



- (51) **International Patent Classification:**
G02B 27/01 (2006.01) *G02B 5/22* (2006.01)
- (21) **International Application Number:**
PCT/US2023/012354
- (22) **International Filing Date:**
05 February 2023 (05.02.2023)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
17/592,957 04 February 2022 (04.02.2022) US
- (71) **Applicant: META PLATFORMS, INC.** [US/US]; 1601 Willow Rd., Menlo Park, California 94025 (US).
- (72) **Inventors: MORRIS, Quintin;** 1601 Willow Road, Menlo Park, California 94025 (US). **LEFEBVRE, Paul Murray;** 1601 Willow Road, Menlo Park, California 94025 (US). **MADANI, Seyed-Ali;** 1601 Willow Road, Menlo Park, California 94025 (US). **LEE, Dong Rim;** 1601 Willow Road, Menlo Park, California 94025 (US). **TOM, Tristan;** 1601 Willow Road, Menlo Park, California 94025 (US). **KERMAN, Kian;** 1601 Willow Road, Menlo Park, California 94025 (US).

(74) **Agent: COLBY, Steven et al.;** Rimon Law, 420 West Main Street, Suite 101B, Boise, Idaho 83702 (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, 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, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, 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).

(54) **Title:** COLOR TUNED OPTICAL MODULES WITH COLOR CALIBRATION OPERATIONS

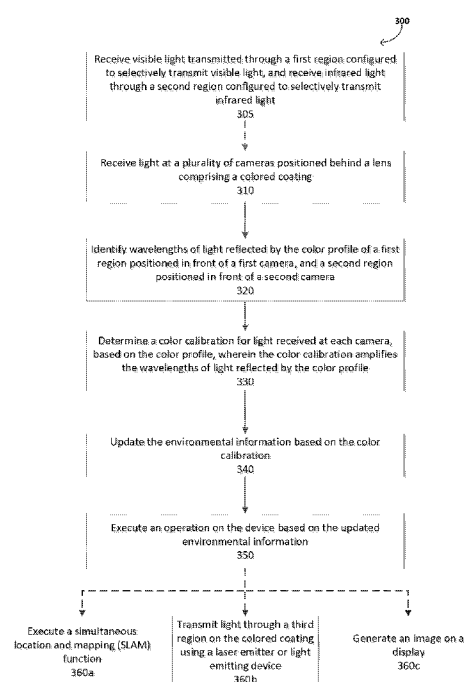


FIGURE 3

(57) **Abstract:** The present invention provides systems and methods for color tuning optical modules and executing color calibration methods on artificial reality systems and devices. Embodiments can include a lens with a colored coating, a plurality of cameras, including a visible spectrum camera and an infrared camera, each positioned behind the lens, and a processor and memory. The colored coating includes a plurality of regions for selectively transmitting light. The processor and memory can be configured to receive light information indicative of environmental information for executing an operation on the device, identify wavelengths of light reflected by the color profile in front of each camera, determine a color calibration to amplify wavelengths of reflected light, update the environmental information based on the color calibration, and execute the operation on the device.

Published:

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

COLOR TUNED OPTICAL MODULES WITH COLOR CALIBRATION OPERATIONS

TECHNICAL FIELD

[0001] The present disclosure generally relates to systems and methods for color calibration using artificial reality devices with color tuned exteriors.

BACKGROUND OF THE INVENTION

[0002] Artificial reality is a form of reality that has been adjusted in some manner before presentation to a user. Artificial reality can include, e.g., a virtual reality (VR), an augmented reality (AR), a mixed reality (MR), a hybrid reality, or some combination and/or derivatives thereof. AR, VR, MR, and hybrid reality devices often receive information through cameras or other optical modules on a headset, e.g., glasses, and provide content through visual means.

[0003] Since artificial reality devices heavily rely on accurate optical information to provide seamless and realistic output for users, the devices rarely have any color cosmetics added due to the stringent optical requirements of any cameras and/or optical modules behind the cover windows, e.g., lenses. Moreover, colored cover windows act as a color filter and create significant challenges to the complex operations of cameras and other optical modules utilizing received and transmitted light.

