the glass article may comprise from 0.5 mol% to 7 mol% MgO. In aspects, the concentration of MgO in the glass article may be greater than 0 mol%, 0.5 mol% or more, 1 mol% or more, 1.5 mol% or more, 2 mol% or more, 2.5 mol% or more, 8 mol% or less, 7 mol% or less, 6 mol% or less, 5.5 mol% or less, 5 mol% or less, 4.5 mol% or less, 4 mol% or less, 3.5 mol% or less, 3 mol% or less, 2.5 mol% or less, 2 mol% or less, 1.5 mol% or less, or 1 mol% or less. In aspects, the concentration of MgO in the glass article may be from greater than or equal to 0 mol% to 8 mol%, from 0.5 mol% to 7 mol%, from 0.5 mol% to 6 mol%, from 1 mol% to 5.5 mol%, from 1 mol% to 5 mol%, from 1.5 mol% to 4.5 mol%, from 1.5 mol% to 4 mol%, from 2 mol% to 3.5 mol%, from 2.5 mol% to 3 mol%, or any range or subrange therebetween. In aspects, the glass article may be substantially free or free of MgO.

[0092] In addition to improving colorant retention, ZnO lowers the viscosity of the glass compositions, which enhances the formability, the strain point, and the Young's modulus, and may improve ion-exchangeability. However, when too much ZnO is added to the glass composition, the diffusivity of sodium and potassium ions in the glass composition decreases which, in turn, adversely impacts the ion-exchange performance (i.e., the ability to ion-exchange) of the resultant colored glass article. In aspects, the glass article may comprise from greater than 0 mol% to 5 mol% ZnO, from greater than 0 mol% to 4.5 mol% ZnO, from 0.1 mol% to 4 mol% ZnO, from 0.25 mol% to 1.25 mol%, or from 0.5 mol% to 1 mol%. In aspects, the concentration of ZnO in the glass article may be greater than 0 mol%, 0.1 mol% or more, 0.25 mol% or more, 0.5 mol% or more, 0.7 mol% or more, 1 mol% or more, 1.5 mol% or more, 2 mol% or more, 5 mol% or less, 4.5 mol% or less, 4 mol% or less, 3.5 mol% or less, 3 mol% or less, 2.5 mol% or less, 2 mol% or less, 1.75 mol% or less, 1.5 mol% or less, 1.25 mol% or less, or 1 mol% or less. In aspects, the concentration of ZnO in the glass composition may be from greater than 0 mol% to 5 mol%, from 0.1 mol% to 4.5 mol%, from 0.25 mol% to 4 mol%, from 0.5 mol% to 3.5 mol%, from 0.75 mol% to 3 mol%, from 1 mol% to 2.5 mol%, from 1.5 mol% to 2 mol%, or any

range or subrange therebetween. In aspects, the glass article may be substantially free or free of ZnO.

[0093] Like ZnO and the alkaline earth oxide MgO, other alkaline earth oxides, for example CaO, SrO and BaO, decrease the melting point of the glass composition. Accordingly, CaO, SrO, and/or BaO may be included in the glass articles to lower the melting point of the glass composition, which may help improve colorant retention.

[0094] In aspects, the glass articles described herein may further comprise CaO. CaO lowers the viscosity of a glass composition, which enhances the formability, the strain point and the Young's modulus, and may improve the ion-exchangeability. However, when too much CaO is added to the glass composition, the diffusivity of sodium and potassium ions in the glass composition decreases which, in turn, adversely impacts the ion-exchange performance (i.e., the ability to ion-exchange) of the resultant glass. In aspects, the concentration of CaO in the glass article may be 0 mol% or more, 0.25 mol% or more, 0.5 mol% or more, 0.75 mol% or more, 1 mol% or more, 7 mol% or less, 6.5 mol% or less, 6 mol% or less, 5.5 mol% or less, 5 mol% or less, 4.5 mol% or less, 4 mol% or less, 3.5 mol% or less, 3 mol% or less, 2.5 mol% or less, 2 mol% or less, 1.75 mol% or less, 1.5 mol% or less, 1.25 mol% or less, or 1 mol% or less. In aspects, the concentration of CaO in the glass article may be from greater than 0 mol% to 7 mol%, from greater than 0 mol% to 6.5 mol%, from 0.25 mol% to 6 mol%, from 0.25 mol% to 5.5 mol%, from 0.25 mol% to 5 mol%, from 0.5 mol% to 4.5 mol%, from 0.5 mol% to 4 mol%, from 0.5 mol% to 3.5 mol%, from 0.75 mol% to 3 mol%, from 0.75 mol% to 2.5 mol%, from 0.75 mol% to 2 mol%, from 1 mol% to 1.75 mol%, from 1 mol% to 1.5 mol%, or any range or subrange therebetween.

[0095] In aspects, the concentration of SrO in the glass article may be greater than 0 mol%, 0.25 mol% or more, 0.5 mol% or more, 0.75 mol% or more, 1 mol% or more, 2 mol% or less, 1.75 mol% or less, 1.5 mol% or less, 1.25 mol% or less, or 1 mol% or less. In aspects, the concentration of SrO in the glass article may be from greater than 0 mol% to 2 mol%, from 0.25 mol% to 1.75 mol%, from 0.5 mol% to 1.5 mol%, from 0.75 mol% to 1.25 mol%, from 0.75 mol% to 1 mol%, or any range or subrange therebetween. In aspects, the glass article may be substantially free or free of SrO.

[0096] In aspects, the concentration of BaO in the glass article may be greater than 0 mol%, 0.25 mol% or more, 0.5 mol% or more, 0.75 mol% or more, 1 mol% or more, 2 mol% or less, 1.75 mol% or less, 1.5 mol% or less, 1.25 mol% or less, or 1 mol% or less. aspects, the concentration of BaO in the glass article may be from greater than 0 mol% to 2 mol%, from 0.25 mol% to 1.75 mol%, from 0.5 mol% to 1.5 mol%, from 0.75 mol% to 1.25 mol%, from 0.75 mol% to 1 mol%, or any range or subrange therebetween. In aspects, the glass article may be substantially free or free of BaO.

[0097] R'O, as used herein, is the sum (in mol%) of MgO, ZnO, CaO, BaO, and SrO (i.e. $R'O = \text{MgO (mol\%)} + \text{ZnO (mol\%)} + \text{CaO (mol\%)} + \text{BaO (mol\%)} + \text{SrO (mol\%)}$). In aspects, the concentration of R'O in the glass article may be greater than 0 mol%, 0.5 mol% or more, 1 mol% or more, 1.5 mol% or more, 2 mol% or more, 2.5 mol% or more, 8 mol% or less, 7.5 mol% or less, 7 mol% or less, 6.5 mol% or less, 6 mol% or less, 5.5 mol% or less, 5 mol% or less, 4.5 mol% or less, 4 mol% or less, or 3.5 mol% or less. In aspects, the concentration of R'O in the glass article may be from greater than 0 mol% to 8 mol%, from 0.5 mol% to 7.5 mol%, from 0.5 mol% to 7 mol%, from 1 mol% to 6.5 mol% from 1 mol% to 6 mol%, from 1.5 mol% to 5.5 mol%, from 1.5 mol% to 5 mol%, from 2 mol% to 4.5 mol%, from 2 mol% to 4 mol%, from 2.5 mol% to 3.5 mol%, or any range or subrange therebetween.

[0098] In aspects, a sum of R_2O , CaO, MgO, and ZnO ($R_2O \text{ (mol\%)} + \text{CaO (mol\%)} + \text{MgO (mol\%)} + \text{ZnO (mol\%)}$) may be 35 mol% or less, for example, from 1 mol% to 30 mol%, from 2 mol% to 30 mol%, from 3 mol% to 25 mol%, from 4 mol% to 25 mol%, from 5 mol% to 20 mol%, 6 mol% to 20 mol%, from 7 mol% to 15 mol%, from 8 mol% to 10 mol%, or any range or subrange therebetween.

[0099] In aspects, a sum of Al_2O_3 , MgO, and ZnO present in the glass article (i.e., $Al_2O_3 \text{ (mol\%)} + \text{MgO (mol\%)} + \text{ZnO (mol\%)}$) may be from 12 mol% to 22 mol%. Without wishing to be bound by theory, it is believed that combinations of Al_2O_3 , MgO, and ZnO within this range may aid in avoiding the formation of undesired crystal phases in the resultant colored glass articles. For example and without limitation, when the colorant package in the glass article includes Cr_2O_3 , combinations of Al_2O_3 , MgO, and ZnO within this range may avoid the formation of Cr-spinel crystals by increasing the solubility of the Cr_2O_3 colorant and thereby expanding the color gamut that may be achieved in the resultant colored glass articles. In aspects, a sum of Al_2O_3 , MgO, and ZnO in the glass article may be from 13 mol%

to 21.5 mol%. In aspects, the sum of Al_2O_3 , MgO , and ZnO in the glass article may be 12 mol% or more, 13 mol% or more, 14 mol% or more, 15 mol% or more, 16 mol% or more, 22 mol% or less, 21.5 mol% or less, 21 mol% or less, 20.5 mol% or less, or 20 mol% or less. In aspects, the sum of Al_2O_3 , MgO , and ZnO in the glass article may be from 12 mol% to 22 mol%, from 13 mol% to 21.5 mol%, from 14 mol% to 21 mol%, from 15 mol% to 20.5 mol%, from 16 mol% to 20 mol%, or any range or subrange therebetween.

[00100] In aspects, a sum of Al_2O_3 , MgO , CaO , and ZnO present in the glass article (i.e., Al_2O_3 (mol%) + MgO (mol%) + CaO (mol%) + ZnO (mol%)) may be from 12 mol% to 24 mol%. Without wishing to be bound by theory, it is believed that combinations of Al_2O_3 , MgO , CaO , and ZnO within this range may aid in avoiding the formation of undesired crystal phases in the glass article. In addition, a relatively high concentration of high field strength modifiers, for example Mg , Ca , and Zn cations, may also improve the mechanical properties, for example fracture toughness, elastic modulus, and drop test performance, of the resultant colored glass article. In aspects, a sum of Al_2O_3 , MgO , CaO , and ZnO in the glass article may be from 12 mol% to 24 mol%. In aspects, the sum of Al_2O_3 , MgO , CaO , and ZnO in the glass article may be 12 mol% or more, 13 mol% or more, 14 mol% or more, 15 mol% or more, 16 mol% or more, 24 mol% or less, 23 mol% or less, 22 mol% or less, 21.5 mol% or less, 21 mol% or less, 20.5 mol% or less, or 20 mol% or less. In aspects, the sum of Al_2O_3 , MgO , CaO , and ZnO in the glass article may be from 12 mol% to 24 mol%, from 13 mol% to 23 mol%, from 13 mol% to 22 mol%, from 14 mol% to 21.5 mol%, from 14 mol% to 21 mol%, from 15 mol% to 20.5 mol%, from 16 mol% to 20 mol%, or any range or subrange therebetween.

[00101] In aspects, the glass article may optionally include Cl , which may enable growth of particular crystal phases containing colorant. For example, when the colorant package included in the glass comprises Au , the inclusion of Cl may enable the growth of certain Au crystals. In aspects, the concentration of Cl in the glass article may be greater than 0 mol%, 0.1 mol% or more, 0.5 mol% or less, or 0.25 mol% or less. In aspects, the concentration of Cl in the glass article may be from greater than 0 mol% to 0.5 mol%, from 0.1 mol% to 0.25 mol%, or any range or subrange therebetween. In aspects, the glass article may be substantially free or free of Cl . In aspects where the colorant package comprises Ag , the glass article can include less than 100 ppm of halides, including Cl .

[00102] In aspects, the glass articles described herein may further comprise ZrO_2 . Without wishing to be bound by theory, it is believed that ZrO_2 may act as a multivalent species that serves as redox couples to supply oxygen to certain colorants, for example Au, during relatively low-temperature heat treatment, which helps improve retention of the colorant. ZrO_2 may also act as an additional colorant, producing colored glass articles that may be, for example, red in color. In aspects, the glass article may comprise ZrO_2 in an amount of 0.01 mol% or more, 0.1 mol% or more, 0.2 mol% or more, 0.25 mol% or more, 0.5 mol% or more, 0.75 mol% or more, 1 mol% or more, 2 mol% or less, 1.75 mol% or less, 1.5 mol% or less, 1 mol% or less, or 0.5 mol% or less. In aspects, the glass article may comprise ZrO_2 in an amount from 0.01 mol% to 2 mol%, from 0.1 mol% to 1.75 mol%, from 0.2 mol% to 1.5 mol%, from 0.25 mol% to 1.25 mol%, from 0.5 mol% to 1 mol%, from 0.75 mol% to 1 mol%, or any range or subrange therebetween.

[00103] In aspects, the glass compositions and the resultant colored glass articles described herein may further comprise Fe_2O_3 , which may help improve colorant retention. Fe_2O_3 is a multivalent species that serves as redox couples to supply oxygen to certain colorants, for example Au, during relatively low-temperature heat treatment, which helps improve retention of the colorant. Fe_2O_3 may also act as a colorant, producing colored glass articles that may, for example, be pink or red in color. In aspects, the glass article may comprise Fe_2O_3 in an amount of greater than 0 mol%, 0.01 mol% or more, 0.05 mol% or more, 0.1 mol% or more, 1 mol% or more, 1 mol% or less, 0.75 mol% or less, 0.5 mol% or less, 0.25 mol% or less, or 0.1 mol% or less. In aspects, the glass article may comprise Fe_2O_3 in an amount from greater than 0 mol% to 1 mol%, from 0.01 mol% to 0.75 mol%, from 0.05 mol% to 0.5 mol%, from 0.1 mol% to 0.25 mol%, or any range or subrange therebetween. In aspects, the glass article may comprise Fe_2O_3 in an amount of 200 parts-per-million (ppm) or more, 250 ppm or more, 300 ppm or more, 350 ppm or more, 400 ppm or less, 1,000 ppm or less, 600 ppm or less, 550 ppm or less, 500 ppm or less, or 450 ppm or less. In aspects, the glass article can comprise Fe_2O_3 in an amount from about 200 ppm to about 1,000 ppm, from about 300 ppm to about 600 ppm, from about 350 ppm to about 550 ppm, from about 400 ppm to about 500 ppm, or any range or subrange therebetween. In aspects, the glass article may be substantially free or free of Fe_2O_3 .

[00104] In aspects, the glass compositions and the resultant colored glass articles described herein may further comprise SnO_2 , Sb_2O_3 , and/or Bi_2O_3 . Like MgO and ZnO , SnO_2 , Sb_2O_3 , and Bi_2O_3 may help lower the melting point of the glass composition. Accordingly, SnO_2 , Sb_2O_3 , and/or Bi_2O_3 may be included in the glass articles to lower the melting point and improve colorant retention. In aspects in which the colorant package includes Ag , SnO_2 also aids in the reduction of Ag in the glass leading to the formation of silver particles in the glass. Without wishing to be bound by theory, in aspects where the colorant package includes Au , it is believed that additions of SnO_2 may also aid in the reduction of Au in the glass, leading to the formation of gold particles. In aspects that include SnO_2 and/or Sb_2O_3 , the SnO_2 and/or Sb_2O_3 may also function as a fining agent.

[00105] In aspects, the glass article may comprise SnO_2 in an amount of greater than 0 mol%, 0.01 mol% or more, 0.05 mol% or more, 0.1 mol% or more, 0.25 mol% or more, 1 mol% or less, 0.75 mol% or less, 0.5 mol% or less, 0.25 mol% or less, or 0.1 mol% or less. In aspects, the glass article may comprise SnO_2 in an amount from greater than 0 mol% to 1 mol%, from 0.01 mol% to 0.75 mol%, from 0.05 mol% to 0.5 mol%, from 0.1 mol% to 0.25 mol%, or any range or subrange therebetween. In aspects, the glass article may be substantially free or free of SnO_2 .

[00106] In aspects, the concentration of Sb_2O_3 in the glass article may be greater than 0 mol%, 0.01 mol% or more, 0.05 mol% or more, 0.1 mol% or more, 1 mol% or less, 0.75 mol% or less, 0.5 mol% or less, 0.25 mol% or less, or 0.1 mol% or less. In aspects, the concentration of Sb_2O_3 in the glass article may be from greater than 0 mol% to 1 mol%, from 0.01 mol% to 0.75 mol%, from 0.05 mol% to 0.5 mol%, from 0.1 mol% to 0.25 mol%, or any range or subrange therebetween. In aspects, the glass article may be substantially free or free of Sb_2O_3 . In aspects, the glass article can comprise Sb_2O_3 in an amount from 0.01 wt% to about 0.5 wt%, from 0.02 wt% to about 0.4 wt%, from 0.05 wt% to about 0.3 wt%, from 0.1 wt% to about 0.2 wt%, or any range or subrange therebetween.

[00107] In aspects, the concentration of Bi_2O_3 in the glass article may be greater than 0 mol%, 0.01 mol% or more, 0.05 mol% or more, 0.1 mol% or more, 1 mol% or less, 0.75 mol% or less, 0.5 mol% or less, 0.25 mol% or less, or 0.1 mol% or less. In aspects, the concentration of Bi_2O_3 in the glass article may be from greater than 0 mol% to 1 mol%, from 0.01 mol% to 0.75 mol%, from 0.05 mol% to 0.5

mol%, from 0.1 mol% to 0.25 mol%, or any range or subrange therebetween. In aspects, the glass article may be substantially free or free of Bi_2O_3 .

[00108] In aspects, the concentration of SO_3 in the glass article may be 0.1 mol% or less, 0.01 mol% or less, or 0.001 mol% or less. In aspects, the glass article may be substantially free or free of SO_3 .

[00109] In aspects, the glass articles described herein may further comprise a reduced concentration or be substantially free or free of P_2O_5 . In aspects where P_2O_5 is included, the P_2O_5 may enhance the ion exchange characteristics of the resultant colored glass article. However, an increased concentration (i.e., greater than 1 mol%) of P_2O_5 may reduce the retention of one or more colorants in the colorant package. Without wishing to be bound by theory, it is believed that P_2O_5 may be more volatile than other glass network formers, for example SiO_2 , which may contribute to reduced retention of colorants in the colorant package. In aspects, the concentration of P_2O_5 in the glass article may comprise be greater than 0 mol%, 0.1 mol% or more, 0.25 mol% or more, 1 mol% or less, 0.75 mol% or less, 0.5 mol% or less, or 0.25 mol% or less. In aspects, the concentration of P_2O_5 in the glass article may comprise be from greater than 0 mol% to 1 mol%, from 0.1 mol% to 0.75 mol%, from 0.25 mol% to 0.5 mol%, or any range or subrange therebetween. In aspects, the glass article may be substantially free or free of P_2O_5 .

[00110] In aspects, the glass articles can comprise at least one colorant in a colorant package that functions to impart a desired color to the glass article. In aspects, the colorant package may comprise at least one of Au, Ag, Cr_2O_3 , transition metal oxides (e.g., CuO, NiO, Co_3O_4 , TiO_2 , Cr_2O_3), rare earth metal oxides (e.g., CeO_2), and/or combinations thereof. In aspects, the glass articles may be from 1×10^{-6} mol% to 10 mol% of colorant (i.e., the sum of all colorants in the colorant package). In aspects, the concentration of the colorant package in the glass article may be 1×10^{-6} mol% or more, 0.0005 mol% or more, 0.001 mol% or more, 0.01 mol% or more, 0.1 mol% or more, 10 mol% or less, 9.5 mol% or less, 9 mol% or less, 8.5 mol% or less, 8 mol% or less, 7.5 mol% or less, 7 mol% or less, 6.5 mol% or less, 6 mol% or less, 5.5 mol% or less, 5 mol% or less, 4.5 mol% or less, 4 mol% or less, 3.5 mol% or less, 3 mol% or less, 2.5 mol% or less, 2 mol% or less, 1.5 mol% or less, 1 mol% or less, 0.5 mol% or less. In aspects, the concentration of the colorant package in the glass article may be from 1×10^{-6} mol% to 10 mol%, from 1×10^{-6} mol% to 9 mol%, from 1×10^{-6} mol% to 8 mol%, from 0.0005 mol% to 7 mol%, from 0.0005 mol% to

6 mol%, from 0.0005 mol% to 5 mol%, from 0.001 mol% to 4 mol%, from 0.001 mol% to 3 mol%, from 0.001 mol% to 2 mol%, from 0.01 mol% to 1.5 mol%, from 0.01 mol% to 1 mol%, from 0.1 mol% to about 0.5 mol%, or any range or subrange therebetween. In aspects, the concentration of the colorant package in the glass article may be from 1×10^{-6} mol% to 1 mol%, from 0.0005 mol% to about 0.5 mol%, from 0.001 mol% to 0.25 mol%, from 0.01 mol% to 0.1 mol%, or any range or subrange therebetween.