SUMMARY OF THE INVENTION

[0004] In meeting the described challenges, the present disclosure provides systems and methods for color tuning optical modules and executing color calibration methods on artificial reality systems and devices. Exemplary embodiments include artificial reality systems with colored lenses specifically tuned to the optical modules of the system. The optical modules can be cameras, such as infrared cameras, visible spectrum cameras, and the like.

[0005] In accordance with a first aspect of the present disclosure, there is provided a device comprising a lens, a plurality of cameras positioned behind the lens, a colored coating on the lens, and a processor and non-transitory memory including computer-executable instructions. The plurality of cameras can include a first camera for processing visible light and a second camera for processing infrared light. The colored coating includes a plurality of regions, with each region having a color profile for selectively transmitting light. A first region is positioned in front of the first camera and the second region is positioned in front of the second camera.

[0006] The computer-executable instructions, when executed by the processor, cause the device to receive light information indicative of at least one of: visible light received at the first camera or infrared light received at the second camera, wherein the received light information provides environmental information for executing an operation on the device; identify wavelengths reflected by the color profile positioned in front of each camera; determine a color calibration for the light information based on the color profile, wherein the color

1 calibration amplifies the wavelengths reflected by the color profile; update the environmental
2 information based on the color calibration; and execute the operation on the device based on
3 the updated environmental information.

4 **[0007]** In some embodiments, the device comprises a laser emitter positioned
5 behind the lens and a third region on the colored coating having a color profile for selectively
6 transmitting infrared light. Embodiments can include two regions for transmitting light, and a
7 region for transmitting infrared light positioned between the two visible light regions.

8 **[0008]** In some embodiments, the colored coating comprises two first regions for
9 selectively transmitting visible light, and the second region for selectively transmitting infrared
10 light is centrally positioned between the two first regions.

11 **[0009]** In some embodiments, the colored coating comprises a first plurality of layers
12 on an inner face of the lens, and a second plurality of layers on an outer face of the lens. The
13 first plurality of layers can include an inner ink layer, a middle high-contrast layer, and an outer
14 anti-reflective layer. In some embodiments, the first plurality of layers comprises an inner ink
15 layer, a middle hard-coat (HC) layer, and an outer anti-reflective (AR) layer. In some
16 embodiments, the inner ink layer is 6-28 micrometers, the middle HC layer is 9-30
17 micrometers, and the outer AR layer is 0.35-0.4 micrometers. The second plurality of layers
18 can include an inner hard-coat (HC) layer, a middle anti-reflective (AR) layer, and an outer
19 anti-fingerprint (AF) layer. In some embodiments, the inner HC layer is 9-10 micrometers,
20 the middle AR layer is 0.35-0.4 micrometers, and the outer AF layer is 0.012-0.013
21 micrometers. The HC layer increases adhesion between the substrate material and the AR
22 layer and improves performance against scratches and abrasion. The colored coating can
23 also include a plurality of ink layers, with each ink layer reflecting a range of wavelengths.

24 **[0010]** In some embodiments, the second region has less than a 20% transmission
25 rate for wavelengths below 750 nm. In another embodiment, the second region has less than
26 a 10% transmission rate for wavelengths below 730 nm. In another embodiment, the second
27 region has less than a 5% transmission rate for wavelengths below 700 nm. In another
28 embodiment, the second region has greater than a 60% transmission rate for wavelengths
29 above 850 nm.

30 **[0011]** Each region can include an on-axis color profile, and an off-axis color profile.
31 The on-axis color profile can have greater than a 90% transmission rate for wavelengths above
32 500 nm. In other embodiments, the on-axis color profile can have greater than a 96%
33 transmission rate for wavelengths between 500-700 nm. The off-axis color profile can have a
34 transmission rate of greater than 64% for wavelengths above 500 nm. The off-axis color profile
35 can have a transmission rate of greater than 73% for wavelengths between 500-700 nm.

36 **[0012]** In some embodiments, the first camera identifies red, green, blue, and yellow
37 wavelength values. Each color profile can further include a transmission profile and reflection

1 profile. The operations on the device can include one or more of generating an image on a
2 display or executing a simultaneous location and mapping (SLAM) function. In some
3 embodiments, the colored coating can be applied to the lens using a pad printing technique.
4 The lens formation and colored coating can also be performed using a thermoformed or
5 injection molding technique. In other embodiments, a colored coating can be applied to the
6 lens using at least one of sputtering and e-beam evaporation techniques.