[00111] In aspects, the colorant package in the glass compositions and the resultant colored glass articles may include colorants that comprise or consist of transition metal oxides, rare earth oxides, or combinations thereof, to achieve a desired color. In aspects, transition metal oxides and/or rare earth oxides may be included in the glass compositions as the sole colorant or in combination with other colorants. In aspects, colorants based on transition metal oxides and/or rare earth oxides may include NiO, Co_3O_4 , Cr_2O_3 , CuO, CeO_2 , TiO_2 and/or combinations thereof. In aspects, colorants based on transition metal oxides and/or rare earth oxides may further include oxides of V, Mn, Fe, Cu, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Cd, Hf, Ta, W, Re, Os, Ir, Pt, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, and Er.

[00112] In aspects, the glass article may comprise a concentration of NiO + Co_3O_4 + Cr_2O_3 + CuO + CeO_2 + TiO_2 of greater than 0 mol%, 0.001 mol% or more, 0.01 mol% or more, 0.02 mol% or more, 0.1 mol% or more, 0.5 mol% or more, 0.7 mol% or more, 0.9 mol% or more, 5 mol% or less, 4 mol% or less, 3 mol% or less, 2.5 mol% or less, 2 mol% or less, 1.5 mol% or less, 1.3 mol% or less, 1 mol% or less, 0.75 mol% or less, 0.5 mol% or less, or 0.25 mol% or less. In aspects, the glass article may comprise a concentration of NiO + Co_3O_4 + Cr_2O_3 + CuO + CeO_2 + TiO_2 can range from greater than 0 mol% to 5 mol%, from 0.001 mol% to 4 mol%, from 0.01 mol% to 3 mol%, from 0.02 mol% to 2.5 mol%, from 0.1 mol% to 2 mol%, from 0.5 mol% to 1.5 mol%, from 0.7 mol% to 1.2 mol%, from 0.9 mol% to 1.3 mol%, or any range or subrange therebetween. In aspects, the glass composition and resultant glass article may comprise 0 mol% of one or more of NiO, Co_3O_4 , Cr_2O_3 , CuO, CeO_2 , and/or TiO_2 .

[00113] In aspects, the glass article may comprise a concentration of NiO + Co_3O_4 + Cr_2O_3 + CuO from 0.001 mol to 3 mol%. In aspects, the glass article may comprise a concentration of NiO + Co_3O_4 + Cr_2O_3 + CuO of greater than 0 mol%, 0.001 mol% or more, 0.01 mol% or more, 0.02 mol% or more, 0.1 mol% or more, 0.2

mol%, 0.5 mol%, 0.8 mol% or more, 1 mol% or more, 3 mol% or less, 2.5 mol% or less, 2 mol% or less, 1.5 mol% or less, 1.3 mol% or less, 1 mol% or less, 0.5 mol% or less, or 0.4 mol% or less. In aspects, the glass article may comprise a concentration of $\text{NiO} + \text{Co}_3\text{O}_4 + \text{Cr}_2\text{O}_3 + \text{CuO}$ from greater than 0 mol% to 3 mol%, from 0.001 mol% to 2.5 mol%, from 0.01 mol% to 2 mol%, from 0.02 mol% to 1.5 mol%, from 0.1 mol% to 1.3, from 0.2 mol% to 1 mol% mol%, from 0.5 mol% to 1 mol%, from 0.5 mol% to 0.8 mol%, or any range or subrange therebetween. In aspects, the glass article may comprise a concentration of $\text{NiO} + \text{Co}_3\text{O}_4 + \text{Cr}_2\text{O}_3 + \text{CuO}$ from 0.01 mol% to 0.5 mol%, from 0.02 mol% to 0.5 mol%, from 0.1 mol% to 0.4 mol%, from 0.2 mol% to 0.4 mol%, or any range or subrange therebetween. In aspects, the glass composition and resultant glass article may comprise 0 mol% of one or more of NiO , Co_3O_4 , Cr_2O_3 , and/or CuO .

[00114] In aspects, the glass article may comprise a concentration of TiO_2 of greater than 0 mol%, 0.01 mol% or more, 0.1 mol% or more, 0.2 mol% or more, 0.3 mol% or more, 2 mol% or less, 1.5 mol% or less, 1 mol% or less, 0.75 mol% or less, 0.5 mol% or less, or 0.4 mol% or less. In aspects, the glass article may comprise a concentration of TiO_2 from greater than 0 mol% to 2 mol%, from 0.01 mol% to 1.5 mol%, from 0.1 mol% to 1 mol%, from 0.2 mol% to 0.75 mol%, from 0.3 mol% to 0.5 mol%, from 0.3 mol% to 0.4 mol%, or any range or subrange therebetween.

[00115] In aspects, the glass article may comprise a concentration of CeO_2 of 0.1 mol% or more, 0.2 mol% or more, 0.3 mol% or more, 2 mol% or less, 1.5 mol% or less, 1 mol% or less, 0.75 mol% or less, 0.5 mol% or less, or 0.4 mol% or less. In aspects, the glass article may comprise a concentration of CeO_2 from 0.1 mol% to 2 mol%, from 0.2 mol% to 1.5 mol%, from 0.2 mol% to 1 mol%, from 0.3 mol% to 0.75 mol%, from 0.3 mol% to 0.5 mol, from 0.3 mol% to 0.4 mol%, or any range or subrange therebetween.

[00116] In aspects, the glass article may comprise a concentration of NiO of greater than 0 mol%, 0.01 mol% or more, 0.015 mol% or more, 0.02 mol% or more, 0.05 mol% or more, 0.1 mol% or more, 0.3 mol% or less, 0.25 mol% or less, 0.2 mol% or less, 0.05 mol% or less, 0.04 mol% or less, 0.035 mol% or less, 0.03 mol% or less, 0.025 mol% or less, 0.02 mol% or less, or 0.015 mol% or less. In aspects, the glass article may comprise a concentration of NiO can be from greater than 0 mol% to 0.05 mol%, from 0.01 mol% to 0.04 mol%, from 0.01 mol% to 0.035 mol%, from 0.015 mol% to 0.03 mol%, from 0.02 mol% to 0.025 mol%, or any range or subrange

therebetween. In aspects, the glass article may comprise a concentration of NiO can be from greater than 0.01 mol% to 0.3 mol%, from 0.02 mol% to 0.3 mol%, from 0.05 mol% to 0.25 mol%, from 0.1 mol% to 0.25 mol%, from 0.15 mol% to 0.2 mol%, or any range or subrange therebetween.

[00117] In aspects, the glass article may comprise a concentration of CuO of greater than 0 mol%, 0.1 mol% or more, 0.15 mol% or more, 0.5 mol% or less, 0.4 mol% or less, 0.35 mol% or less, 0.3 mol% or less, 0.25 mol% or less, 0.2 mol% or less, or 0.15 mol% or less. In aspects, the glass article may comprise a concentration of CuO from greater than 0 mol% to 0.5 mol%, from 0.1 mol% to 0.4 mol% from 0.1 mol% to 0.35 mol%, from 0.15 mol% to 0.3 mol%, from 0.15 mol% to 0.25 mol%, from 0.15 mol% to 0.2 mol%, or any range or subrange therebetween.

[00118] In aspects, the glass article may comprise a concentration of Co_3O_4 of greater than 0 mol%, 0.0001 mol% or more, 0.0002 mol% or more, 0.0005 mol% or more, 0.001 mol% or more, 0.05 mol% or less, 0.04 mol% or less, 0.03 mol% or less, 0.02 mol% or less, 0.01 mol% or less, 0.0095 mol% or less, 0.009 mol% or less, 0.0085 mol% or less, 0.008 mol% or less, 0.0075 mol% or less, 0.007 mol% or less, 0.0065 mol% or less, 0.006 mol% or less, 0.0055 mol% or less, 0.005 mol% or less, 0.0045 mol% or less, 0.004 mol% or less, 0.0035 mol% or less, 0.003 mol% or less, 0.0025 mol% or less, or 0.002 mol% or less. In aspects, the glass article may comprise a concentration of Co_3O_4 from greater than 0 mol% to 0.01 mol% or less, from 0.0001 mol% to 0.009 mol% or less, from 0.0001 mol% to 0.008 mol%, from 0.0001 mol% to 0.007 mol%, from 0.0002 mol% to 0.006 mol%, from 0.0002 mol% to 0.005 mol%, from 0.0005 mol% to 0.004 mol%, from 0.0005 mol% to 0.003 mol%, from 0.01 mol% to 0.02 mol%, or any range or subrange therebetween. In aspects, the glass article may comprise a concentration of Co_3O_4 from 0.0001 mol% to 0.05 mol%, from 0.0005 mol% to 0.05 mol%, from 0.01 mol% to 0.05 mol%, from 0.02 mol% to 0.04 mol%, from 0.02 mol% to 0.03 mol%, or any range or subrange therebetween.

[00119] In aspects, the glass article may comprise a concentration of Cr_2O_3 of greater than 0 mol%, 0.01 mol% or more, 0.015 mol% or more, 0.02 mol% or more, or 0.05 mol% or less, 0.04 mol% or less, 0.035 mol% or less, 0.035 mol% or less, 0.03 mol% or less, 0.025 mol% or less, 0.02 mol% or less, 0.015 mol% or less, or 0.01 mol% or less. In aspects, the glass article may comprise a concentration of Cr_2O_3 from greater than 0 mol% to 0.05 mol%, from 0.01 mol% to 0.04 mol%, from 0.01

mol% to 0.035 mol%, from 0.015 mol% to 0.03 mol%, from 0.02 mol% to 0.025 mol%, or any range or subrange therebetween.

[00120] In aspects, the colorant package in the glass compositions and the resultant colored glass articles may comprise or consist of Au as a colorant to achieve a desired color. In aspects, Au may be included in the glass compositions as the sole colorant or in combination with other colorants. As described herein, in aspects, the glass compositions and the resultant colored glass articles may be formulated to improve the retention of Au, thereby expanding the color gamut achievable in the resultant colored glass articles. In aspects, the glass article may comprise a concentration of Au of 0.0005 mol% or more, 0.001 mol% or more, 0.002 mol% or more, 0.005 mol% or more, 0.01 mol% or more, 1 mol% or less, 0.75 mol% or less, 0.5 mol% or less, 0.25 mol% or less, 0.1 mol% or less, or 0.05 mol% or less. In aspects, the glass article may comprise a concentration of Au from 0.0005 mol% to 1 mol%, from 0.001 mol% to 0.75 mol%, from 0.002 mol% to 0.5 mol%, from 0.005 mol% to 0.25 mol%, from 0.01 mol% to 0.1 mol%, from 0.01 mol% to 0.05 mol%, or any range or subrange therebetween. In aspects, the glass article may comprise a concentration of Au of 1 ppm or more, 5 ppm or more, 10 ppm or more, 15 ppm or more, 100 ppm or more, 500 ppm or more, 1,000 ppm or more, 1 mol% or less, 0.75 mol% or less, 0.5 mol% or less, 10,000 ppm or less, 2,000 ppm or less, 1,000 ppm or less, 500 ppm or less, 100 ppm or less, 50 ppm or less, or 20 ppm or less. In aspects, the glass article may comprise a concentration of Au from 1 ppm to 10,000 ppm, from 1 ppm to 2,000 ppm, from 5 ppm to 1,000 ppm, from 5 ppm to 500 ppm, from 10 ppm to 100 ppm, from 15 ppm to 50 ppm, or any range or subrange therebetween. A different color gamut may be achieved by including secondary colorants in addition to Au. For example, in aspects, the glass composition and resultant colored glass article may comprise greater than or equal to 0 mol% and less than or equal to 1 mol% of a cation “M”, wherein “M” is at least one of F, Cl, Br, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Se, Nb, Mo, Ru, Rh, Pd, Ag, Cd, In, Te, W, Ir, Pt, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, and Er.

[00121] In aspects, the colorant package used in the glass compositions and the resultant colored glass articles described herein may comprise or consist of Cr₂O₃ as a colorant to achieve a desired color. In aspects, Cr₂O₃ may be included in the glass compositions as the sole colorant or in combination with other colorants. For example, in aspects where Cr₂O₃ is utilized as a colorant, other transition metal oxides

may be included in the glass composition to modify the color imparted to the glass, including, for example and without limitation, CuO, NiO, and/or Co₃O₄. As described herein, in aspects, the glass compositions and the resultant colored glass articles may be formulated to improve the solubility of Cr₂O₃, thereby expanding the color gamut achievable in the resultant colored glass articles. In aspects, the glass article may comprise Cr₂O₃ of greater than 0 mol% or more, 0.001 mol% or more, 0.005 mol% or less, 0.01 mol% or more, 0.05 mol% or more, 2 mol% or less, 1.5 mol% or less, 1 mol% or less, 0.5 mol% or less, or 0.1 mol% or less. In aspects, the glass article may comprise Cr₂O₃ from greater than 0 mol% to 2 mol%, from 0.001 mol% to 1.5 mol%, from 0.005 mol% to 1 mol%, from 0.01 mol% to 0.05 mol%, from 0.05 mol% to 0.1 mol%, or any range or subrange therebetween. In aspects, the glass article may comprise Cr₂O₃ from 100 ppm to 10,000 ppm, from 100 ppm to 5,000 ppm, from 300 ppm to 2,000 ppm, from 500 ppm to 1,000 ppm, or any range or subrange therebetween.

[00122] In aspects where the colorant package includes Cr₂O₃ as a colorant, the glass compositions and the resultant colored glass articles are per-alkali (i.e., R₂O (mol%) + R'O (mol%) – Al₂O₃ (mol%) is 0.5 mol% or more) to increase the solubility of Cr₂O₃ and avoid Cr-spinel crystal formation. However, when the glass composition has an excessive amount of alkali after charge balancing Al₂O₃, the alkali may form non-bridging oxygen around SiO₂, which degrades fracture toughness. Accordingly, in aspects, R₂O + R'O – Al₂O₃ in the glass article may be limited (e.g., less than or equal to 6 mol%) to prevent a reduction in fracture toughness.

[00123] In aspects, R₂O + R'O – Al₂O₃ in the glass article may be from 0.5 mol% to 6 mol% or from 1 mol% to 5.5 mol%. In aspects, R₂O + R'O – Al₂O₃ in the glass article may be 0.5 mol% or more, 1 mol% or more, 1.5 mol% or more, 2 mol% or more, 6 mol% or less, 5.5 mol% or less, 5 mol% or less, 4.5 mol% or less, 4 mol% or less, 3.5 mol% or less, 3 mol% or less, or 2.5 mol% or less. In aspects, R₂O + R'O – Al₂O₃ in the glass article may be from 0.5 mol% to 6 mol%, from 0.5 mol% to 5.5 mol%, from 1 mol% to 5 mol%, from 1 mol% to 4.5 mol%, from 1.5 mol% to 4 mol%, from 1.5 mol% to 3.5 mol%, from 2 mol% to 3 mol%, from 2 mol% to 2.5 mol%, or any range or subrange therebetween.

[00124] In aspects where the colorant package comprises Cr₂O₃ as a colorant, the glass compositions and the resultant colored glass articles may satisfy at least one of the following conditions and achieve the desired color: (1) less than or equal to

17.5 mol% Al_2O_3 and/or $\text{R}_2\text{O} + \text{R}'\text{O} - \text{Al}_2\text{O}_3$ greater than or equal to 0.5 mol%; (2) $\text{Al}_2\text{O}_3 + \text{MgO} + \text{ZnO}$ less than or equal to 22 mol%; and (3) $\text{MgO} + \text{ZnO}$ less than or equal to 4.5 mol%. In aspects where the colorant comprises Cr_2O_3 , different color gamuts may be achieved by including other colorants in addition to Cr_2O_3 . For example, in aspects, the glass composition and resultant colored glass article may comprise NiO , Co_3O_4 , CuO , or combinations thereof in addition to Cr_2O_3 .

[00125] In aspects, the glass article may comprise from greater than 0 mol% to 4 mol% NiO as a colorant in addition to Cr_2O_3 . In aspects, the concentration of NiO in the glass article may be greater than 0 mol%, 0.01 mol% or more, 0.05 mol% or more, 4 mol% or less, 3 mol% or less, 2 mol% or less 1 mol% or less, 0.5 mol% or less, 0.25 mol% or less, 0.1 mol% or less. In aspects, the concentration of NiO in the glass article may be from greater than 0 mol% to 4 mol%, from greater than 0 mol% to 3 mol%, from 0.01 mol% to 2 mol%, from 0.01 mol% to 1 mol%, from 0.01 mol%, from 0.5 mol%, from 0.05 mol% to 0.25 mol%, from 0.05 mol% to 0.1 mol%, or any range or subrange therebetween.

[00126] In aspects, the glass article may comprise from greater than 0 mol% to 2 mol% Co_3O_4 as a colorant in addition to Cr_2O_3 . In aspects, the concentration of Co_3O_4 in the glass article may be greater than 0 mol%, 0.001 mol% or more, 0.005 mol% or more, 0.01 mol% or more, 2 mol% or less, 1.5 mol% or less, 1 mol% or less, 0.5 mol% or less, 0.1 mol% or less, or 0.05 mol% or less. In aspects, the concentration of Co_3O_4 in the glass article may be from greater than 0 mol% to 2 mol%, from 0.001 mol% to 1.5 mol%, from 0.001 mol% to 1 mol%, from 0.005 mol% to 0.5 mol%, from 0.005 mol% to 0.1 mol%, from 0.01 mol% to 0.05 mol%, or any range or subrange therebetween.

[00127] In aspects, the glass article may comprise from greater than 0 mol% to 5 mol% CuO as a colorant in addition to Cr_2O_3 . In aspects, the concentration of CuO in the glass article may be greater than 0 mol%, 0.05 mol% or more, 0.1 mol% or more, 0.5 mol% or more, 1 mol% or more, 5 mol% or less, 4 mol% or less, 3 mol% or less, or 2 mol% or less. In aspects, the concentration of CuO in the glass article may be from greater than 0 mol% to 5 mol%, from 0.05 mol% to 4 mol%, from 0.1 mol% to 3 mol%, from 0.5 to 2 mol%, from 1 mol% to 2 mol%, or any range or subrange therebetween.

[00128] In aspects, the colorant package used in the glass compositions and the resultant colored glass articles may comprise or consist of Ag as a colorant to

achieve a desired color. As described herein, in aspects, the glass compositions and the resultant colored glass articles may be formulated to improve the retention of Ag, thereby expanding the color gamut achievable in the resultant colored glass articles. In aspects, Ag may be included in the glass compositions as the sole colorant or in combination with other colorants. In aspects where Ag is utilized as a colorant in the glass composition, the color is created by the presence of anisotropic silver particles in the colored glass article that are formed from the reduction of silver ions in the glass composition. Accordingly, in aspects, the glass article may comprise a concentration of Ag from 0.01 mol% to 5 mol%. In aspects, the glass article may comprise a concentration of Ag of 0.01 mol% or more, 0.05 mol% or more, 0.1 mol% or more, 5 mol% or less, 2.5 mol% or less, 1 mol% or less, 0.75 mol% or less, 0.5 mol% or less, 0.25 mol% or less. In aspects, the concentration of Ag in the glass article may be from 0.01 mol% to 5 mol%, from 0.01 mol% to 2.5 mol%, from 0.05 mol% to 1 mol%, from 0.05 mol% to 0.75 mol%, from 0.1 mol% to 0.5 mol%, from 0.1 mol% to 0.25 mol%, or any range or subrange therebetween.

[00129] Conventionally, halide-free colored glass articles that comprise silver in as-formed condition (i.e., colored glass articles that have not been subjected to mechanical stretching) produce only yellow, orange, and red colors upon a suitable heat treatment applied to the glass article in as-formed condition. These colors are generated by the formation of isotropic (i.e., nominally spherical) silver particles in the conventional, halide-free colored glass article. These isotropic silver particles support a single localized surface plasmon resonance. Isotropic silver particles are the most energetically favorable to form because they have the lowest surface area to volume ratio and, as a result, they are the most common geometry observed in colored glass articles that comprise silver.