7 **[0013]** In accordance with a second aspect of the present disclosure, there is
8 provided a computer-implemented method, comprising: receiving light information at a
9 plurality of cameras positioned behind a lens comprising a colored coating, wherein the
10 colored coating comprises a plurality of regions each having a color profile, and wherein the
11 light information is indicative of at least one of visible light or infrared light, and the light
12 information provides environmental information for executing an operation on a computing
13 device; identifying wavelengths reflected by the color profile of a first region positioned in front
14 of a first camera, and a second region positioned in front of a second camera; determining a
15 color calibration for the light information received at each camera, based on the color profile,
16 wherein the color calibration amplifies wavelengths reflected by the color profile; updating the
17 environmental information based on the color calibration; and executing the operation on the
18 computing device based on the updated environmental information.

19 **[0014]** In some embodiments, the method comprises: transmitting light through a
20 third region on the colored coating using a laser emitter, the third region comprising a color
21 profile for selectively transmitting infrared light.

22 **[0015]** In some embodiments, the method comprises: receiving visible light
23 transmitted through two first regions configured to selectively transmit visible light, and
24 receiving infrared light through the second region configured to selectively transmit infrared
25 light, wherein the second region is centrally positioned between the two first regions.

26 **[0016]** In some embodiments, the operation on the computing device comprises
27 generating an image on a display.

28 **[0017]** In some embodiments, the operation on the computing device comprises
29 executing a simultaneous location and mapping (SLAM) function.

30 **[0018]** In some embodiments, the second region has less than a 20%
31 transmission rate for wavelengths below 750 nm.

32 **[0019]** In some embodiments, the second region transmits less than 10% of
33 wavelengths below 730 nm.

34 **[0020]** In some embodiments, the second region transmits greater than 60% of
35 wavelengths above 850 nm.

36 **[0021]** In some embodiments, each region comprises an on-axis color profile, and
37 an off-axis color profile.

1 **[0022]** In some embodiments, the on-axis color profile for at least one region
2 transmits greater than 90% of wavelengths above 500 nm.

3 **[0023]** In some embodiments, the off-axis color profile for at least one region
4 transmits greater than 64% of wavelengths above 500 nm.

5 **[0024]** In accordance with a second aspect of the present disclosure, there is provided
6 a system, comprising: a lens; a camera positioned behind the lens; a colored coating on the
7 lens, wherein the colored coating comprises at least one region comprising a reflection color
8 profile and a transmission color profile; and a camera module, associated with a device,
9 comprising at least one processor and a non-transitory memory including computer-
10 executable instructions, which when executed by the processor, cause the device to at least:
11 receive images from the camera, the images indicative of a view through the lens; determine
12 a color calibration based on the colored coating on the lens, wherein the color calibration
13 amplifies the reflection color profile; and update the received images based on the color
14 calibration.

15 **[0025]** In some embodiments, the coating comprises at least one of a printed ink
16 or a film.

17 **[0026]** In some embodiments, the printed ink is infrared transparent ink.

18 **[0027]** In some embodiments, the camera positioned behind the lens comprises
19 an infrared camera and a visible spectrum camera.

20 **[0028]** In some embodiments, the lens is a curved lens.

21 **[0029]** In some embodiments, the device is a wearable headset.

22 **[0030]** In some embodiments, the transmission color profile and the reflection
23 color profile each comprises a plurality of wavelengths.

24 **[0031]** In some embodiments, each of the plurality of wavelengths comprises a
25 set of red, green, blue or yellow color values.

26 **[0032]** In some embodiments, the system further comprises means for adjusting a
27 white balance of the received images.

28 **[0033]** In some embodiments, each region is positioned in front of the camera.

29 **[0034]** In some embodiments, the colored coating on the lens includes at least
30 two regions with different transmission color profiles and reflection color profiles.

31 **[0035]** In some embodiments, the transmission color profiles and the reflection
32 color profiles each comprise on-axis color values and off-axis color values.

33 **[0036]** In some embodiments, the system further comprises three cameras
34 positioned behind the lens, and three regions positioned in front of each camera.

35 **[0037]** In some embodiments, the camera module further comprises instructions
36 to at least:

37 based on the color calibration, apply a third color profile from a light source, wherein

1 the third color profile tunes the received images to compensate for the colored coating; and
2 dynamically adjust the color calibration when the received images indicate a change
3 in the view through the lens.

4 **[0038]** Exemplary embodiments of the present invention can utilize a variety of
5 hardware, such as glasses, headsets, controllers, peripherals, mobile computing devices,
6 displays, and user interfaces to effectuate the methods and operations discussed herein.
7 Embodiments can further communicate with local and/or remote servers, databases, and
8 computing systems. In various embodiments, the artificial reality device can include glasses,
9 a headset, a display, a microphone, a speaker, and any of a combination of peripherals, and
10 computing systems.

11 **[0039]** It will be appreciated that any features described herein as being suitable for
12 incorporation into one or more aspects or embodiments of the present disclosure are intended
13 to be generalizable across any and all aspects and embodiments of the present disclosure.
14 Other aspects of the present disclosure can be understood by those skilled in the art in light
15 of the description, the claims, and the drawings of the present disclosure. The foregoing
16 general description and the following detailed description are exemplary and explanatory only
17 and are not restrictive of the claims.

18 BRIEF DESCRIPTION OF THE DRAWINGS

19 **[0040]** The summary, as well as the following detailed description, is further
20 understood when read in conjunction with the appended drawings. For the purpose of
21 illustrating the disclosed subject matter, there are shown in the drawings exemplary
22 embodiments of the disclosed subject matter; however, the disclosed subject matter is not
23 limited to the specific methods, compositions, and devices disclosed. In addition, the drawings
24 are not necessarily drawn to scale. In the drawings:

25 **[0041]** FIG. 1 illustrates a lens in accordance with embodiments of the present
26 invention.

27 **[0042]** FIG. 2A illustrates image signal processing operations in accordance with
28 embodiments of the present invention.

29 **[0043]** FIG. 2B illustrates example reflected colors in accordance with the
30 embodiments of the present invention.

31 **[0044]** FIG. 3 illustrates an example flowchart for executing operations in
32 accordance with the present invention.

33 **[0045]** FIG. 4 illustrates an example flowchart illustrating color calibration operations
34 in accordance with the present invention.

35 **[0046]** FIG. 5A illustrates an example transmission vs. wavelength graph for a
36 coating in accordance with embodiments of the present invention.

37 **[0047]** FIG. 5B illustrates an example reflection (%) versus wavelength (nm) graph

1 for a coating in accordance with embodiments of the present invention.

2 [0048] FIG. 5C illustrates another example reflection (%) versus wavelength (nm)
3 graph for a coating in accordance with embodiments of the present invention.

4 [0049] FIG. 5D illustrates an example transmission (%) versus wavelength (nm)
5 graph for a coating in accordance with embodiments of the present invention.

6 [0050] FIG. 6 illustrates a lens layer design in accordance with embodiments of the
7 present invention.

8 [0051] FIG. 7 illustrates a reflection color profile in accordance with embodiments of
9 the present invention.

10 [0052] FIG. 8 illustrates a transmission color profile in accordance with embodiments
11 of the present invention.

12 [0053] FIG. 9 illustrates a thermoform process in accordance with embodiments of
13 the present invention.

14 [0054] FIG. 10 illustrates an injection molding process in accordance with
15 embodiments of the present invention.

16 [0055] FIG. 11 illustrates a sputter deposition apparatus in accordance with
17 embodiments of the present invention.

18 [0056] FIG. 12 illustrates an electron-beam evaporation apparatus in accordance
19 with embodiments of the present invention.

20 [0057] FIG. 13 illustrates an AR headset in accordance with embodiments of the
21 present invention.

22 [0058] FIG. 14 illustrates another head-mounted AR headset in accordance with
23 embodiments of the present invention.

24 [0059] FIG. 15 illustrates a block diagram of a hardware/software architecture in
25 accordance with embodiments of the present invention.

26 [0060] FIG. 16 illustrates a block diagram of an example computing system
27 according to an exemplary aspect of the application.

28 [0061] FIG. 17 illustrates a computing system in accordance with exemplary
29 embodiments of the present invention.