[00130] In contrast, colored glass articles that comprise anisotropic silver particles can produce a much broader range of colors, for example pink, purple, blue, green, brown, and black. As used herein, anisotropic silver particles refer to silver particles having an aspect ratio greater than 1, where the aspect ratio is the ratio of a longest dimension of the particle to a shortest dimension of the particle (e.g., a ratio of the length of the particle to the width of the particle is greater than 1). This is in contrast to an isotropic silver particle in which the aspect ratio is 1. The broader color gamut produced in glasses having anisotropic silver particles is because anisotropic silver particles support two distinct plasmonic modes: a higher energy transverse

mode, and a lower energy longitudinal mode. These two distinct plasmonic modes can be observed via absorption spectra of the colored glass articles, which typically have at least two distinct peaks when anisotropic silver particles are present in the glass. By varying the aspect ratio of anisotropic particles, the resonant absorption of these two plasmonic modes can be tuned and, as a result, the color shifted.

[00131] Conventionally, the formation of anisotropic metallic silver particles in glass can be either induced by elongating spherical particles of silver through shear forces (e.g., by stretching the colored glass article via re-draw) using mechanical stretching processes. The mechanical stretching process results in a glass article having silver particles that are generally aligned in parallel with one another along the stretching direction (i.e., the glass is polarized).

[00132] A conventional alternative to mechanical stretching processes for creating anisotropic metallic particles in a glass article is the incorporation of halides (e.g., F, Cl, and Br) in the glass composition. In halide-containing colored glass articles, anisotropic silver particles are formed by templating the particles on elongated and/or pyramidal-shaped halide crystals. However, the inclusion of halides in the glass composition may be undesirable.

[00133] In contrast, the colored glass articles comprising Ag as a colorant described herein may generate a broad range of colors, for example yellow, orange, red, green, pink, purple, brown, and black without the inclusion of halides in the glass composition or the use of mechanical stretching processes. Without being bound by any particular theory, it is believed that anisotropic silver particles may form in the colored glass articles of the present disclosure due to a mechanism similar to the template growth caused by the inclusion of halides in the glass composition. However, instead of templating on a halide-containing crystal or mechanically stretching isotropic silver particles, it has been unexpectedly found that anisotropic silver crystals may form on nano-sized crystals of spodumene, lithium silicate, and/or beta quartz during heat treatment of the glass article in its as-formed condition. Additionally and/or alternatively, it is believed that anisotropic silver particles may precipitate at the interfaces between phase-separated regions of the colored glass article and/or regions that are only partially crystalized. Further, these crystals and/or phase-separated regions may form a nucleation site for the growth of anisotropic silver particles.

[00134] Accordingly, in aspects, the glass article including silver as a colorant may comprise less than 100 parts per million (ppm) of halides. For example, the glass compositions and the resultant colored glass articles comprising Ag as a colorant may comprise less than 100 ppm halides, for example less than 50 ppm halides, less than 25 ppm halides, less than 10 ppm halides, or even 0 ppm halides.

[00135] As noted previously, colored glass articles comprising Ag produced using mechanical stretching processes generally include anisotropic silver particles similar to those of the colored glass article of the present application. However, it should be noted that these mechanical stretching processes also result in the anisotropic silver particles being ordered and aligned (*e.g.*, the longer dimensions of each anisotropic silver particles are facing in the same direction, for example in the direction of mechanical stretching). Put more simply, the colored glass articles produced using mechanical stretching processes are polarized due to the alignment of the anisotropic silver particles in the glass as a result of mechanical stretching.

[00136] In contrast, in the aspects described herein, the colored glass articles comprising Ag as a colorant, which are not subjected to mechanical stretching processes, are non-polarized. In aspects, the anisotropic silver particles of the colored glass article are not aligned (*e.g.*, the longer dimensions of two or more anisotropic silver particles are facing in different directions) and, instead, the anisotropic silver particles are randomly aligned in the glass. As used herein, “length” refers to the longest dimension of the anisotropic silver particle. The “width” refers to the dimension of the anisotropic particle that is perpendicular to the length. To obtain the length and width of the anisotropic silver particles, a calibration is set by measuring the scale bar on the electron micrograph, converting each pixel to the appropriate unit length. The image is then converted into a grayscale image. A software measuring tool is then used to measure the number of pixels from one end to the other of each particle as well as the number of pixels across the greatest width of the particle. In aspects, an automated script is run to measure the length and aspect ratios of multiple particles automatically. In aspects, a length of the anisotropic silver particles can be 10 nm or more, 12 nm or more, 14 nm or more, 16 nm or more, 18 nm or more, 22 nm or more, 34 nm or more, 36 nm or more, 38 nm or more, 40 nm or less, 38 nm or less, 36 nm or less, 34 nm or less, 32 nm or less, 30 nm or less, 28 nm or less, 26 nm or less, 24 nm or less, 22 nm or less, or 20 nm or less. In aspects, the length of the anisotropic silver particles can range from 10 nm to 40 nm, from 12 nm to 36 nm,

from 14 nm to 34 nm, from 14 nm to 32 nm, from 14 nm to 28 nm, from 14 nm to 26 nm, from 16 nm to 22 nm, from 16 nm to 20 nm, or any range or subrange therebetween. In aspects, a width of the anisotropic silver particles can be 6 nm or more, 8 nm or more, 10 nm or more, 12 nm or more, 14 nm or more, 20 nm or less, 18 nm or less, 16 nm or less, 14 nm or less, 12 nm or less, or 10 nm or less. In aspects, the width of the anisotropic silver particles can be from 6 nm to 20 nm, from 8 nm to 18 nm, from 8 nm to 16 nm, from 10 nm to 14 nm, or any range or subrange therebetween. As used herein, “aspect ratio” is defined as the ratio of the length to the width of an anisotropic silver particle. In aspects, an aspect ratio of the anisotropic silver particle can be greater than 1, 1.5 or more, 2 or more, 2.5 or more, 3 or less, 2.5 or less, 2 or less, or 1.5 or less. In aspects, the aspect ratio of the anisotropic silver particle can range from greater than 1 to 3, from 1.5 to 2.5, from 2 to 2.5, or any range or subrange therebetween.

[00173] The glass articles that include Ag as a colorant may further comprise one or more rare-earth oxides, for example CeO₂, Nd₂O₃, and/or Er₂O₃. Rare-earth oxides may be added to provide additional visible light absorbance to the glass (in addition to that imparted by the silver) to further alter the color of the glass. Rare-earth oxides may also be added to increase the Young’s modulus and/or the annealing point of the glass.

[00174] In aspects, the glass articles that include Ag as a colorant may further comprise a concentration of CeO₂ of greater than 0 mol%, 0.05 mol% or more, 4 mol% or less, 3 mol% or less, 2 mol% or less, 1 mol% or less, or 0.5 mol% or less. In aspects, the glass articles that include Ag as a colorant may further comprise a concentration of CeO₂ from greater than 0 mol% to 4 mol%, from greater than 0 mol% to 3 mol%, from 0.05 mol% to 1 mol%, from 0.05 mol% to 0.5 mol%, or any range or subrange therebetween. In aspects, the glass article may be substantially free and/or free of CeO₂.

[00175] In aspects, the glass articles that include Ag as a colorant may comprise a concentration of Nd₂O₃ that is greater than 0 mol%, 0.1 mol% or more, 4 mol% or less, 3 mol% or less, 2 mol% or less, 1 mol% or less, or 0.5 mol% or less. In aspects, the glass articles that include Ag as a colorant may comprise a concentration of Nd₂O₃ from greater than 0 mol% to 4 mol%, from greater than 0 mol% to 3 mol%, from 0.1 mol% to 1 mol%, from 0.1 mol% to 0.5 mol%, or any range or subrange therebetween.

[00176] In aspects, the glass articles that include Ag as a colorant may comprise a concentration of Er_2O_3 that is greater than 0 mol%, 0.1 mol% or more, 4 mol% or less, 3 mol% or less, 2 mol% or less, 1 mol% or less, or 0.5 mol% or less. In aspects, the glass articles that include Ag as a colorant may comprise a concentration of Er_2O_3 from greater than 0 mol% to 4 mol%, from greater than 0 mol% to 3 mol%, from 0.1 mol% to 1 mol%, from 0.1 mol% to 0.5 mol%, or any range or subrange therebetween.

[00177] In aspects, the glass articles described herein may further include tramp materials, for example, TiO_2 , MnO , MoO_3 , WO_3 , Y_2O_3 , CdO , As_2O_3 , sulfur-based compounds (e.g., sulfates), halogens, or combinations thereof. In aspects, the glass article may be substantially free or free of tramp materials, for example TiO_2 , MnO , MoO_3 , WO_3 , Y_2O_3 , CdO , As_2O_3 , sulfur-based compounds (e.g., sulfates), halogens, or combinations thereof.

[00178] In aspects, decreasing the melting point of the glass article may help improve colorant retention because the glass compositions may be melted at relatively lower temperatures and colorant evaporation may be reduced. Accordingly, the glass articles described herein may optionally include MgO and/or ZnO , which help lower the melting point of the glass articles. B_2O_3 , Li_2O , and Na_2O also decrease the melting point of the glass articles. As described herein, other components may be added to the glass article to lower the melting point thereof, for example SnO_2 , Sb_2O_3 , and Bi_2O_3 . In aspects, the glass article may have a melting point of 1300°C or more, 1325°C or more, 1350°C or more, 1375°C or more, 1400°C or more, 1550°C or less, 1525°C or less, 1500°C or less, 1475°C or less, or 1450°C or less. In aspects, the melting point of the glass article can be from 1300°C to 1550°C , from 1325°C to 1525°C , from 1350°C to 1500°C , from 1375°C to 1475°C , from 1400°C to 1450°C , or any range or subrange therebetween. In aspects, a liquidus temperature of the glass article may be 1000°C or more, 1050°C or more, 1100°C or more, 1400°C or less, 1350°C or less, or 1300°C or less. In aspects, a liquidus temperature of the glass article may be from 1000°C to 1400°C , from 1050°C to 1350°C , from 1100°C to 1300 , or any range or subrange therebetween.

[00179] In aspects, the viscosity of the glass article may be adjusted to prevent devitrification of the glass composition and formation of colorant particles, for example Au particles, during melting and forming. Formation of colorant particles during melting and forming may limit the color gamut that may be achieved by heat

treatment. In aspects, to achieve the desired viscosity and thereby prevent formation of colorant particles before melting, the glass articles described herein may satisfy the relationship $5.72 \cdot \text{Al}_2\text{O}_3 \text{ (mol\%)} - 21.4 \cdot \text{ZnO (mol\%)} - 2.5 \cdot \text{P}_2\text{O}_5 \text{ (mol\%)} - 35 \cdot \text{Li}_2\text{O (mol\%)} - 16.6 \cdot \text{B}_2\text{O}_3 \text{ (mol\%)} - 20.5 \cdot \text{MgO (mol\%)} - 23.3 \cdot \text{Na}_2\text{O (mol\%)} - 27.9 \cdot \text{SrO (mol\%)} - 18.5 \cdot \text{K}_2\text{O (mol\%)} - 26.3 \cdot \text{CaO (mol\%)}$ is greater than -609 mol%. In aspects, the glass articles described herein may satisfy the relationship $5.72 \cdot \text{Al}_2\text{O}_3 \text{ (mol\%)} - 21.4 \cdot \text{ZnO (mol\%)} - 2.5 \cdot \text{P}_2\text{O}_5 \text{ (mol\%)} - 35 \cdot \text{Li}_2\text{O (mol\%)} - 16.6 \cdot \text{B}_2\text{O}_3 \text{ (mol\%)} - 20.5 \cdot \text{MgO (mol\%)} - 23.3 \cdot \text{Na}_2\text{O (mol\%)} - 27.9 \cdot \text{SrO (mol\%)} - 18.5 \cdot \text{K}_2\text{O (mol\%)} - 26.3 \cdot \text{CaO (mol\%)}$ is greater than -609 mol%, greater than or equal to -575 mol%, greater than or equal to -550 mol%, or even greater than or equal to -525 mol%. In aspects, the glass compositions and the resultant glass articles described herein may satisfy the relationship $5.72 \cdot \text{Al}_2\text{O}_3 \text{ (mol\%)} - 21.4 \cdot \text{ZnO (mol\%)} - 2.5 \cdot \text{P}_2\text{O}_5 \text{ (mol\%)} - 35 \cdot \text{Li}_2\text{O (mol\%)} - 16.6 \cdot \text{B}_2\text{O}_3 \text{ (mol\%)} - 20.5 \cdot \text{MgO (mol\%)} - 23.3 \cdot \text{Na}_2\text{O (mol\%)} - 27.9 \cdot \text{SrO (mol\%)} - 18.5 \cdot \text{K}_2\text{O (mol\%)} - 26.3 \cdot \text{CaO (mol\%)}$ is less than or equal to -400 mol%, less than or equal to -425 mol%, or even less than or equal to -450 mol%. In aspects, the glass articles described herein may satisfy the relationship $5.72 \cdot \text{Al}_2\text{O}_3 \text{ (mol\%)} - 21.4 \cdot \text{ZnO (mol\%)} - 2.5 \cdot \text{P}_2\text{O}_5 \text{ (mol\%)} - 35 \cdot \text{Li}_2\text{O (mol\%)} - 16.6 \cdot \text{B}_2\text{O}_3 \text{ (mol\%)} - 20.5 \cdot \text{MgO (mol\%)} - 23.3 \cdot \text{Na}_2\text{O (mol\%)} - 27.9 \cdot \text{SrO (mol\%)} - 18.5 \cdot \text{K}_2\text{O (mol\%)} - 26.3 \cdot \text{CaO (mol\%)}$ is from -609 mol% to -400 mol%, from -575 mol% to -425 mol%, from -550 mol% to -450 mol%, from -525 mol% to -450 mol%, or any range or subrange therebetween.

[00180] In aspects where the colorant package comprises Au, relatively smaller concentrations of $\text{R}_2\text{O} - \text{Al}_2\text{O}_3$ (e.g., less than or equal to 1.5 mol%) may result in a blue or purple glass article. Relatively higher concentrations of $\text{R}_2\text{O} - \text{Al}_2\text{O}_3$ (e.g., greater than 1.5 mol%) may result in an orange or red glass article. For example, in aspects in which the colorant package includes Au, $\text{R}_2\text{O} - \text{Al}_2\text{O}_3$ may be from -5 mol% to 1.5 mol% and b^* may be from -25 to 10 (exclusive of b^* greater than -0.5 and less than 0.5). In aspects, $\text{R}_2\text{O} - \text{Al}_2\text{O}_3$ may be from -3 mol% to 1.5 mol% and b^* may be from -15 to 7 (exclusive of b^* greater than -0.5 and less than 0.5). In aspects, $\text{R}_2\text{O} - \text{Al}_2\text{O}_3$ may be from -5 mol% to 1.5 mol%, from -1 mol% to 1.5 mol%, from 0 mol% to 1.5 mol%, or any range or subrange therebetween; and b^* may be from -25 to 10 (exclusive of b^* greater than -0.5 and less than 0.5), from -15 to 7, from -10 to 5 (exclusive of b^* greater than -0.5 and less than 0.5), from -10 to 5 (exclusive of b^* greater than -0.5 and less than 0.5), or any range or subrange

therebetween. In aspects in which the colorant package includes Au, $R_2O - Al_2O_3$ may be from 1.5 mol% to 7 mol% and b^* may be from 0.5 to 25. In aspects, $R_2O - Al_2O_3$ may be from 1.5 mol% to 5 mol% and b^* may be from 0.5 to 15. In aspects, $R_2O - Al_2O_3$ may be from 1.5 mol% to 7 mol%, from 1.5 mol% to 5 mol%, from 1.5 mol% to 3 mol%, or any range or subrange therebetween; and b^* may be from 0.5 to 25, from 2.5 to 15, from 5 to 10, or any range or subrange therebetween.

[00181] In aspects, the glass article may comprise from 60 mol% to 70 mol% SiO_2 ; from 11 mol% to 17 mol% Al_2O_3 ; from 2 mol% to 8 mol% B_2O_3 ; from 9 mol% to 14 mol% Li_2O ; from 2 mol% to 6 mol% Na_2O ; and from 1×10^{-6} mol% to 0.01 mol% Au. In further aspects, the glass article can further comprise from 0.1 mol% to 2 mol% MgO ; from 0.1 mol% to 2 mol% ZnO ; and. In even further aspects, $MgO + ZnO$ is from 0.1 mol% to 4.5 mol%. In further aspects, the glass article can further comprise from 0.1 mol% to 0.5 mol% K_2O ; and from 1×10^{-6} mol% to 0.05 mol% Au. In even further aspects, $R_2O - Al_2O_3$ is from 0 mol% to 3 mol%.

[00182] In aspects, the glass article may comprise from 40 mol% to 70 mol% SiO_2 ; from 8 mol% to 20 mol% Al_2O_3 ; from 1 mol% to 10 mol% B_2O_3 ; from 1 mol% to 20 mol% Li_2O ; from 1 mol% to 15 mol% Na_2O ; from 0 mol% to 6 mol% MgO ; from 0 mol% to 5 mol% ZnO ; and from 1×10^{-6} mol% to 1 mol% Au, wherein: $MgO + ZnO$ is from 0.1 mol% and to 6 mol%. In further aspects, the glass article may further comprise from 0 mol% to 8 mol% MgO and from 0.0005 mol% to 1 mol% Au.

[00183] In aspects, the glass article may comprise from 50 mol% to 80 mol% SiO_2 ; from 7 mol% to 25 mol% Al_2O_3 ; from 1 mol% to 15 mol% B_2O_3 ; from 5 mol% to 20 mol% Li_2O ; from 0.5 mol% to 15 mol% Na_2O ; from greater than 0 mol% to 1 mol% K_2O ; and from 1×10^{-6} mol% to 1 mol% Au, wherein: $R_2O - Al_2O_3$ is from -5 mol% to 7 mol%. In aspects, the glass article can comprise from 50 mol% to 70 mol% SiO_2 ; from 10 mol% to 17.5 mol% Al_2O_3 ; from 3 mol% to 10 mol% B_2O_3 ; from 8.8 mol% to 14 mol% Li_2O ; from 1.5 mol% to 8 mol% Na_2O ; and from 0 mol% to 2 mol% Cr_2O_3 , wherein: $R_2O + R'O - Al_2O_3$ is from 0.5 mol% to 6 mol%, and $Al_2O_3 + MgO + ZnO$ is from 12 mol% to 22 mol%.

[00184] In aspects, the glass article may comprise from 50 mol% to 70 mol% SiO_2 ; from 10 mol% to 20 mol% Al_2O_3 ; from 4 mol% to 10 mol% B_2O_3 ; from 7 mol% to 17 mol% Li_2O ; from 1 mol% to 9 mol% Na_2O ; from 0.01 mol% to 1 mol% SnO_2 ; and from 0.01 mol% to 5 mol% Ag, wherein $R_2O - Al_2O_3$ is from 0.2 mol% to

5.00 mol%. In aspects, the glass article may comprise from 50 mol% to 70 mol% SiO₂; from 10 mol% to 20 mol% Al₂O₃; from 1 mol% to 10 mol% B₂O₃; from 7 mol% to 14 mol% Li₂O; from 0.01 mol% to 8 mol% Na₂O; from 0.01 mol% to 1 mol% K₂O; from 0 mol% to 7 mol% CaO; and from 0 mol% to 8 mol% MgO, wherein Li₂O + K₂O + Na₂O + CaO + MgO + ZnO is 25 mol% or more and at least one of: CuO + NiO + Co₃O₄ + Cr₂O₃ is 0.001 mol% or more, CeO₂ is 0.1 mol% or more, and/or TiO₂ is 0.1 mol% or more.

[00185] Throughout the disclosure, fracture toughness (K_{IC}) represents the ability of a glass composition to resist fracture. Fracture toughness is measured on a non-strengthened glass article, such as measuring the K_{IC} value prior to ion exchange (IOX) treatment of the glass article, thereby representing a feature of a glass substrate prior to IOX. The fracture toughness test methods described herein are not suitable for glasses that have been exposed to IOX treatment. Accordingly, where the fracture toughness of an ion exchanged article is referred to, it means the fracture toughness of a non-ion exchanged article with the same composition and microstructure (when present) as the center (i.e., a point located at least 0.5t from every surface of the article or substrate where t is the thickness of the article or substrate) of the ion exchanged article (which corresponds to the portion of the ion exchanged article least affected by the ion exchange process and, hence, a composition and microstructure comparable to a non-ion exchanged glass). Fracture toughness is measured by the chevron notched short bar method. The chevron notched short bar (CNSB) method is disclosed in Reddy, K.P.R. et al, “Fracture Toughness Measurement of Glass and Ceramic Materials Using Chevron-Notched Specimens,” J. Am. Ceram. Soc., 71 [6], C-310-C-313 (1988) except that Y^*_m is calculated using equation 5 of Bubsey, R.T. et al., “Closed-Form Expressions for Crack-Mouth Displacement and Stress Intensity Factors for Chevron-Notched Short Bar and Short Rod Specimens Based on Experimental Compliance Measurements,” NASA Technical Memorandum 83796, pp. 1-30 (October 1992). Unless otherwise specified, all fracture toughness values were measured by chevron notched short bar (CNSB) method.