30 DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

31 [0062] The present disclosure provides systems and methods for color tuning optical
32 modules and executing color calibration methods. Embodiments discussed herein allow for
33 cosmetic color tuning on a lens or cover window, with the colored coating having specific
34 optical functionality for camera and optical modules adjacent to it. As applied to artificial reality
35 devices, lenses of such devices can be tuned to reflect a particular color in non-camera area
36 and transmit a known but different color in camera areas. As such, any color effects due to
37 lenses in front of the cameras can be calibrated to promote optimal camera performance.

1 **[0063]** Embodiments include unique optical stack combinations, using anti-reflective,
2 infrared, and/or opaque ink, for example. Such devices and color calibrations techniques can
3 be applied to cameras for specified wavelengths, such as infrared in the 840-860 nm range,
4 the visible spectrum range, and others.

5 **[0064]** The present disclosure can be understood more readily by reference to the
6 following detailed description taken in connection with the accompanying figures and
7 examples, which form a part of this disclosure. It is to be understood that this disclosure is
8 not limited to the specific devices, methods, applications, conditions or parameters described
9 and/or shown herein, and that the terminology used herein is for the purpose of describing
10 particular embodiments by way of example only and is not intended to be limiting of the
11 claimed subject matter.

12 **[0065]** Also, as used in the specification including the appended claims, the singular
13 forms “a,” “an,” and “the” include the plural, and reference to a particular numerical value
14 includes at least that particular value, unless the context clearly dictates otherwise. The term
15 “plurality”, as used herein, means more than one. When a range of values is expressed,
16 another embodiment includes from the one particular value and/or to the other particular value.
17 Similarly, when values are expressed as approximations, by use of the antecedent “about,” it
18 will be understood that the particular value forms another embodiment. All ranges are
19 inclusive and combinable. It is to be understood that the terminology used herein is for the
20 purpose of describing particular aspects only and is not intended to be limiting.

21 **[0066]** It is to be appreciated that certain features of the disclosed subject matter
22 which are, for clarity, described herein in the context of separate embodiments, can also be
23 provided in combination in a single embodiment. Conversely, various features of the disclosed
24 subject matter that are, for brevity, described in the context of a single embodiment, can also
25 be provided separately or in any sub combination. Further, any reference to values stated in
26 ranges includes each and every value within that range.

27 **[0067]** FIG. 1 illustrates a front view of a lens 100 of a device, such as an artificial
28 reality device, in accordance with embodiments. The lens 100 comprises a plurality of regions
29 having unique optical characteristics. The regions can comprise color profiles, e.g., a reflection
30 color profile and/or a transmission color profile that selectively tune light traveling through the
31 regions. The optical characteristics can further comprise on-axis and off-axis color profiles,
32 with different optical characteristics.

33 **[0068]** In various embodiments, lenses can appear to be a single, uniform color,
34 despite a plurality of regions with unique optical characteristics. The coating on the lens can
35 comprise a plurality of regions, each of which serves to simultaneously reflect a particular
36 color, while transmitting a known but different color. Camera modules and other hardware
37 behind each lens region can calibrate out the known color distortion to enable normal

1 functionality. Accordingly, the coating, with its distinct color regions, enables the creation and
2 use of lenses in a plurality of colors and designs for a variety of devices, such as AR headsets,
3 other head-mounted devices, and technologies utilizing light filtered through a lens.

4 **[0069]** An artificial reality device, for example, can comprise a plurality of cameras
5 configured to receive light transmitted through the lens. The lens coating, such as a colored
6 coating, affects the transmission of light through the lens. For example, a lens with a black
7 color coating will typically have a much lower transmission rate than a clear lens. Similarly,
8 the colored lens can act as a filter to light passing through. Cameras receiving light through
9 the lens can be tuned to the unique color characteristics of the lens to ensure accuracy in
10 various operations executed in response to the received image(s).

11 **[0070]** In embodiments, a lens can comprise a plurality of regions tuned to provide
12 specific optical characteristics based on the hardware, e.g., cameras, light emitters, etc.,
13 behind the lens. Lens 100 comprises a plurality of regions tuned to optimize operations related
14 to visible light and infrared light. In particular, region 110 can optimize operations utilizing light
15 in the infrared spectrum 150, and regions 120, 130a, and 130b can optimize operations
16 utilizing light in the visible spectrum 140. The size of each region 110, 120, 130a, 130b can
17 vary, and may be the same or different, depending on the optical requirements of the cameras
18 and artificial reality system. The location of each region can be positioned anywhere on the
19 lens as well.