[00186] In aspects, the glass articles formed from the glass compositions described herein may have an increased fracture toughness such that the colored glass articles are more resistant to damage. In aspects, the glass article may have a K_{IC} fracture toughness as measured by a CNSB method, prior to ion exchange, of 0.7 MPa·m^{1/2} or more, 0.8 MPa·m^{1/2} or more, 0.9 MPa·m^{1/2} or more, or 1.0 MPa·m^{1/2} or

more. In aspects, the glass article **350 and/or 511** formed from the glass compositions described herein may have an increased fracture toughness such that the colored glass articles are more resistant to damage. In aspects, the glass article **350 and/or 511** may have a K_{IC} fracture toughness as measured by the DCB method, prior to ion exchange, of $0.6 \text{ MPa}\cdot\text{m}^{1/2}$ or more, $0.7 \text{ MPa}\cdot\text{m}^{1/2}$ or more, $0.8 \text{ MPa}\cdot\text{m}^{1/2}$ or more, $0.9 \text{ MPa}\cdot\text{m}^{1/2}$ or more, $1.0 \text{ MPa}\cdot\text{m}^{1/2}$ or more.

[00187] Throughout the disclosure, the dielectric constant of the glass article is measured using a split post dielectric resonator (SPDR) at a frequency of 10 GHz. The dielectric constant was measured on samples of the glass article having a length of 3 inches (76.2 mm), a width of 3 inches (76.2 mm), and a thickness of less than 0.9 mm. In aspects, the glass article **350 and/or 511** comprises a dielectric constant D_k at 10 GHz of 6.4 or less, 6.3 or less, 6.2 or less, 6.1 or less, 6 or less, 5.6 or more, 5.7 or more, 5.8 or more, 5.9 or more, or 6.0 or more. In aspects, the glass article **350 and/or 511** comprises a dielectric constant D_k at 10 GHz in a range from 5.6 to 6.4, from 5.7 to 6.3, from 5.8 to 6.2, from 5.9 to 6.1, from 5.9 to 6, or any range or subrange therebetween. In aspects, the dielectric constant at frequencies from 10 GHz to 60 GHz (e.g., from 26 GHz to 40 GHz) can be within one or more of the above-mentioned ranges. Without wishing to be bound by theory, it is believed that the dielectric constant of the glass article measured at 10 GHz approximates the dielectric constant at frequencies from 10 GHz to 60 GHz. Accordingly, a dielectric constant reported for a colored glass article at a frequency of 10 GHz approximates the dielectric constant of the colored glass article at frequencies in a range from 10 GHz to 60 GHz, inclusive of endpoints.

[00188] In aspects, although not shown, the natively colored glass housing can further comprise a coating disposed on the first major surface of the glass article, for example. For example, the coating can be an anti-reflective coating, an anti-glare coating, an easy-to-clean coating, a low-friction coating, an oleophobic coating, a diamond-like coating, a scratch-resistant coating, an abrasion-resistant coating, a polymeric hard coating, or a combination thereof. A scratch-resistant coating may comprise an oxynitride, for example, aluminum oxynitride or silicon oxynitride with a thickness of about 500 micrometers or more. In such aspects, the abrasion-resistant layer may comprise the same material as the scratch-resistant layer. In aspects, a low friction coating may comprise a highly fluorinated silane coupling agent, for example, an alkyl fluorosilane with oxymethyl groups pendant on the silicon atom. In such

aspects, an easy-to-clean coating may comprise the same material as the low friction coating. In other aspects, the easy-to-clean coating may comprise a protonatable group, for example an amine, for example, an alkyl aminosilane with oxymethyl groups pendant on the silicon atom. In such aspects, the oleophobic coating may comprise the same material as the easy-to-clean coating. In aspects, a diamond-like coating comprises carbon and may be created by applying a high voltage potential in the presence of a hydrocarbon plasma.

[00189] In further aspects, a polymeric hard coating can comprise one or more of an ethylene-acid copolymer, a polyurethane-based polymer, an acrylate resin, and a mercapto-ester resin. Example aspects of ethylene-acid copolymers include ethylene-acrylic acid copolymers, ethylene-methacrylic acid copolymers, and ethylene-acrylic-methacrylic acid terpolymers (e.g., Nucrel, manufactured by DuPont), ionomers of ethylene acid copolymers (e.g., Surlyn, manufactured by DuPont), and ethylene-acrylic acid copolymer amine dispersions (e.g., Aquacer, manufactured by BYK). Example aspects of polyurethane-based polymers include aqueous-modified polyurethane dispersions (e.g., Eleglas®, manufactured by Axalta). Example aspects of acrylate resins that can be UV curable include acrylate resins (e.g., Uveköl® resin, manufactured by Allinex), cyanoacrylate adhesives (e.g., Permabond® UV620, manufactured by Krayden), and UV radical acrylic resins (e.g., Ultrabond windshield repair resin, for example, Ultrabond (45CPS)). Example aspects of mercapto-ester resins include mercapto-ester triallyl isocyanurates (e.g., Norland optical adhesive NOA 61). In further aspects, the polymeric hard coating can comprise ethylene-acrylic acid copolymers and ethylene-methacrylic acid copolymers, which may be ionomerized to form ionomer resins through neutralization of the carboxylic acid residue with typically alkali-metal ions, for example, sodium and potassium, and also zinc. Such ethylene-acrylic acid and ethylene-methacrylic acid ionomers may be dispersed in water and coated onto the substrate to form an ionomer coating. Alternatively, such acid copolymers may be neutralized with ammonia which, after coating and drying liberates the ammonia to reform the acid copolymer as the coating. By providing a coating comprising a polymeric coating, the foldable apparatus can comprise low energy fracture. In further aspects, the polymeric hard coating can comprise an optically transparent hard-coat layer. Suitable materials for an optically transparent polymeric hard-coat layer include but are not limited to a cured acrylate resin material, an inorganic-organic hybrid polymeric material, an

aliphatic or aromatic hexafunctional urethane acrylate, a siloxane-based hybrid material, and a nanocomposite material, for example, an epoxy and urethane material with nanosilicate. As used herein, “inorganic-organic hybrid polymeric material” means a polymeric material comprising monomers with inorganic and organic components. An inorganic-organic hybrid polymer is obtained by a polymerization reaction between monomers having an inorganic group and an organic group. An inorganic-organic hybrid polymer is not a nanocomposite material comprising separate inorganic and organic constituents or phases, for example, inorganic particulates dispersed within an organic matrix. More specifically, suitable materials for an optically transparent polymeric (OTP) hard-coat layer include, but are not limited to, a polyimide, a polyethylene terephthalate (PET), a polycarbonate (PC), a poly methyl methacrylate (PMMA), organic polymer materials, inorganic-organic hybrid polymeric materials, and aliphatic or aromatic hexafunctional urethane acrylates. In aspects, an OTP hard-coat layer may consist essentially of an organic polymer material, an inorganic-organic hybrid polymeric material, or aliphatic or aromatic hexafunctional urethane acrylate. In aspects, an OTP hard-coat layer may consist of a polyimide, an organic polymer material, an inorganic-organic hybrid polymeric material, or aliphatic or aromatic hexafunctional urethane acrylate. In aspects, an OTP hard-coat layer may include a nanocomposite material. In aspects, an OTP hard-coat layer may include a nano-silicate and at least one of epoxy or urethane materials. Suitable compositions for such an OTP hard-coat layer are described in U.S. Pat. Pub. No. 2015/0110990, which is hereby incorporated by reference in its entirety by reference thereto. As used herein, “organic polymer material” means a polymeric material comprising monomers with only organic components. In aspects, an OTP hard-coat layer may comprise an organic polymer material manufactured by Gunze Limited and having a hardness of 9H, for example Gunze’s “Highly Durable Transparent Film.” As used herein, “inorganic-organic hybrid polymeric material” means a polymeric material comprising monomers with inorganic and organic components. An inorganic-organic hybrid polymer is obtained by a polymerization reaction between monomers having an inorganic group and an organic group. An inorganic-organic hybrid polymer is not a nanocomposite material comprising separate inorganic and organic constituents or phases, for example, inorganic particulates dispersed within an organic matrix. In aspects, the inorganic-organic hybrid polymeric material may include polymerized monomers comprising an

inorganic silicon-based group, for example, a silsesquioxane polymer. A silsesquioxane polymer may be, for example, an alkyl-silsesquioxane, an aryl-silsesquioxane, or an aryl alkyl-silsesquioxane having the following chemical structure: $(\text{RSiO}_{1.5})_n$, where R is an organic group for example, but not limited to, methyl or phenyl. In aspects, an OTP hard-coat layer may comprise a silsesquioxane polymer combined with an organic matrix, for example, SILPLUS manufactured by Nippon Steel Chemical Co., Ltd. In aspects, an OTP hard-coat layer may comprise 90 wt% to 95 wt% aromatic hexafunctional urethane acrylate, e.g., PU662NT (Aromatic hexafunctional urethane acrylate) manufactured by Miwon Specialty Chemical Co.) and 10 wt% to 5 wt% photo-initiator (e.g., Darocur 1173 manufactured by Ciba Specialty Chemicals Corporation) with a hardness of 8H or more. In aspects, an OTP hard-coat layer composed of an aliphatic or aromatic hexafunctional urethane acrylate may be formed as a stand-alone layer by spin-coating the layer on a polyethylene terephthalate (PET) substrate, curing the urethane acrylate, and removing the urethane acrylate layer from the PET substrate.

[00190] In aspects, the glass article **350 and/or 511** can comprise one or more compressive stress regions. In aspects, a compressive stress region may be created by chemically strengthening. Chemically strengthening may comprise an ion exchange process, where ions in a surface layer are replaced by—or exchanged with—larger ions having the same valence or oxidation state. Without wishing to be bound by theory, chemically strengthening the glass article can enable good impact resistance, good puncture resistance, and/or higher flexural strength. A compressive stress region may extend into a portion of glass article for a depth called the depth of compression (DOC). As used herein, depth of compression means the depth at which the stress in the chemically strengthened glass articles described herein changes from compressive stress to tensile stress. Depth of compression can be measured by a surface stress meter or a scattered light polariscope (SCALP, wherein values reported herein were made using SCALP-5 made by Glasstress Co., Estonia) depending on the ion exchange treatment and the thickness of the glass article being measured. Where the stress in the glass article is generated by exchanging potassium ions into the substrate, a surface stress meter, for example, the FSM-6000 (Orihara Industrial Co., Ltd. (Japan)), is used to measure depth of compression. Unless specified otherwise, compressive stress (including surface CS) is measured by surface stress meter (FSM) using commercially available instruments, for example the FSM-6000, manufactured

by Orihara. Surface stress measurements rely upon the accurate measurement of the stress optical coefficient (SOC), which is related to the birefringence of the glass. Unless specified otherwise, SOC is measured according to Procedure C (Glass Disc Method) described in ASTM standard C770-16, entitled “Standard Test Method for Measurement of Glass Stress-Optical Coefficient,” the contents of which are incorporated herein by reference in their entirety. Where the stress is generated by exchanging sodium ions into the glass article, and the glass article is thicker than about 400 μm , SCALP is used to measure the depth of compression and central tension (CT). Where the stress in the glass article is generated by exchanging both potassium and sodium ions into the glass article, and the article being measured is thicker than about 400 μm , the depth of compression and CT are measured by SCALP. Without wishing to be bound by theory, the exchange depth of sodium may indicate the depth of compression while the exchange depth of potassium ions may indicate a change in the magnitude of the compressive stress (but not the change in stress from compressive to tensile). The refracted near-field (RNF; the RNF method is described in U.S. Patent No. 8,854,623, entitled “Systems and methods for measuring a profile characteristic of a glass sample”, which is incorporated herein by reference in its entirety) method also may be used to derive a graphical representation of the stress profile. When the RNF method is utilized to derive a graphical representation of the stress profile, the maximum central tension value provided by SCALP is utilized in the RNF method. The graphical representation of the stress profile derived by RNF is force balanced and calibrated to the maximum central tension value provided by a SCALP measurement. As used herein, “depth of layer” (DOL) means the depth that the ions have exchanged into the glass article (e.g., sodium, potassium). Throughout the disclosure, DOL is measured in accordance with ASTM C-1422. Without wishing to be bound by theory, a DOL is usually greater than or equal to the corresponding DOC. Through the disclosure, when the maximum central tension cannot be measured directly by SCALP (as when the article being measured is thinner than about 400 μm) the maximum central tension can be approximated by a product of a maximum compressive stress and a depth of compression divided by the difference between the thickness of the glass article and twice the depth of compression, wherein the compressive stress and depth of compression are measured by FSM.

[00191] In aspects, the glass article **350 and/or 511** can comprise a first compressive stress region extending to a first depth of compression from the first

major surface **332 and/or 513**. In aspects, the glass article **350 and/or 511** can comprise a second compressive stress region extending to a second depth of compression from the second major surface **330 and/or 515**. In aspects, the first depth of compression and/or the second depth of compression as a percentage of the thickness **337 and/or 517** can be about 5% or more, about 10% or more, about 12% or more, about 15% or more, about 30% or less, about 25% or less, about 22% or less, about 20% or less, about 17% or less, or about 15% or less. In aspects, the first depth of compression and/or the second depth of compression as a percentage of the thickness **337 and/or 517** can be in a range from about 5% to about 30%, from about 10% to about 25%, from about 10% to about 22%, from about 12% to about 20%, from about 12% to about 17%, from about 15% to about 17%, or any range or subrange therebetween. In aspects, the first depth of compression and/or the second depth of compression can be about 10 μm or more, about 20 μm or more, about 30 μm or more, about 40 μm or more, about 50 μm or more, about 60 μm or more, about 500 μm or less, about 200 μm or less, about 150 μm or less, about 100 μm or less, about 90 μm or less, or about 80 μm or less. In aspects, the first depth of compression and/or the second depth of compression can be in a range from about 10 μm to about 500 μm , from about 20 μm to about 200 μm , from about 30 μm to about 150 μm , from about 40 μm to about 100 μm , from about 50 μm to about 90 μm , from about 60 μm to about 80 μm , or any range or subrange therebetween.

[00192] In aspects, the glass article **350 and/or 511** can comprise a first depth of layer of one or more alkali-metal ions associated with the first compressive stress region, and/or the glass article **350 and/or 511** can comprise a second depth of layer of one or more alkali-metal ions associated with the second compressive stress region and the second depth of compression. As used herein, the one or more alkali-metal ions of a depth of layer of one or more alkali-metal ions can include sodium, potassium, rubidium, cesium, and/or francium. In aspects, the one or more alkali ions of the first depth of layer of the one or more alkali ions and/or the second depth of layer of the one or more alkali ions comprises potassium. In aspects, the first depth of layer and/or the second depth of layer, as a percentage of the thickness **517**, can be about 1% or more, about 5% or more, about 10% or more, about 12% or more, about 15% or more, about 25% or less, about 20% or less, about 17% or less, about 15% or less, or about 10% or less. In aspects, the first depth of layer and/or the second depth of layer, as a percentage of the thickness **517**, can be in a range from about 1% to

about 25%, from about 5% to about 20%, from about 10% to about 17%, from about 12% to about 15%, or any range or subrange therebetween. In aspects, the first depth of layer of the one or more alkali-metal ions and/or the second depth of layer of the one or more alkali-metal ions can be about 1 μm or more, about 10 μm or more, about 15 μm or more, about 20 μm or more, about 25 μm or more, about 30 μm or more, about 200 μm or less, about 150 μm or less, about 100 μm or less, about 60 μm or less, about 45 μm or less, about 30 μm or less, or about 20 μm or less. In aspects, the first depth of layer of the one or more alkali-metal ions and/or the second depth of layer of the one or more alkali-metal ions can be in a range from about 1 μm to about 200 μm , from about 1 μm to about 150 μm , from about 10 μm to about 100 μm , from about 15 μm to about 600 μm , from about 20 μm to about 45 μm , from about 20 μm to about 30 μm , or any range or subrange therebetween.

[00193] In aspects, the first compressive stress region can comprise a maximum first compressive stress, and/or the second compressive stress region can comprise a maximum second compressive stress. In further aspects, the maximum first compressive stress and/or the maximum second compressive stress can be about 100 MegaPascals (MPa) or more, about 300 MPa or more, 400 MPa or more, about 500 MPa or more, about 600 MPa or more, about 700 MPa or more, about 1,500 MPa or less, about 1,200 MPa or less, about 1,000 MPa or less, or about 800 MPa or less. In further aspects, the maximum first compressive stress and/or the maximum second compressive stress can be in a range from about 100 MPa to about 1,500 MPa, from about 300 MPa to about 1,200 MPa, from about 400 MPa to about 1,000 MPa, from about 500 MPa to about 1,000 MPa, from about 600 MPa to about 900 MPa, from about 700 MPa to about 800 MPa, or any range or subrange therebetween.

[00194] In aspects, the glass article **350 and/or 511** can comprise a tensile stress region. In further aspects, the tensile stress region can be positioned between the first compressive stress region and the second compressive stress region. In further aspects, the tensile stress region can comprise a maximum tensile stress. In even further aspects, the maximum tensile stress can be about 10 MPa or more, about 30 MPa or more, about 50 MPa or more, about 60 MPa or more, about 80 MPa or more, about 250 MPa or less, about 200 MPa or less, about 100 MPa or less, about 80 MPa or less, or about 60 MPa or less. In even further aspects, the maximum tensile stress can be in a range from about 10 MPa to about 250 MPa, from about 30 MPa to

about 200 MPa, from about 50 MPa to about 100 MPa, from about 60 MPa to about 80 MPa, or any range or subrange therebetween.

[00195] In aspects, the glass article **350 and/or 511** comprises an average transmittance over the wavelength range from 400 nm to 750 nm of 10% or more, about 15% or more, 20% or more, about 25% or more, about 30% or more, 40% or more, 60% or more, 70% or more, 75% or more, 80% or more, 82% or more, 85% or more, 87% or more, 92% or less, 91% or less, 90% or less, 89% or less, 88% or less, 87% or less, 86% or less, 85% or less, 80% or less, 75% or less, or 70% or less. In aspects, the glass article **350 and/or 511** comprises an average transmittance over the wavelength range from 400 nm to 750 nm from 10% to 92%, from 15% to 92%, from 20% to 91%, from 20% to 91%, from 25% to 91%, from 30% to 90%, from 40% to 90%, from 60% to 89%, from 70% to 88%, from 75% to 87%, from 80% to 86%, from 82% to 85%, or any range or subrange therebetween. Alternatively, the glass article **350 and/or 511** can be opaque.

[00196] In aspects, the color exhibited by glass article **350 and/or 511** can correspond to at least one 10 nm band with lower transmittance than the average transmittance over the visible spectrum (e.g., from 400 nm to 700 nm). In aspects, the glass article **350 and/or 511** can exhibit a total transmittance of at least one 10 nm band within the wavelength range of 380 nm to 750 nm that is 3% or more, 5% or more, 8% or more, 10% or more, 20% or more, 40% or more, 50% or more, 60% or more, 70% or more, 80% or less, 78% or less, 75% or less, 72% or less, 70% or less, 68% or less, or 65% or less. In aspects, the glass article **350 and/or 511** can exhibit a total transmittance of at least one 10 nm band within the wavelength range of 380 nm to 750 nm in range from 3% to 80%, from 5% to 78%, from 8% to 75%, from 10% to 72%, from 20% to 70%, from 40% to 68%, from 50% to 65%, or any range or subrange therebetween.

[00197] Glass articles of the present disclosure can exhibit saturated colors. For example, the CIE L* value can be about 50 or more with an absolute value of the CIE a* value of about 0.3 or more (e.g., about 15 or more) and an absolute value of the CIE b* value of about 0.2 or more (e.g., about 5 or more). In aspects, the glass article **350 and/or 511** can comprise a CIE L* value of 50 or more, 60 or more, 70 or more, 75 or more, 80 or more, 85 or more, 90 or more, 96 or less, 92 or less, 90 or less, 88 or less, 85 or less, 82 or less, 80 or less, 75 or less, 65 or less, or 55 or less. In aspects, the glass article **350 and/or 511** can comprise a CIE L* value from 50 to 96,

from 60 to 92, from 70 to 90, from 75 to 88, from 80 to 85, or any range or subrange therebetween.

[00198] In aspects, the glass article **350 and/or 511** can comprise an absolute value of a CIE a^* (i.e., $|a^*|$) value of 0.3 or more, 0.5 or more, 0.8 or more, 1 or more, 3 or more, 5 or more, 10 or more, 15 or more, 18 or more, 20 or more, 25 or more, or 30 or more. In aspects, the CIE a^* value can be about -35 or more, -20 or more, -18 or more, -15 or more, -10 or more, -5 or more, -3 or more, -1 or more, 0.3 or more, 0.5 or more, 0.8 or more, 1 or more, 5 or more, 8 or more, 10 or more, 18 or more, 20 or more, 25 or more, 65 or less, 40 or less, 25 or less, 18 or less, 10 or less, 8 or less, 5 or less, 3 or less, 1 or less, -0.3 or more, -0.5 or more, -0.8 or more, -1 or less, -3 or less, -5 or less, -8 or less, -10 or less, -15 or less, -18 or less, -20 or less, or -25 or less. In aspects, the CIE a^* value (excluding values from -0.3 to 0.3) can range from about -35 to 65, from -20 to 40, from -18 to 25, from -15 to 20, from -10 to 18, from -5 to 10, from -3 to 5, from -1 to 3, from -0.8 to 1, or any range or subrange therebetween. For example, the CIE a^* value (excluding value from -0.3 to 0.3) can range from -35 to 60, -20 to 60, -10 to 25, from -5 to 25, or any range or subrange therebetween. Alternatively, the CIE a^* value can range from -35 to -0.3, from -18 to -0.5, from -15 to -1, from -10 to -1, from -8 to -1, from -5 to -1, or any range or subrange therebetween. Alternatively, the CIE a^* value can range from 0.3 to 65, from 0.3 to 25, from 0.3 to 18, from 0.3 to 10, from 0.5 to 8, from 1 to 5, or any range or subrange therebetween. In aspects, the CIE a^* value can be about -3 or less, for example, in a range from about -35 to about -3, from about -20 to about -3, from about -18 to about -3, from about -15 to about -3, from about -10 to about -5, or any range or subrange therebetween.

[00199] In aspects, the glass article **350 and/or 511** can comprise an absolute value of a CIE b^* (i.e., $|b^*|$) value of 0.2 or more, 0.3 or more, 0.5 or more, 1 or more, 1.5 or more, 3 or more, 5 or more, 8 or more, 10 or more, 20 or more, 50 or more, 70 or more, or 80 or more. In aspects, the CIE b^* value can be -90 or more, -85 or more, -75 or more, -50 or more, -35 or more, -20 or more, -5 or more, -1 or more, 0.2 or more, 0.3 or more, 0.5 or more, 1 or more, 3 or more, 5 or more, 8 or more, 10 or more, 20 or more, 50 or more, 70 or more, 120 or less, 90 or less, 82 or less, 75 or less, 50 or less, 35 or less, 20 or less, 8 or less, 5 or less, -0.2 or less, -0.3 or less, -0.5 or less, -1 or less, -5 or less, -10 or less, -20 or less, -35 or less, -50 or less, or -70 or less. In aspects, the CIE b^* value (excluding from -0.2 to 0.2) can range from -90 to

120, from -85 to 75, from -50 to 50, from -35 to 35, from -20 to 20, from -5 to 8, from -1 to 5, from 0.2 to 3, from 0.3 to 1, or any range or subrange therebetween. For example, the CIE b^* value can range from -20 to 5, from -10 to 5, from -5 to 5, from -5 to 3, from -5 to 1, from -5 to -0.2, from -3 to -0.3, from -1 to -0.5, or any range or subrange therebetween. Alternatively, the CIE b^* value can range from 0.2 to 90, from 0.5 to 82, from 1 to 75, from 1 to 20, from 1 to 5, from 1.5 to 5, or any range or subrange therebetween. Alternatively, the CIE b^* value can range from -90 to -0.2, from -85 to -0.5, from -20 to -1, from -10 to -1, from -1 to -5, or any range or subrange therebetween. In aspects, the CIE b^* value can be about 5 or more, for example, in a range from about 5 to about 120, from about 5 to about 90, from about 5 to about 75, from about 5 to about 50, from about 5 to about 35, from about 5 to about 25, from about 5 to about 20, from about 5 to about 8, or any range or subrange therebetween.

[00200] In aspects, as shown in **FIG. 6**, the glass article **511** can comprise a plurality of particulates (e.g., particulate **603**, **605**, and **613**). As used herein, a “maximum dimension” of a particulate is the longest linear distance from one end of the particulate to another end of the particulate such that a line segment connecting the two ends is entirely within the particulate (other than at the ends). For example, particulate **603** or **605** is circular in the two-dimensional image shown in **FIG. 6**; so, the maximum dimension **605** or **609** is equal to the diameter of the circular shape. For example, the particulate **613** is an irregular, elongated shape, and the maximum dimension **613** is the longest line segment of all line segments between pairs of two points (e.g., ends) of the particulate **613** with the line segment therebetween (not shown) being entirely within the particulate **613** (other than at the endpoints of the line segment). Throughout the disclosure, a “particulate” comprising a maximum dimension of 30 nm or more and the “particulate” comprises a colorant (as discussed above). In aspects, a distribution of the maximum dimension of the plurality of particulates can have a single peak (e.g., unimodal), for example, corresponding to predominantly smaller particulates like particulate **603** or predominantly larger particulates like particulate **609** or **613**. Alternatively, in aspects, a distribution of the maximum dimension of the plurality of particulates can have more than one peak (e.g., bimodal or otherwise having more than one local maximum), for example, with a set a smaller particulates (e.g., particulate **603**) and a set of larger particulates (e.g., particulate **609** or **613**).

[00201] In further aspects, a majority of the particulates can have maximum dimension less than 50 μm . In even further aspects, 80% or more of a distribution of the maximum dimension of the plurality of particulates can be from about 30 nm to about 50 μm , from about 30 nm to about 40 μm , from about 70 nm to about 30 μm , from about 100 nm to about 20 μm , from about 200 nm to about 10 μm , or any range or subrange therebetween. In even further aspects, 80% or more of a distribution of the maximum dimension of the plurality of particulates can be from about 2 μm to about 50 μm , from about 2 μm to about 40 μm , from about 2 μm to about 30 μm , from about 10 μm to about 20 μm , or any range or subrange therebetween. In even further aspects, 60% or more of a distribution of the maximum dimension of the plurality of particulates can be from about 30 nm to about 50 μm , from about 50 nm to about 40 μm , from about 70 nm to about 30 μm , from about 100 nm to about 20 μm , from about 200 nm to about 10 μm , or any range or subrange therebetween. In even further aspects, 60% or more of a distribution of the maximum dimension of the plurality of particulates can be from about 2 μm to about 50 μm , from about 2 μm to about 40 μm , from about 2 μm to about 30 μm , from about 10 μm to about 20 μm , or any range or subrange therebetween. In even further aspects, 50% or more of a distribution of the maximum dimension can be from 2 μm to 40 μm , from 10 μm to 40 μm , from 30 nm to 30 μm , or from 2 μm to 30 μm . In even further aspects, a fraction of the distribution of the maximum dimension of the plurality of particulates that is greater than 50 μm can be about 25% or less, about 20% or less, about 15% or less, about 10% or less, about 5% or less, about 4% or less, about 3% or less, about 2% or less, or about 1% or less. In even further aspects, a fraction of the distribution of the maximum dimension of the plurality of particulates that is greater than 100 μm can be about 10% or less, about 7% or less, about 6% or less, about 5% or less, about 4% or less, about 3% or less, about 2% or less, or about 1% or less. In even further aspects, a maximum value of the maximum dimension of the plurality of particulates can be 200 μm or less, about 150 μm or less, about 100 μm or less, about 80 μm or less, about 60 μm or less, about 50 μm or less, or about 40 μm or less.

[00202] In further aspects, a median value of the maximum dimension of the plurality of particulates can be about 30 nm or more, about 40 nm or more, about 50 nm or more, about 70 nm or more, about 100 nm or more, about 200 nm or more, about 500 nm or more, about 800 nm or more, about 1 μm or more, about 2 μm or more, about 5 μm or more, about 10 μm or more, about 50 μm or less, about 45 μm or

less, about 40 μm or less, about 35 μm or less, about 30 μm or less, about 25 μm or less, about 20 μm or less, about 15 μm or less, about 10 μm or less, about 5 μm or less, or about 1 μm or less. In further aspects, a median value of the maximum dimension of the plurality of particulates can be in a range from about 30 nm to about 50 μm , from about 40 nm to about 45 μm , from about 50 nm to about 40 μm , from about 100 nm to about 40 μm , from about 200 nm to about 40 μm , from about 500 nm to about 35 μm , from about 800 nm to about 35 μm , from about 1 μm to about 30 μm , from about 2 μm to about 25 μm , from about 5 μm to about 20 μm , from about 10 μm to about 15 μm , or any range or subrange therebetween. In further aspects, a median value of the maximum dimension of the plurality of particulates can be in a range from about 30 nm to about 40 μm , from about 2 μm to about 30 μm , from about 10 μm to about 20 μm , or any range or subrange therebetween. In further aspects, a median value of the maximum dimension of the plurality of particulates can be less than 10 μm , for example, from about 30 nm to about 10 μm , from about 40 nm to about 10 μm , from about 50 nm to about 5 μm , from about 70 nm to about 5 μm , from about 100 nm to about 1 μm , from about 200 nm to about 1 μm , from about 500 nm to about 1 μm , or any range or subrange therebetween. In aspects, the plurality of particulates can include a set of particulates with a maximum dimension from 30 nm to 2 μm or from 50 nm to 2 μm .

[00203] As used herein, a concentration of the plurality of particulates is measured for a section of the glass article comprising a 1 mm x 1 mm portion of the major surfaces and all the material therebetween using optical microscopy. Throughout the disclosure, density of the glass article is measured in accordance with ASTM D792. Consequently, a mass of the portion of the glass article where the measurement occurs can be calculated. In aspects, a concentration of the plurality of particulates in the glass article can be about 1 particulate per kilogram (p/kg) or more, about 2 p/kg or more, about 5 p/kg or more, about 10 p/kg or more, about 20 p/kg or more, about 30 p/kg or more, about 1,000 p/kg or less, about 500 p/kg or less, about 200 p/kg or less, about 100 p/kg or less, about 80 p/kg or less, about 60 p/kg or less, about 40 p/kg or less, or about 20 p/kg or less. In aspects, a concentration of the plurality of particulates in the glass article can range from about 1 p/kg to about 1,000 p/kg or, from about 2 p/kg to about 500 p/kg, from about 5 p/kg or to about 200 p/kg, from about 10 p/kg to about 100 p/kg, from about 20 p/kg to about 80 p/kg, from about 30 p/kg or to about 60 p/kg, or any range or subrange therebetween.

[00204] Throughout the disclosure, a “cluster of particulates” refers to a collection of particulates where each particulate in the cluster is within 15 μm of another particulate in the cluster of particulates. With reference to a “cluster of particulates,” a “maximum dimension” dimension refers to the distance of the longest line segment between ends of the particulate. Unlike the “maximum dimension” of a single particle, the “maximum dimension” of a cluster of particulates is not limited to having the line segment entirely within the particulate. For example, as shown in **FIGS. 10-13**, clusters **1001**, **1101**, **1201**, and **1301** have a maximum dimension **1011**, **1111**, **1211**, or **1311** from one end of the cluster to another end, where each particulate in the cluster is within 15 μm of another particulate in the cluster. With reference to **FIG. 10**, particulate **1003** is separated from particulate **1005** by spacing **1015**, where the spacing is about 6 μm that is less than 15 μm and the distance between other adjacent pairs of particulates is less than spacing **1015**. Also, it is to be noted that the maximum dimension **1013** of the particulate **1003** is not required to be measured in the same direction as the maximum dimension **1011** of the cluster **1001**.

[00205] In aspects, a majority of the clusters of particulates can have a maximum dimension less than 50 μm . In further aspects, 80% or more of a distribution of the maximum dimension of the clusters of particulates can be from about 30 nm to about 50 μm , from about 50 nm to about 40 μm , from about 70 nm to about 30 μm , from about 100 nm to about 20 μm , from about 200 nm to about 10 μm , or any range or subrange therebetween. In further aspects, 80% or more of a distribution of the maximum dimension of the clusters of particulates can be from about 2 μm to about 50 μm , from about 2 μm to about 40 μm , from about 10 μm to about 30 μm , or any range or subrange therebetween. In further aspects, 60% or more of a distribution of the maximum dimension of the clusters of particulates can be from about 30 nm to about 50 μm , from about 50 nm to about 40 μm , from about 70 nm to about 30 μm , from about 100 nm to about 20 μm , from about 200 nm to about 10 μm , or any range or subrange therebetween. In further aspects, 60% or more of a distribution of the maximum dimension of the clusters of particulates can be from about 2 μm to about 50 μm , from about 2 μm to about 40 μm , from about 2 μm to about 30 μm , from about 10 μm to about 30 μm , or any range or subrange therebetween. In even further aspects, 50% or more of a distribution of the maximum dimension can be from 10 μm to 40 μm , from 30 nm to 30 μm , or from 2 μm to 30 μm . In further aspects, a fraction of the distribution of the maximum dimension of the

clusters of particulates that is greater than 50 μm can be about 25% or less, about 20% or less, about 15% or less, about 10% or less, about 5% or less, about 4% or less, about 3% or less, about 2% or less, or about 1% or less. In further aspects, a fraction of the distribution of the maximum dimension of the clusters of particulates that is greater than 100 μm can be about 10% or less, about 7% or less, about 6% or less, about 5% or less, about 4% or less, about 3% or less, about 2% or less, or about 1% or less. In even further aspects, a maximum value of the maximum dimension of the plurality of particulates can be 200 μm or less, about 150 μm or less, about 100 μm or less, about 80 μm or less, about 60 μm or less, about 50 μm or less, or about 40 μm or less.

[00206] In further aspects, a median value of the maximum dimension of the clusters of particulates can be about 50 nm or more, about 100 nm or more, about 500 nm or more, about 1 μm or more, about 2 μm or more, about 5 μm or more, about 10 μm or more, about 50 μm or less, about 45 μm or less, about 40 μm or less, about 35 μm or less, about 30 μm or less, about 25 μm or less, about 20 μm or less, about 15 μm or less, about 10 μm or less, about 5 μm or less, or about 1 μm or less. In further aspects, a median value of the maximum dimension of the clusters of particulates can be in a range from about 50 nm to about 50 μm , from about 100 nm to about 50 μm , from about 500 nm to about 45 μm , from about 1 μm to about 45 μm , from about 2 μm to about 40 μm , from about 5 μm to about 40 μm , from about 10 μm to about 40 μm , from about 15 μm to about 40 μm , from about 15 μm to about 35 μm , from about 20 μm to about 25 μm , or any range or subrange therebetween. In further aspects, a median value of the maximum dimension of the clusters of particulates can be in a range from about 2 μm to about 40 μm , about 10 μm to about 40 μm , from about 10 μm to about 30 μm , from about 15 μm to about 30 μm , from about 15 μm to about 25 μm , or any range or subrange therebetween.

[00207] As used herein, a concentration of the clusters of particulates is measured for a section of the glass article comprising a 1 mm x 1 mm portion of the major surfaces and all the material therebetween using optical microscopy. In aspects, a concentration of clusters of particulates in the glass article can be about 1 cluster per kilogram (c/kg) or more, about 2 c/kg or more, about 5 c/kg or more, about 10 c/kg or more, about 20 c/kg or more, about 30 c/kg or more, about 1,000 c/kg or less, about 500 c/kg or less, about 200 c/kg or less, about 100 c/kg or less, about 80 c/kg or less, about 60 c/kg or less, about 40 c/kg or less, or about 20 c/kg or less. In aspects, a

concentration of clusters of particulates in the glass article can range from about 1 c/kg to about 1,000 c/kg or, from about 2 c/kg to about 500 c/kg, from about 5 c/kg or to about 200 c/kg, from about 10 c/kg to about 100 c/kg, from about 20 c/kg to about 80 c/kg, from about 30 c/kg or to about 60 c/kg, or any range or subrange therebetween.

[00208] Without wishing to be bound by theory, it is believed that traditional colorant approaches produce particles less than 50 nm (e.g., less than 30 nm), if any. For example, as described above, the length of silver particles is less than 40 nm with smaller maximum values provided. Likewise, gold particles for imparting color comprise nanometer scale maximum dimensions (e.g., less than 30 nm, less than 20 nm, from 1 nm to 20 nm). Indeed, it is believed that particulates of gold and silver larger than 50 nm would not be effect as colorants. Consequently, the particulates (and clusters thereof) described herein are of a different scale than would be achieved in traditional approaches. Further, the present inventors have discovered that these particulates can enable a more saturated color to be achieved. Indeed, the more saturated color can be achieved without noticeable visual defects associated with the particulates when a majority of the particulates (or a portion described above) have a maximum dimension less than about 50 μm (e.g., less than about 40 μm). Since the particulates described herein comprise colorants, the particulates enable higher amounts of colorant to be included in glass articles without noticeable visual defects to achieve colors that may not otherwise be possible with a natively colored glass article and/or natively colored glass housing. Providing more saturated colors can be aesthetically pleasing.

[00209] On the other hand, large aggregates encountered in conventional approaches to increasing colorant concentration tend to about 100 μm or more, which can be noticeable with the naked eye and/or aesthetically unpleasing. In contrast, the particulates of the present disclosure can have a median of a maximum dimension of a particulate and/or a median of a maximum dimension of a cluster size that is 50 μm or less (e.g., 40 μm or less, from 10 μm to 30 μm), and/or a distribution of the particulates or clusters of the present disclosure greater than 40 μm or more (e.g., 50 μm or more) can be less than 40% (e.g., less than 20%).

[00210] Aspects of methods of making the glass article and/or natively colored glass housing in accordance with aspects of the disclosure will be discussed

with reference to the flow chart in **FIG. 7** and example method steps illustrated in **FIGS. 8-9**.

[00211] In a first step **701** of methods of the disclosure, methods can start with obtaining raw materials for the glass article and/or natively colored glass article, which can be obtained, for example, by purchase or otherwise obtaining the raw materials. In aspects, the raw materials can be melted together and formed in a glass article by the end of step **701**. For example, precursor materials comprising a combination of constituent glass components and one or more colorants in a colorant package described herein may be melted together. In further aspects, the glass article can be provided by forming them with a variety of ribbon forming processes, for example, slot draw, down-draw, fusion down-draw, up-draw, press roll, redraw, or float. Alternatively, the glass article may be provided by purchase or otherwise obtaining a substrate or by forming the glass article. In aspects, methods can comprise milling the precursor materials or at least the precursor material comprising the colorant to reduce an associated particle size, which can increase a particulate size in the resulting glass article. In aspects, the initial glass article may be exposed to a heat treatment to produce color in the glass article, as described below in step **705**.

[00212] After step **701**, methods can proceed to step **703** comprising melting together the raw materials to form a glass article. Amounts the raw materials (mol% on an oxide basis) can be within one or more of the ranges discussed above for the composition of glass article. In aspects, the raw materials can further comprise an additive that can impact the resulting color and/or ultraviolet (UV)-related properties of the glass article but will volatilize during the melting of the raw materials to form the glass article. Exemplary aspects of such additives include nitrates (e.g., KNO_3 , NaNO_3), sulfates (e.g., K_2SO_4 , Na_2SO_4), and carbon (e.g., charcoal, carbon black). In further aspects, the raw materials can include a source of nitrate (e.g., KNO_3 , NaNO_3) with the amount of nitrate in the raw materials can be about 1.5 wt% or more, about 2 wt% or more, about 2.5 wt% or more, about 5 wt% or less, about 3 wt% or less, or about 2.9 wt% or less. In further aspects, the raw materials can include a source of nitrate (e.g., KNO_3 , NaNO_3) with the amount of nitrate in the raw materials can range from about 1.5 wt% to about 5 wt%, from about 2 wt% to about 3 wt%, from about 2.5 wt% to about 2.9 wt%, or any range or subrange therebetween. In further aspects, an amount of the source of sulfate in the precursor materials can range from about 0.01 wt% to about 1 wt%, from about 0.02 wt% to about 1 wt%, from about 0.05 wt%

to about 0.5 wt%, from about 0.1 wt% to about 0.3 wt%, from about 0.15 wt% to about 0.25 wt%, from about 0.2 wt% to about 0.25 wt%, or any range or subrange therebetween. In aspects, step **703** can further comprise applying pressure from a roller to break apart any large (e.g., 50 μm or more) particulates.