20 **[0071]** In addition, an artificial reality device can comprise one or more cameras or
21 laser emitters behind each lens region. The lens, which can be a colored lens, can affect
22 operations by the device, such as displaying images, executing location functions, and general
23 operations on a virtual reality device.

24 **[0072]** In various embodiments, the coating, such as a colored coating, comprises a
25 plurality of regions each comprising a color profile. The color profiles selectively transmit light
26 and can comprise on-axis and off-axis color profiles that transmit light differently, based on
27 the angle of transmission through the lens.

28 **[0073]** In embodiments, one or more cameras positioned behind each lens region
29 receives transmitted light. A computing system, comprising a processor and non-transitory
30 memory comprising computer-executable instructions, operates with the camera, to receive
31 information associated with the received light wavelengths, determine a color calibration, and
32 update the received information to perform one or more operations. In various embodiments,
33 such operations can be artificial reality functions.

34 **[0074]** In embodiments, the processor and memory can comprise instructions that
35 receive light one or more cameras. The received light can provide environmental information,
36 such as scene information, that can be usable to execute one or more operations on the
37 device. Since the color profiles are known, the computing system can identify, among other

1 things, wavelengths of light reflected by the color profile positioned in front of each camera.
2 The computing system can further determine a color calibration based on the known color
3 profile. In examples, as discussed herein, the color calibration amplifies wavelengths of light
4 reflected by the color profile. The computing system can then update environmental
5 information obtained from the received light, based on the color calibration. The device can
6 then execute one or more operations based on updated environmental information.

7 **[0075]** In various embodiments, the executed operation can be a display and/or
8 projection of the environmental information via one or more light emitting devices. The display
9 can occur on a plurality of display devices, such as a monitor, external display, mobile device,
10 AR/VR headset, and the like. In other embodiments, the operation can relate to one or more
11 functions of an AR device, such as a user interaction, processing of visual data, simultaneous
12 location and mapping (SLAM) functions, capturing a picture, obtaining environmental
13 information, or emitting light, e.g., through a laser emitter, light emitting diode (LED), etc.,
14 through the lens, and any of a plurality of features and functions utilizing the received light.

15 **[0076]** In various embodiments, as illustrated in FIG. 1, a lens can comprise a
16 plurality of first regions 130a, 130b optimized to receive wavelengths in the visible spectrum.
17 The first regions can be symmetrically positioned on the lens. One or more first regions 120
18 (i.e., optimizing visible spectrum wavelengths) can be centrally placed on the lens. In
19 embodiments, regions optimized for visible wavelengths can be placed beneath a second
20 region optimized in the infrared spectrum 110.

21 **[0077]** As illustrated in FIG. 1, two regions 120a, 130b can be placed symmetrically
22 on the lens, with a left region and right region. A third region 120 can be placed centrally, and
23 equidistant from regions 130a, 130b. In embodiments, the third region 120 is positioned above
24 regions 130a, 130b. Regions 130a, 130b, and 120 can be optimized for visible spectrum
25 wavelengths. In some embodiments, regions 130a, 130b comprise a color profile to optimize
26 received light for high resolution SLAM operations. Such color profiles for regions 130a, 130b
27 can be the same or different. Region 120 can optimize wavelengths for receipt at a camera,
28 such as an RGB camera or a visible spectrum camera, which in embodiments, can be placed
29 directly behind region 120. The centralized placement of region 120 and any camera hardware
30 behind the region 120 enhances environmental information, e.g., scene information obtained
31 by the camera. In devices such as head gear, glasses, and associated AR/VR devices, such
32 positioning can be particularly useful in capturing images reflective of the view of a user
33 wearing the device.

34 **[0078]** In some embodiments, a lens can further include at least one region 110
35 optimized to enhance operations utilizing infrared light. Like region 120, region 110 can be
36 centrally positioned. In embodiments, region 110 can be placed above other regions, e.g.,
37 regions 130a, 130b, 120. Moreover, one or more hardware devices, such a camera and/or

1 laser emitter can be positioned behind region 110. A camera behind infrared region 110 can
2 receive light filtered by the color profile of region 110. A laser emitter behind infrared region
3 110 can emit light through region 110. In any or all cases, a computing system associated with
4 the lens and associated hardware devices can enhance, tune, and/or optimize operations
5 associated with light being received and/or emitted through the color profiles of each region
6 110, 120, 130a, 130b on the lens.