[00213] After step **703**, as shown in **FIG. 8**, methods can proceed to step **705** comprising heating the glass article. In aspects, as shown, heating the glass article can comprise placing the glass article **511** in an oven **801**. In aspects, different color coordinates within the color gamut may be achieved by altering the heat treatment cycle of the glass composition used to produce the resultant colored glass articles. The heat treatment cycle is characterized by the temperature of the environment (i.e., the oven) and the duration of the cycle (i.e., the time exposed to the heated environment). As used herein, the phrase “temperature of the heat treatment cycle” refers to the temperature of the environment (i.e., the oven). Unless otherwise indicated, glass articles described herein are heat treated in an isothermal oven to produce the resultant colored glass articles. Although, in other aspects, methods may follow arrow **704 or 706** from step **703** omitting step **705**, for example, if the glass article does not need to be heat treated to be colored or if the color was otherwise developed by the end of step **703**.

[00214] In aspects, the precursor glass article may be exposed to a heat treatment to produce color in the glass. For example and without limitation, the heat treatment may induce the formation of colorant particles in the glass which, in turn, cause the glass to become colored. In aspects, the glass may appear clear (i.e., colorless) prior to heat treatment. Examples of colorant particles may include, for example and without limitation, Au particles (e.g., when the colorant package in the glass comprises Au), randomly oriented, anisotropic silver particles (e.g., when the colorant package comprises Ag) and/or the like, thereby forming a colored glass article. The time and/or temperature of the heat treatment may be specifically selected to produce a colored glass article having a desired color. Without wishing to be bound by theory, it is believed that a desired color is a result of the morphology of the particles precipitated in the glass which, in turn, is dependent on the time and/or temperature of the heat treatment. Accordingly, it should be understood that a single glass composition can be used to form colored glass articles having different colors based on the time and/or temperature of the applied heat treatment in addition to the composition of the colorant package included in the glass. Specifically, different color

coordinates within the color gamut may be achieved by altering the heat treatment cycle of the glass composition used to produce the resultant colored glass articles. The heat treatment cycle is characterized by the temperature of the environment (i.e., the oven) and the duration of the cycle (i.e., the time exposed to the heated environment). As used herein, the phrase “temperature of the heat treatment cycle” refers to the temperature of the environment (i.e., the oven). In aspects, glass articles formed from the glass compositions described herein are heat treated in an isothermal oven to produce the resultant colored glass articles.

[00215] In aspects, the temperature of the heat treatment cycle 500°C or more, 550°C or more, 575°C or more, 600°C or more, 625°C or more, 650°C or more, 800°C or less, 775°C or less, 750°C or less, 725°C or less, or 700°C or less. In aspects, the temperature of the heat treatment cycle can range from 500°C to 800°C, from 550°C to 750°, from 575°C to 725°C, from 600°C to 725°C, from 625°C to 700°C, from 650°C to 700°C, or any range or subrange therebetween. In aspects, the duration of the heat treatment cycle can be 0.15 hours or more, 0.25 hours or more, 0.5 hours or more, 1 hour or more, 2 hours or more, 24 hours or less, 16 hours or less, 8 hours or less, 6 hours or less, 4 hours or less, or 3 hours or less. In aspects, the duration of the heat treatment cycle can range from 0.15 hours to 24 hours, from 0.25 hours to 16 hours, from 0.5 hours to 8 hours, from 1 hour to 6 hours, from 1 hour to 4 hours, from 2 hours to 4 hours, or any range or subrange therebetween.

[00216] In embodiments, the heat treatment may comprise ramping up to a heat treatment temperature at a heating rate and cooling down from the heat treatment temperature at a cooling rate. In embodiments, the selected heating rate and cooling rate may affect the color coordinates of the resultant colored glass articles. In aspects, the heating rate of the heat treatment may be 2°C/min or more, 3°C/min or more, 10°C/min or less, 7°C/min or less, or 5°C/min or less. In aspects, the heating rate of the heat treatment can range from 2°C/min to 10°C/min, from 3°C/min to 7°C/min, from 3°C/min to 5°C/min, or any range or subrange therebetween. In aspects, the cooling rate of the heat treatment may be 1°C/min or more, 2°C/min or more, 10°C/min or less, 8°C/min or less, 6°C/min or less, or 4°C/min or less. In aspects, the cooling rate of the heat treatment can range from 1°C/min to 10°C/min, from 1°C/min to 8°C/min, from 2°C/min to 6°C/min, from 2°C/min to 4°C/min, or any range or subrange therebetween.

[00217] Exemplary aspects of heat treatments for glass articles including Ag are presented. For example, colored glass articles having an orange color may be formed by heat treating the precursor glass article at a heat treatment temperature from about 590°C to about 610°C for a heat treatment time from about 45 minutes to about 180 minutes. For example, colored glass articles having a red color may be formed by heat treating the precursor glass article at a heat treatment temperature from about 600°C to about 615°C for a heat treatment time from about 180 minutes to about 300 minutes. colored glass articles having a green color may be formed by heat treating the precursor glass article at a heat treatment temperature from about 620°C to about 640°C for a heat treatment time from about 20 minutes to about 40 minutes. For example, colored glass articles having a brown color may be formed by heat treating the precursor glass article at a heat treatment temperature from about 640°C to about 660°C for a heat treatment time from about 30 minutes to about 90 minutes. For example, colored glass articles having a purple color may be formed by heat treating the precursor glass article at a heat treatment temperature from about 625°C to about 650°C for from about 30 minutes to about 90 minutes.

[00218] After step 703 or 705, as shown in **FIG. 9**, methods can proceed to step 707 comprising chemically strengthening the glass article. In aspects, as shown, step 707 can comprise contacting at least a portion of the glass article 511 with a molten salt solution 903 (e.g., contained in a bath 901). For example, as shown, the glass article 511 can be immersed in the molten salt solution 903 contained in the bath 901. In aspects, step 707 can develop the first compressive stress region, the second compressive stress region, and/or the tensile stress region discussed above and the corresponding region can comprise a maximum stress and/or depth of compression within one or more of the corresponding ranges discussed above. In aspects, the molten salt solution comprises sodium and/or potassium ions (e.g., from KNO₃ and/or NaNO₃). In aspects, the temperature of the molten salt solution 903 can be about 300°C or more, about 360°C or more, about 400°C or more, about 500°C or less, about 460°C or less, or about 420°C or less. In aspects, the temperature of the molten salt solution 903 can be in a range from about 300°C to about 500°C, from about 360°C to about 460°C, from about 400°C to about 420°C, or any range or subrange therebetween. In aspects, the glass article 511 can be in contact with the molten salt solution 903 for about 30 minutes or more, about 45 minutes or more, about 1 hour or more, about 8 hours or less, about 4 hours or less, about 2 hours or less, or about 1.5

hours or less. In aspects, the glass article **511** can be in contact with the molten salt solution **903** for a time in a range from about 30 minutes to about 8 hours, from about 45 minutes to about 4 hours, from about 1 hour to about 2 hours, from about 1 hour to about 1.5 hours, or any range or subrange therebetween.

[00219] After step **707**, methods can proceed to step **709** comprising assembling the glass article **511** into a natively colored glass housing, an electronic device (e.g., consumer electronic device). In aspects, step **709** can comprise disposing and/or attaching the glass article to the reflector (e.g., in a natively colored glass housing).

[00220] After step **703**, **705**, **707**, or **709**, methods can be complete upon reaching step **711**. In aspects, methods of making a glass article and/or a natively colored glass housing in accordance with aspects of the disclosure can proceed along steps **701**, **703**, **705**, **707**, **709**, and **711** of the flow chart in **FIG. 7** sequentially, as discussed above. In aspects, methods can follow arrow **702** from step **701** to step **707**, for example, if the glass article is colored by the end of step **701**. In aspects, methods can follow arrow **704** from step **703** to step **711**, for example if methods are complete at the end of step **703**. In aspects, methods can follow arrow **706** from step **703** to step **707**, for example, if the glass article does not need to be heat treated to be colored or if the color was otherwise developed by the end of step **703**. In aspects, methods can follow arrow **708** from step **705** to step **711**, for example, if methods are complete at the end of step **705**. In aspects, methods can follow arrow **710** from step **707** to step **711**, for example, if methods are complete at the end of step **707**. Any of the above options may be combined to make a foldable apparatus in accordance with the embodiments of the disclosure.

EXAMPLES

[00221] Various aspects will be further clarified by the following examples. Examples 10-13 were formed as a glass article with the Composition A stated in Table 1, and Example 1 was formed as a glass article with the Composition B stated in Table 1. Examples 1 and 10-13 comprised a thickness of 2.4 mm. For compositions A-B, the CIE L* values were from 80 to 84, the CIE a* values were from -12 to -10, and the CIE b* values were from 1 to 5.

Table 1: Composition (mol%) of Examples 10-13

	Composition A (mol%)	Composition B (mol%)
SiO ₂	57.9	58.45
Al ₂ O ₃	24.4	24.2
B ₂ O ₃	6.55	6.45
Li ₂ O	4.35	5.7
Na ₂ O	1.35	3.85
K ₂ O	0.3	0.6
CaO	3.65	0.65
SnO ₂	0	0
Cr ₂ O ₃ (ppm)	700	700

[00222] FIGS. 10-13 clusters **1001**, **1101**, **1201**, and **1301**, respectively, for Examples 10-13 taken from glass comprising Composition A. The properties of Examples 10-13 are shown in Table 2. The number of clusters per kilogram of material comprising Composition A ranged from about 10 clusters per kilogram to about 150 clusters per kilogram.

[00223] As shown in FIG. 10, cluster **1001** of Example 10 comprised particulates **1003**, **1005**, **1007**, and **1009** with particulate **1013** being the largest with a maximum dimension of 6 μm . Particulates **1003**, **1005**, **1007**, and **1009** comprised corresponding maximum dimensions less than 10 μm . The largest spacing between adjacent particulates in the cluster **1001** was between particulates **1003** and **1005** with a spacing **1015** of 6 μm . The maximum dimension **1011** of cluster **1001** was 21 μm .

[00224] As shown in FIG. 11, cluster **1101** of Example 11 comprised particulates **1103**, **1105**, **1107**, and **1109**, although particulate **1103** is likely a collection of particulates in contact with one another. The largest particulate in FIG. 11 is particulate **1103** with maximum dimension **1113** of 13 μm . Particulates **1105**, **1107**, and **1109** comprised corresponding maximum dimensions less than 10 μm . The largest spacing between adjacent particulates in the cluster **1101** was between particulates **1105** and **1107** with a spacing **1115** of 10 μm . The maximum dimension **1111** of the cluster **1101** was 50 μm .

[00225] As shown in FIG. 12, cluster **1201** of Example 12 comprised particulates **1203**, **1205**, **1207**, and **1209**, although particulate **1203** is likely two particulates in contact. The largest particulate in FIG. 12 is particulate **1203** with a maximum dimension **1213** of 22 μm . Particulates **1205**, **1207**, and **1209** comprised corresponding maximum dimensions less than 10 μm . The largest spacing between adjacent particulates in the cluster **1201** was between particulates **1203** and **1205** with

a spacing **1215** of 12 μm . The maximum dimension **1211** of the cluster **1201** was 42 μm .

[00226] As shown in **FIG. 13**, cluster **1301** of Example 13 comprised particulates **1303**, **1305**, **1307**, and **1309**, although particulate **1307** is likely several particulates in contact with one another and particulate **1305**. The largest particulate in **FIG. 13** is particulate **1303** with a maximum dimension **1313** of 4 μm . Particulates **1303**, **1305**, **1307**, and **1309** comprised corresponding maximum dimensions of less than 10 μm . The maximum spacing between adjacent particulates in the cluster **1301** was between particulates **1305** and **1305** with a spacing **1315** of 15 μm . The maximum dimension **1311** of the cluster **1301** was 32 μm .

Table 2: Properties of Clusters in **FIGS. 10-13**

Example/FIG.	10	11	12	13
Cluster maximum dimension (μm)	21	50	42	32
Particulate maximum dimension (μm)	6	13	22	4
Maximum spacing (μm)	6	10	12	15

Table 3: Distribution of Cluster Maximum Dimension

Range (μm)	Distribution (%)
30 nm to < 10 μm	2
10 μm to < 20 μm	17
20 μm to < 30 μm	27
30 μm to < 40 μm	23
40 μm to < 50 μm	12
50 μm to < 75 μm	10
75 μm to < 100 μm	5
100 μm to < 150 μm	4
150 μm or more	0

[00227] Table 3 presents the distribution of cluster maximum dimension of Example 1 comprising Composition B. The concentration of clusters ranged from about 10 clusters per kilogram to about 200 cluster per kilogram. As shown in Table 3, the maximum value of the maximum dimension of a cluster detected was less than 150 μm . Less than 10% of the clusters had a maximum dimension of 75 μm or more. Less than 20% of the clusters had a maximum dimension of 50 μm or more. About

50% of the clusters had a maximum dimension from 20 μm to 40 μm . More than 80% of the clusters had a maximum dimension less than 50 μm . More than 50% and more than 60% (e.g., 65%) of the clusters had a maximum dimension less than 40 μm . A median of the maximum value of the maximum dimension of the clusters was about 33 μm . An analysis by XPS of the particulates in Example 1 confirmed that about 90% or more of the particulates comprised a colorant (i.e., chromium).

[00228] As shown in **FIGS. 10-13**, the clusters can comprise multiple particulates, for example, 4 or more particulates. Consequently, it is expected that the distribution of maximum dimension of particulates would have a median of the maximum dimension of less than 10 μm . Indeed 13 of the 16 particulates labeled in **FIGS. 10-13** had a maximum dimension of 10 μm or less.

[00229] The above observations can be combined to provide glass articles and natively colored glass articles including the same that contain a plurality of particulates that can provide a saturated color, which can be aesthetically pleasing. Providing the more saturated color can be achieved without noticeable visual defects associated with the particulates, for example, when a majority of the particulates (or a portion described above) have a maximum dimension less than about 50 μm (e.g., less than about 40 μm). Since the particulates comprise colorants, the particulates enable higher amounts of colorant to be included in glass articles without noticeable visual defects to achieve colors that may not otherwise be possible with a natively colored glass article and/or natively colored glass housing.

[00230] Without wishing to be bound by theory, it is believed that traditional colorant approaches produce particles less than 50 nm (e.g., less than 30 nm), if any. For example, as described above, the length of silver particles is less than 40 nm with smaller maximum values provided. Likewise, gold particles for imparting color comprise nanometer scale maximum dimensions (e.g., less than 30 nm, less than 20 nm, from 1 nm to 20 nm). Indeed, it is believed that particulates of gold and silver larger than 50 nm would not be effect as colorants. Consequently, the particulates (and clusters thereof) described herein are of a different scale than would be achieved in traditional approaches.

[00231] On the other hand, large aggregates encountered in conventional approaches to increasing colorant concentration tend to about 100 μm or more, which can be noticeable with the naked eye and/or aesthetically unpleasing. In contrast, the particulates of the present disclosure can have a median of a maximum dimension of a

particulate and/or a median of a maximum dimension of a cluster size that is 50 μm or less (e.g., 40 μm or less, from 10 μm to 30 μm), and/or a distribution of the particulates or clusters of the present disclosure greater than 40 μm or more (e.g., 50 μm or more) can be less than 40% (e.g., less than 20%).

[00232] The inventors of the present application have discovered that particulates and/or clusters a corresponding maximum dimension (e.g., median of the corresponding maximum dimension or maximum value of the corresponding maximum dimension) from 30 nm to 50 μm (e.g., from 50 nm to 50 μm , 2 μm to 40 μm , etc.) may not be noticeable to the naked eye in combination with the saturated colors of the present disclosure. Without wishing to be bound by theory, it is believed that the particulates and/or clusters of particulates do not change the color of the glass article even though the particulates and/or clusters comprise the colorant. Further, particulates with a maximum dimension of less than or equal to 2 μm (e.g., from 30 nm to 2 μm , from 50 nm to 2 μm) may not be visible even with optical microscopy techniques. Consequently, glass articles with the particulates and/or clusters of particulates described herein can be made in a more cost-effective manner relative to glass articles that are free of such particulates. For example, cheaper and/or less purified raw materials that result in such particulates and/or clusters can be used, and/or processing time associated with dissolving the raw materials can be reduced that can reduce costs and increase cycle time. Further, without wishing to be bound by theory, the particulates and/or clusters of the present disclosure may increase a toughness (e.g., fracture resistance) of the glass article, for example, by deflecting and/or arresting crack propagation that is incident on such structures.

[00233] The glass-based material of the glass article can provide good dimensional stability, good impact resistance, good crack resistance, good puncture resistance, and/or good flexural strength. The glass article can include a compressive stress region (e.g., be chemically strengthened), which can provide improved crack resistance, puncture resistance, impact resistance, and/or improved flexural strength. Minimizing the combination of R_2O , CaO , MgO , and ZnO in the glass composition may provide the resultant colored glass article with a desirable dielectric constant, for example when the colored glass article is used as a portion of a housing for an electronic device. Providing a dielectric constant for frequencies from 10 GHz to 60 GHz from 5.6 to 6.4 can allow wireless communication through the glass article.

[00234] Providing a natively colored glass housing with a colored glass article can eliminate the need for an additional layer to impart color to the housing, which can simplify assembly and provide a more consistent color. Consequently, the natively colored glass housing including the glass article can provide an aesthetically pleasing appearance (e.g., color) while simultaneously protecting an electronic device from damage and/or permitting wireless communication therethrough.

[00235] Directional terms as used herein—for example, up, down, right, left, front, back, top, bottom—are made only with reference to the figures as drawn and are not intended to imply absolute orientation.

[00236] It will be appreciated that the various disclosed aspects may involve features, elements, or steps that are described in connection with that aspect. It will also be appreciated that a feature, element, or step, although described in relation to one aspect, may be interchanged or combined with alternate aspects in various non-illustrated combinations or permutations.

[00237] It is also to be understood that, as used herein the terms “the,” “a,” or “an,” mean “at least one,” and should not be limited to “only one” unless explicitly indicated to the contrary. For example, reference to “a component” comprises aspects having two or more such components unless the context clearly indicates otherwise. Likewise, a “plurality” is intended to denote “more than one.”

[00238] As used herein, the term “about” means that amounts, sizes, formulations, parameters, and other quantities and characteristics are not and need not be exact, but may be approximate and/or larger or smaller, as desired, reflecting tolerances, conversion factors, rounding off, measurement error and the like, and other factors known to those of skill in the art. Ranges can be expressed herein as from “about” one particular value, and/or to “about” another particular value. When such a range is expressed, aspects include from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent “about,” it will be understood that the particular value forms another aspect. Whether or not a numerical value or endpoint of a range in the specification recites “about,” the numerical value or endpoint of a range is intended to include two aspects: one modified by “about,” and one not modified by “about.” It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint and independently of the other endpoint.

[00239] The terms “substantial,” “substantially,” and variations thereof as used herein are intended to note that a described feature is equal or approximately equal to a value or description. For example, a “substantially planar” surface is intended to denote a surface that is planar or approximately planar. Moreover, as defined above, “substantially similar” is intended to denote that two values are equal or approximately equal. In aspects, “substantially similar” may denote values within about 10% of each other, for example, within about 5% of each other, or within about 2% of each other.

[00240] Unless otherwise expressly stated, it is in no way intended that any method set forth herein be construed as requiring that its steps be performed in a specific order. Accordingly, where a method claim does not actually recite an order to be followed by its steps or it is not otherwise specifically stated in the claims or descriptions that the steps are to be limited to a specific order, it is in no way intended that any particular order be inferred.

[00241] While various features, elements, or steps of particular aspects may be disclosed using the transitional phrase “comprising,” it is to be understood that alternative aspects, including those that may be described using the transitional phrases “consisting of” or “consisting essentially of,” are implied. Thus, for example, implied alternative aspects to an apparatus that comprises A+B+C include aspects where an apparatus consists of A+B+C and aspects where an apparatus consists essentially of A+B+C. As used herein, the terms “comprising” and “including”, and variations thereof shall be construed as synonymous and open-ended unless otherwise indicated.

[00242] The above aspects, and the features of those aspects, are exemplary and can be provided alone or in any combination with any one or more features of other aspects provided herein without departing from the scope of the disclosure.

[00243] It will be apparent to those skilled in the art that various modifications and variations can be made to the present disclosure without departing from the spirit and scope of the disclosure. Thus, it is intended that the present disclosure cover the modifications and variations of the aspects herein provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A glass article comprising:
 - a thickness defined between a first major surface and a second major surface opposite the first major surface; and
 - a plurality of particulates distributed throughout a volume of the glass article, the plurality of particulates comprising a colorant, the plurality of particulates comprising a plurality of clusters, each cluster comprising one or more particulates of the plurality of particulates with adjacent pairs of particulates within 15 micrometers of one another, and a median of a maximum dimension of the plurality of clusters is from about 2 μm to about 40 μm ,
 - wherein the glass article exhibits a CIE L* value of about 50 or more, an absolute value of a CIE a* value of the glass article is about 0.3 or more, and an absolute of the CIE b* value of the glass article is about 0.2 or more, and the glass article comprises at least one alkali metal oxide.
2. The glass article of any one of claims 1-2, wherein the colorant comprises chromium, cerium, cobalt, gold, silver, nickel, or combinations thereof.
3. The glass article of claim 2, wherein a concentration of the colorant is about 50 ppm or more.
4. The glass article of claim 3, wherein the concentration of the colorant is from about 500 ppm to about 10,000 ppm.
5. The glass article of any one of claims 1-4, wherein the plurality of particulates comprise a median of an maximum dimension ranging from about 30 nm to about 40 μm .
6. The glass article of any one of claims 1-4, wherein a median of the maximum dimension of the plurality of particulates is from about 2 μm to about 30 μm .
7. The glass article of any one of claims 1-4, wherein 80% or more of a distribution of a maximum dimension of the plurality of particulates is from about 30 nm to about 50 μm .

8. The glass article of any one of claims 1-4, wherein 60% or more of a distribution of a maximum dimension of the plurality of particulates is from about 2 μm to about 40 μm .
9. The glass article of any one of claims 7-8, wherein 5% or less of the distribution of the maximum dimension of the plurality of particulates is 100 μm or more.
10. The glass article of any one of claims 5-9, wherein a maximum value of the maximum dimension of the plurality of particulates is about 50 μm or less.
11. The glass article of any of claims 5-10, wherein the plurality of particulates further comprises a set of particulates with a maximum dimension from 30 nm to 2 μm .
12. The glass article of any one of claims 1-11, wherein a concentration of the plurality of particulates in the glass article is about 10 particulates per kilogram of the glass article or more.
13. The glass article of claim 12, wherein the concentration of the plurality of particulates in the glass article ranges from about 100 particulates per kilogram of the glass article to about 100 particulates per kilogram of the glass article.
14. The glass article of any one of claims 1-13, wherein 80% or more of a distribution of the maximum dimension of the plurality of clusters is from about 2 μm to about 50 μm .
15. The glass article of claim 14, wherein 60% or more of a distribution of the maximum dimension of the plurality of clusters is from about 2 μm to about 40 μm .
16. The glass article of any one of claims 14-15, wherein 5% or less of the distribution of the maximum dimension of the plurality of clusters is 100 μm or more.

17. The glass article of any one of claims 13-16, wherein a concentration of the plurality of clusters in the glass article is about 10 particulates per kilogram of the glass article or more.

18. The glass article of claim 17, wherein the concentration of the plurality of clusters in the glass article ranges from about 100 particulates per kilogram of the glass article to about 100 particulates per kilogram of the glass article.

19. The glass article of any one of claims 1-18, wherein the glass article comprises a CIE a^* value from about -15 to -1.

20. The glass article of any one of claims 1-19, wherein the CIE b^* value is from about 1.5 to about 5.

21. The glass article of any one of claims 1-20, wherein the CIE L^* value is from about 80 to 96.

22. The glass article of any one of claims 1-21, further comprising:
from about 50 mol% to about 75 mol% SiO_2 ;
from about 5 mol% to about 20 mol% Al_2O_3 ;
from about 15 mol% to about 20 mol% of the at least one alkali metal oxide;
and
at least one of B_2O_3 or P_2O_5 .

23. The glass article of any one of claims 1-21, wherein the glass article comprises, as a mol% of the glass article:
from 60 mol% to 65 mol% SiO_2 ;
from 12 mol% to 17 mol% Al_2O_3 ;
from 3 mol% to 6 mol% B_2O_3 ;
from 10 mol% to 16 mol% of at least one alkali metal oxide, alkali metal oxides including Li_2O , Na_2O , and K_2O ;
from 3 mol% to 5 mol% CaO ;
from 0 mol% to 1 mol% ZrO_2 ; and
from 0 mol% to 0.25 mol% SnO_2 .

24. The glass article of any one of claims 1-23, wherein the glass article comprises a soda lime glass, an alkali aluminosilicate glass, an alkali containing borosilicate glass, or an alkali aluminoborosilicate glass.

25. The glass article of any one of claims 1-24, wherein the glass article comprises at least one crystalline phase.

26. The glass article of claim 25, wherein a crystallinity of the glass article is 10 wt% or less.

27. The glass article of any one of claims 1-26, further comprising a first compressive stress region extending to a first depth of compression from the first compressive stress region.

28. The glass article of claim 27, wherein a maximum compressive stress of the first compressive stress region is about 400 MegaPascals or more.

29. The glass article of any one of claims 1-28, wherein the glass article comprises a dielectric constant at frequencies from 10 GigaHertz to 60 GigaHertz of from about 5.6 to about 6.4.

30. The glass article of any one of claims 1-29, wherein the glass article exhibits a fracture toughness of $0.60 \text{ MPam}^{1/2}$ or more, and a Young's modulus from about 50 GigaPascals to about 100 GigaPascals.

31. A natively colored glass housing for an electronic device comprising:
the glass article of any one of claims 1-30;
circuitry comprising an antenna that transmits signals within a range of 26 GHz to 40 GHz;
the glass article at least partially surrounding the circuitry; and
a structure formed as an integral portion of the glass article, wherein the structure comprises a perimeter demarcating a second thickness of the structure that differs from the thickness of the glass article by at least $150 \text{ }\mu\text{m}$,

wherein the antenna is positioned and oriented such that the signals are transmitted through the structure of the glass sheet of the panel of the housing.

32. A natively colored glass housing for a consumer electronic device, the housing comprising:

the glass article of any one of claims 1-30; and

a reflector layer disposed on the glass article, the reflector layer is opaque and has a CIE L* value > 70 ,

wherein the thickness of the glass article is from about 30 micrometers to about 5 millimeters, a total transmittance of at least one 10 nm band within the wavelength range of 380 nm to 750 nm through the first thickness is from 3% to 80%.

33. A consumer electronic product, comprising:

a housing comprising a front surface, a back surface, and side surfaces;

electrical components at least partially within the housing, the electrical components comprising a controller, a memory, and a display, the display at or adjacent the front surface of the housing; and

a cover substrate disposed over the display,

wherein at least one of a portion of the housing comprises the glass article of any one of claims 1-30.

34. A glass article comprising:
a first major surface, a second major surface opposite the first major surface,
and a thickness therebetween;
particulates distributed throughout a volume of the glass article, the
particulates comprising a colorant and forming clusters having adjacent pairs of the
particulates within 15 micrometers of one another, and
wherein the glass article exhibits a CIE L* value of about 50 or more, an
absolute value of a CIE a* value of the glass article is about 0.3 or more, and an
absolute of the CIE b* value of the glass article is about 0.2 or more.
35. The glass article of claim 34, wherein at least some of the clusters have a
maximum dimension within a range from 2 μm to 40 μm .
36. The glass article of any one of claims 34-35, wherein the colorant comprises
chromium, cerium, cobalt, gold, silver, nickel, or combinations thereof.
37. The glass article of claim 36, wherein a concentration of the colorant is about
50 ppm or more.
38. The glass article of claim 37, wherein the concentration of the colorant is up to
about 10,000 ppm in the glass article.
39. The glass article of any one of claims 33-38, wherein 80% or more of a
distribution of a maximum dimension of the plurality of particulates is from about 30
nm to about 50 μm .
40. The glass article of any one of claims 34-39, wherein a maximum value of the
maximum dimension of the plurality of particulates is about 50 μm or less.
41. The glass article of any one of claims 34-40, wherein the plurality of
particulates further comprises a set of particulates with a maximum dimension from
30 nm to 2 μm .

42. The glass article of any one of claims 34-41, wherein a concentration of the plurality of particulates in the glass article is about 10 particulates per kilogram of the glass article or more.

43. The glass article of claim 42, wherein the concentration of the plurality of particulates in the glass article ranges from about 100 particulates per kilogram of the glass article to about 100 particulates per kilogram of the glass article.

44. The glass article of any one of claims 34-43, wherein the glass article comprises a CIE a^* value from about -15 to -1.

45. The glass article of any one of claims 34-44, wherein the CIE b^* value is from about 1.5 to about 5.

46. The glass article of any one of claims 34-45, wherein the CIE L^* value is from about 80 to 96.

47. The glass article of any one of claims 34-46, further comprising a structure formed as an integral portion of the glass article, wherein the structure comprises a perimeter demarcating a second thickness of the structure that differs from the thickness of the glass article by at least 150 μm .

48. A natively colored glass housing for an electronic device comprising:
the glass article of any one of claims 34-47;
circuitry, the glass article at least partially surrounding the circuitry; and
a structure formed as an integral portion of the glass article, wherein the structure comprises a perimeter demarcating a second thickness of the structure that differs from the thickness of the glass article by at least 150 μm .

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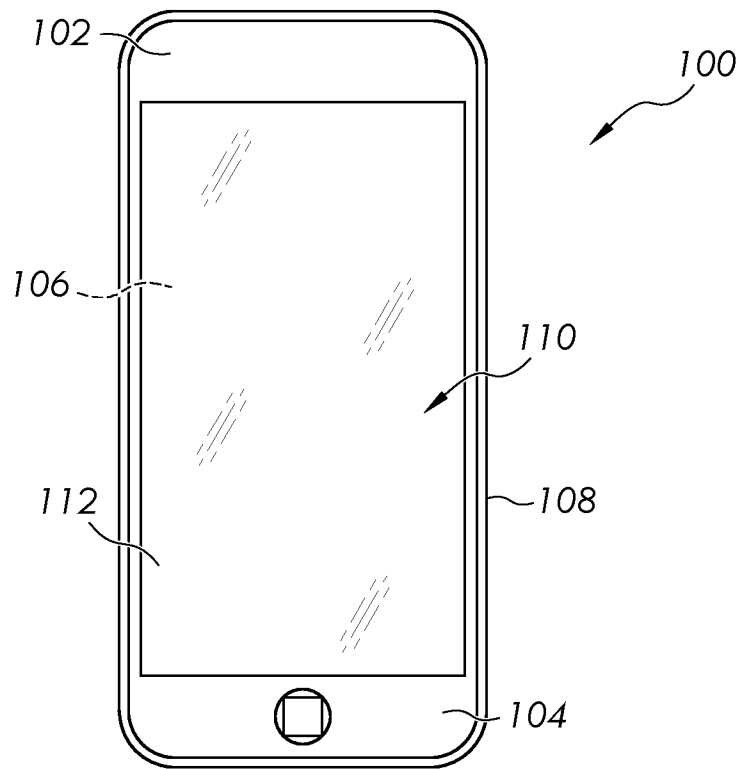


FIG. 1

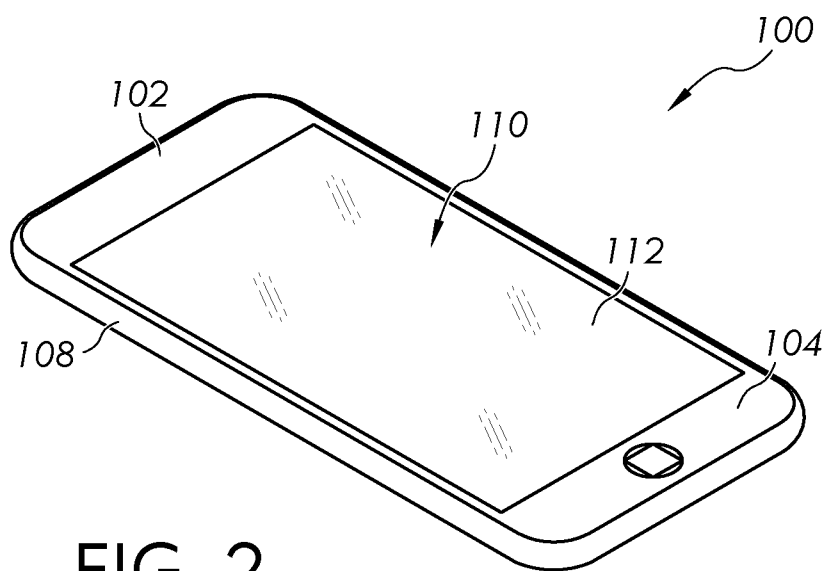


FIG. 2

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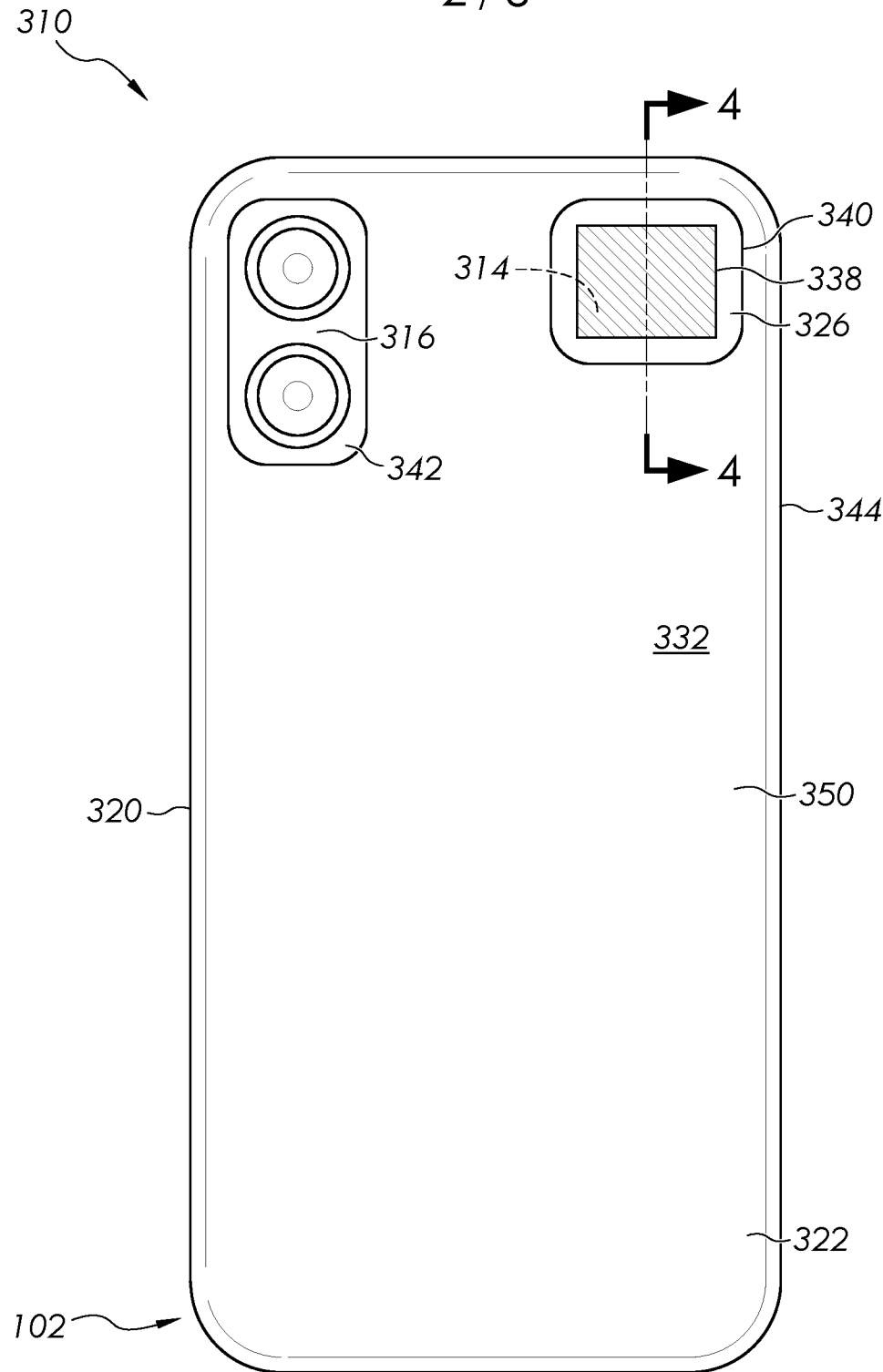
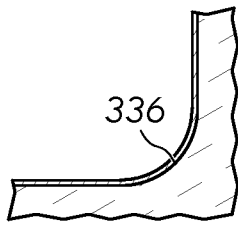
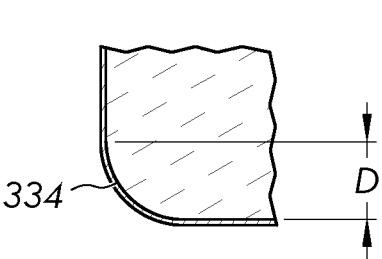
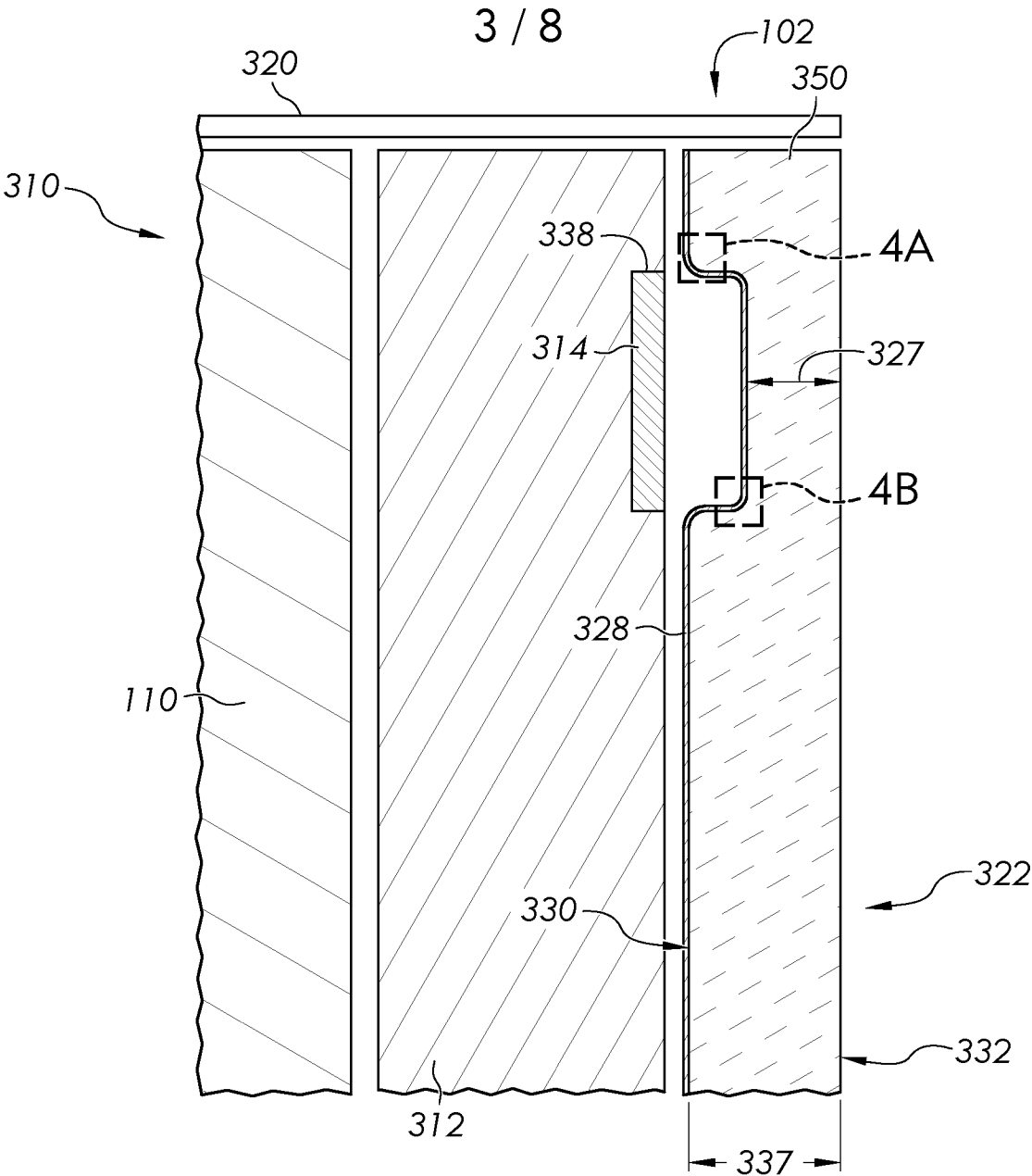