7 **[0079]** It will be appreciated that the position of the various regions can be adjusted
8 based on the particular camera, emitter, and/or computing system components behind the
9 lens. For example, visible wavelength regions 130a, 130b can be tuned to enhance operations
10 utilizing visible wavelengths. Such regions 130a, 130b can further enhance user experience
11 and visibility through a placement in front of a line of sight of the user and providing greater
12 transmission of wavelengths within the visible realm.

13 **[0080]** FIG. 2A illustrates an overview of color correction operation, executable by
14 one or more computing systems utilizing light filtered through lenses comprising a coating with
15 a plurality of color regions. FIG. 2B illustrates two different colors resulting from embodiments
16 of the color tuning process discussed herein. A first, original, AR design 250 provides a
17 yellow/green reflected color. A second, new, AR design 255 provides a violet color.

18 **[0081]** In a system 2100 utilizing a lens or cover window without a tint, such as a
19 clear lens, and/or in systems that do not utilize any lens or cover window, light 205a traveling
20 through does not change. To a camera or other light receiving device behind the lens or cover
21 window, the object 210 appears with its natural color. In other words, the lens or cover window
22 does not filter, distort, or otherwise alter the appearance of the object 210.

23 **[0082]** However, in a system 2200 utilizing a colored window 240, such as a lens
24 with a blue tint, light 205b traveling through the colored window 240 becomes distorted, as the
25 colored window selectively reflects certain wavelengths of light and transmits other
26 wavelengths of light. An object 220 viewed through the colored window 240 becomes distorted
27 and can appear to have an inaccurate color. In one example, if the object is a white cup,
28 viewing the object through a blue-tinted lens can make the object appear blue.

29 **[0083]** To correct this color distortion, image signal processing (ISP) tuning 225 can
30 compensate for the impact of the colored window 240. In embodiments, the ISP tuning 225
31 provides a color calibration and/or white balance adjustment to compensate for the known
32 color distortion caused by the colored window 240. A computing device in communication with
33 the one or more cameras or light receptors receiving the filtered light can apply ISP tuning 225
34 techniques to color correct the object 230. Continuing the above example, the lens reflects
35 blue light causing the user to see a blue tint. The camera behind the colored window 240
36 accordingly receives less transmitted blue light, and needs to color correct for the discrepancy,
37 since the object's color became distorted from the colored window 240. The ISP tuning 225

1 can color correct this distortion to account for the blue color profile of the colored window, and
2 cause the object to appear white, i.e., its natural color.

3 **[0084]** As discussed herein, many AR/VR devices and headsets utilize a plurality of
4 cameras behind the lens, and execute operations based on the images received. The images
5 are often reflective of environmental information, such as the scene a user sees through the
6 lens. Since the received images typically serve as the foundation for many operations on the
7 artificial reality device, it is essential that the computing system and its processor accurately
8 identify and detect the view through the lens. Accordingly, the ISP tuning operations 225 help
9 ensure that the received light is color corrected, based on the color profile of the lens in front
10 of the camera and/or light receptor device. By knowing the color profile in front of the cameras
11 and/or light receptor device and having the ability to tune and color correct the received light,
12 devices and systems can effectively and accurately function despite the color of the lens. This
13 enables a plurality of lens colors, designs, and configurations, that could not previously be
14 implemented, due to color distortions and inaccuracies caused by filtered light.

15 **[0085]** Moreover, such systems, methods, and devices can be applied to windows
16 comprising a variety of shapes and sizes, such as flat lenses, curved lenses, and other 2D
17 and 3D lens shapes.

18 **[0086]** FIG. 3 illustrates an example flowchart illustrating example methods for
19 executing color calibrations and associated operations 300 in accordance with exemplary
20 embodiments discussed herein. Such methods can be applied on various systems and
21 devices, such as AR/VR devices, headsets, and one or more computing devices, as discussed
22 herein.