FIG. 3



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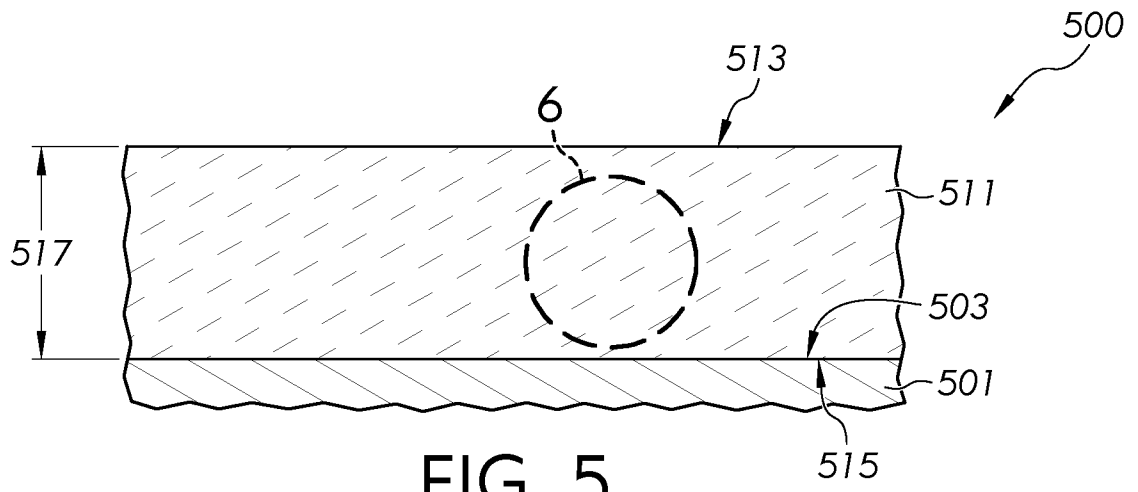


FIG. 5

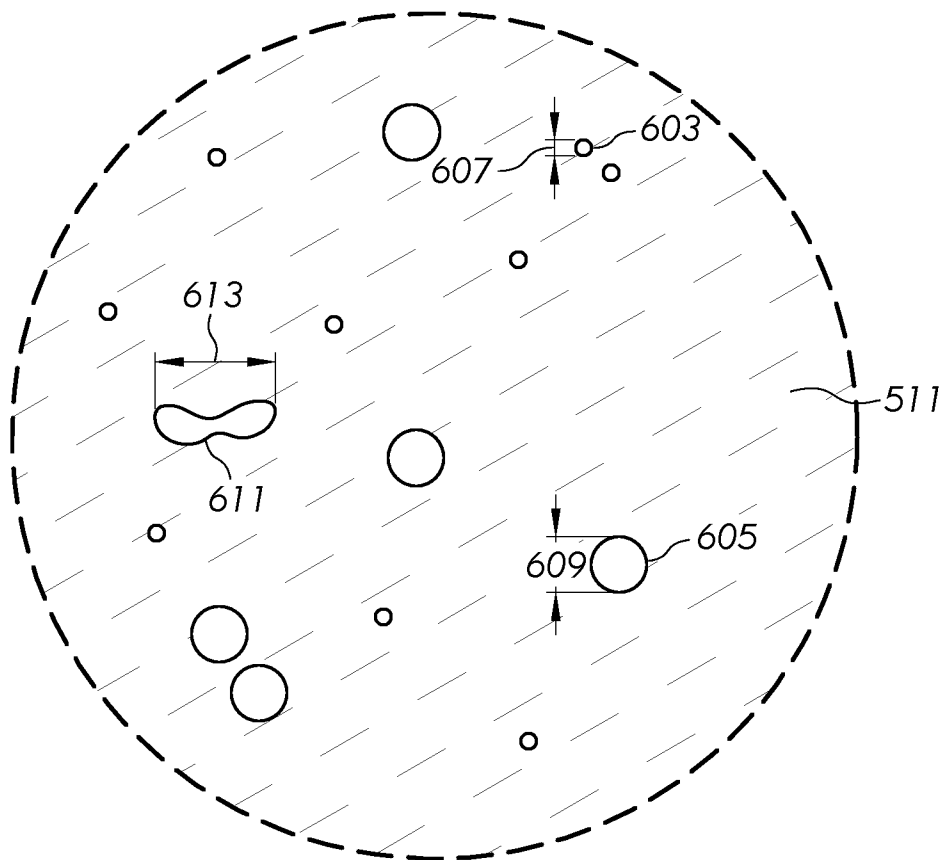


FIG. 6

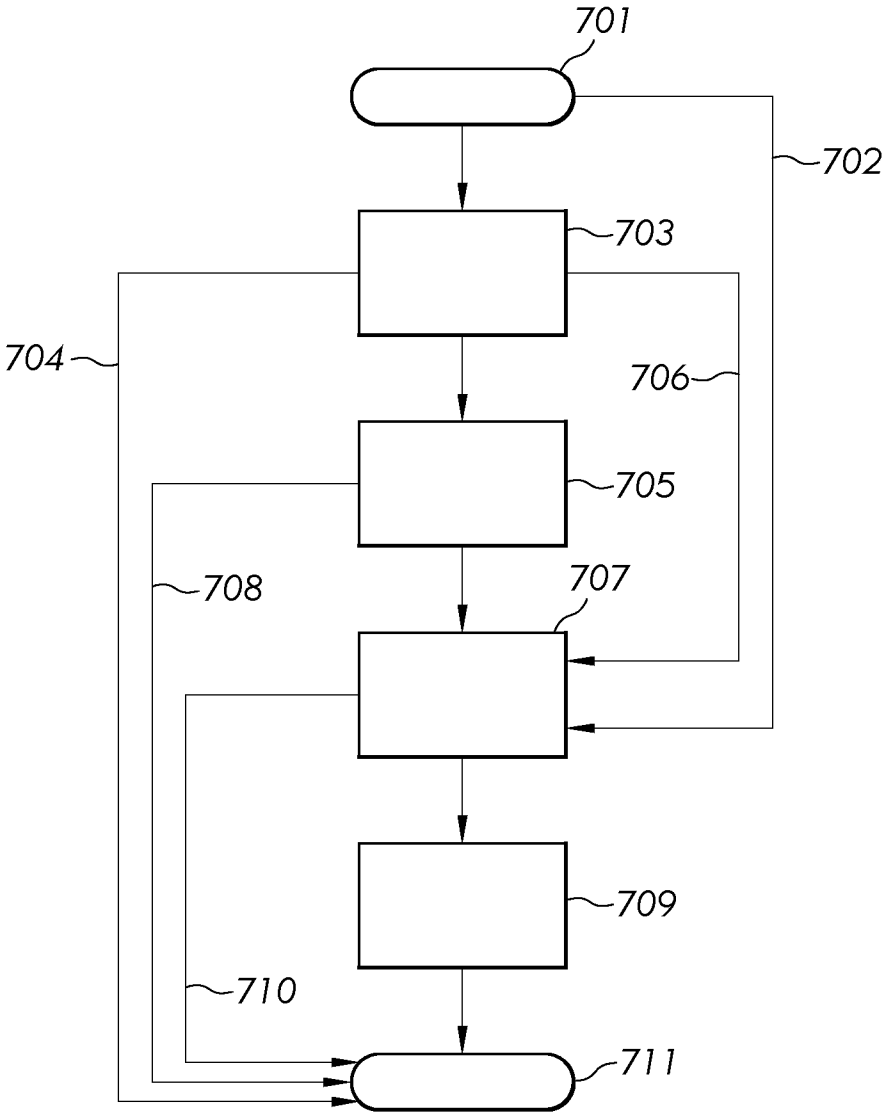


FIG. 7

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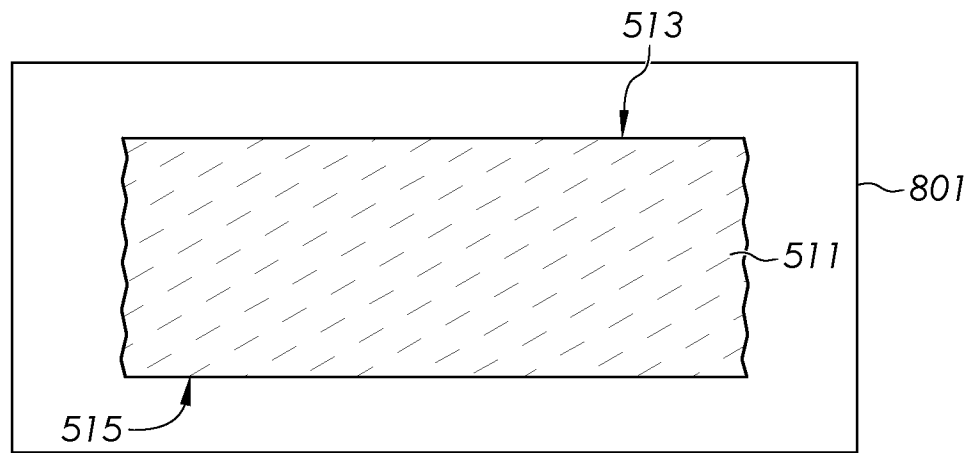


FIG. 8

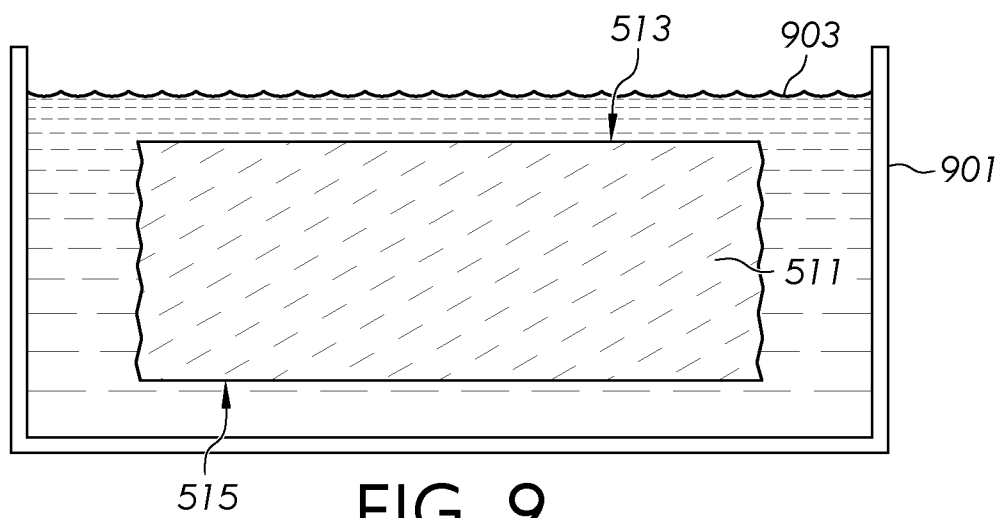


FIG. 9

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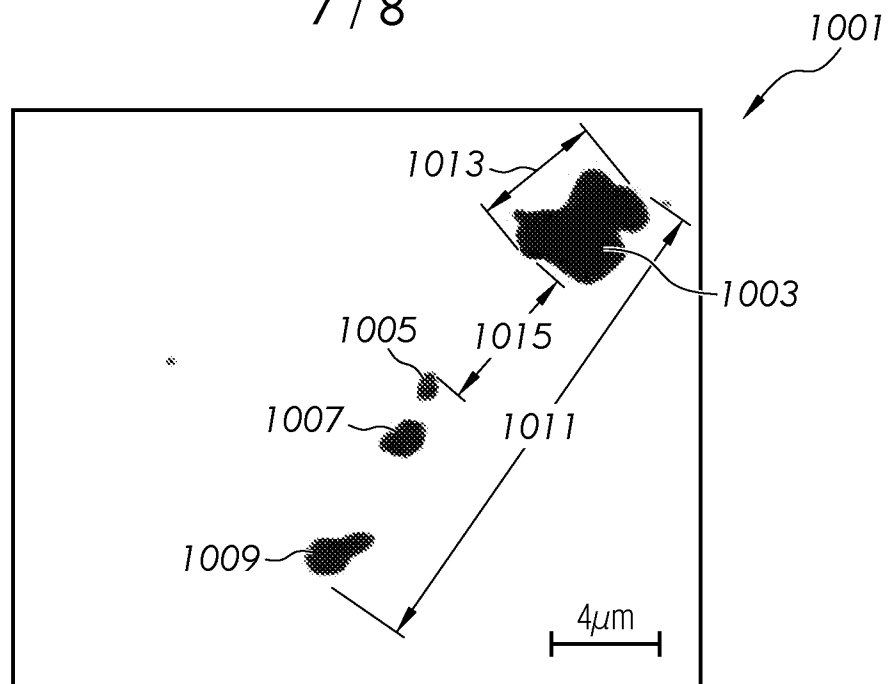


FIG. 10

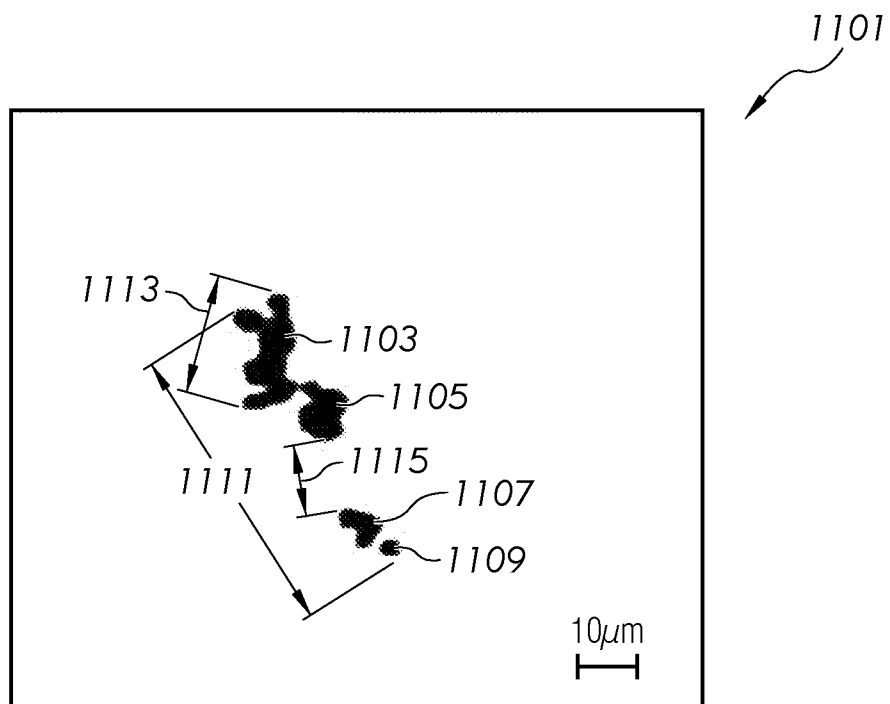


FIG. 11

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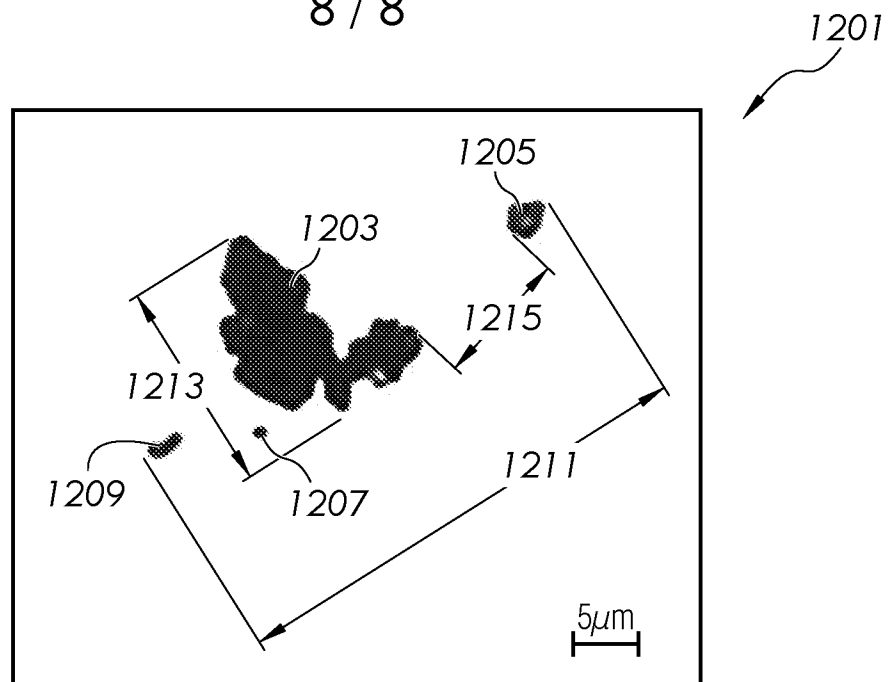


FIG. 12

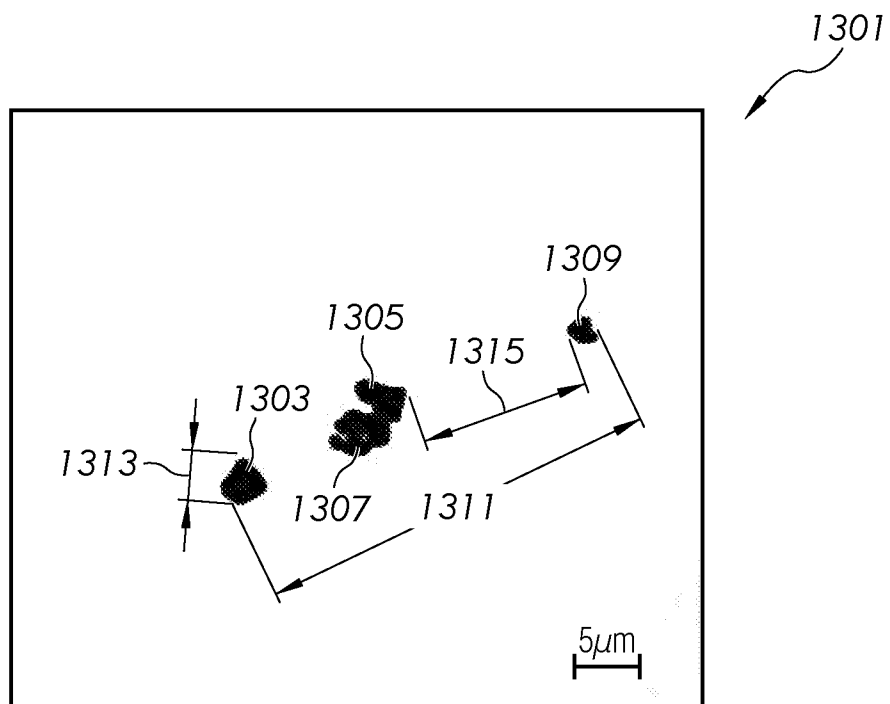


FIG. 13

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2023/082809

A. CLASSIFICATION OF SUBJECT MATTER INV. C03C3/091 C03C4/02 C03C14/00 H05K5/00 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) C03C H05K		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 779 734 A (SIMONFI P ET AL) 18 December 1973 (1973-12-18) example I -----	1-21, 24-30, 34-47
X	JP 2003 160740 A (SANYU CO LTD) 6 June 2003 (2003-06-06) item 15 in par. [0006] page 6, paragraphs 28, 30; examples 17, 19, 20 -----	1-21, 24-30, 34-47
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 11 March 2024		Date of mailing of the international search report 26/03/2024
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Saldamli, Saltuk

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2023/082809

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 3779734	A	18-12-1973	DE 1917154 A1	05-02-1970
			FR 2006175 A1	19-12-1969
			US 3779734 A	18-12-1973

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