23 **[0087]** Various embodiments can utilize colored lenses comprising one or more
24 regions comprising a color profile. In embodiments comprising a plurality of regions, two or
25 more regions can have the same or different color profiles. Any of a variety of lens designs
26 and color profiles can be utilized in accordance with embodiments.

27 **[0088]** In embodiments, a system can receive visible light transmitted through a first
28 region configured to selectively transmit visible light and receive infrared light through a
29 second region configured to selectively transmit infrared light 305. Such regions can be on a
30 colored lens, for example, on an AR/VR headset and/or in accordance with other device
31 embodiments discussed herein. Accordingly, the first region's color profile allows for the
32 selective transmission of visible light and the second region's color profile allows for the
33 selective transmission of infrared light. It will be appreciated that more or less regions can be
34 present on systems, and that the particular color profiles defined in step 305 are but one
35 example.

36 **[0089]** Regardless of various color profiles and the number of regions, exemplary
37 embodiments receive light at a plurality of cameras positioned behind a lens comprising a

1 color coating 310. The light can be indicative of environmental information, such as scenery,
2 a view through the lens, and the like.

3 **[0090]** In embodiments, received light provides environmental information for
4 executing an operation on the device. In one example, on an artificial reality headset, cameras
5 positioned behind the lens can execute an operation to capture an image intended to reflect a
6 snapshot of the environment beyond the lens. Since the colored lens and the regions in front
7 of the camera distort the light, a color calibration, based on the color profile of the region in
8 front of the camera, can help generate an image with realistic colors (see, e.g., FIG. 2A).

9 **[0091]** When light is first received at the plurality of cameras 310, systems can further
10 identify wavelengths of light reflected by the color profile of a first region positioned in front of
11 a first camera and a second region positioned in front of a second camera 320. In various
12 embodiments, one or more cameras can be positioned behind a region, and the colored lens
13 can comprise a plurality of regions. The design of the lens, with regard to placement and
14 number of regions can vary based on the system's purpose, function, use, and design, among
15 other factors.

16 **[0092]** The color calibration for light received at each camera can be based on the
17 color profile of the region through which the light travels. A color profile can further comprise
18 a transmission profile and a reflection profile, indicative of wavelengths selectively transmitted
19 and reflected, respectively. In an example, in a region having a color profile tuned to selectively
20 transmit visible light, a computing system can calibrate the received light information based
21 on the wavelengths filtered, reflected, and/or transmitted.

22 **[0093]** In particular, systems and methods determine a color calibration for light
23 received at each camera based on the color profile, wherein the color calibration amplifies
24 wavelengths of light reflected by the color profile 330. For example, a color profile can
25 comprise a reflection profile, indicative of wavelengths that are reflected. In embodiments,
26 reflection profiles can indicate a percentage, ratio, or other indication of an amount of light
27 reflected per wavelength and/or wavelength range. Similarly, embodiments can utilize
28 reflection profiles associated with the color profile to assist in the determination of the color
29 calibration, and determination of wavelengths of light for amplification.

30 **[0094]** Systems and methods can further update the environmental information
31 based on the color calibration 340. As discussed herein, the environmental information can be
32 indicative of a view through the lens, from the perspective of a user or other viewer or viewing
33 device. In other examples, environmental information can comprise one or more objects,
34 colors, and features. Systems and methods execute one or more operations on the device
35 based on the updated environmental information 350.

36 **[0095]** An example of an operation can be an execution of a simultaneous location
37 and mapping (SLAM) function 360a. Other possible operations include light transmission

1 through the colored coating 360b. Such light transmissions can utilize one or more of a laser
2 emitter, a light emitting diode (LED), or other light emitting device. An operation can comprise
3 generating, projecting, and/or displaying an image on a display 360c. The display can be, for
4 example, one or more monitors, computing devices, screens, mobile devices in
5 communication with the devices and computing systems utilized herein. Tracking operations,
6 auto-focus, and AR/VR functions, among many other operations can utilize environmental
7 information.

8 **[0096]** FIG. 4 illustrates another exemplary method for executing color calibration
9 operations 400 in accordance with embodiments. Similar to FIG. 3 and other examples
10 discussed herein, the color calibration 400 can operate on artificial reality devices, headsets,
11 and related computing systems. Such systems receive images from at least one camera,
12 wherein the images are indicative of a view through a lens 410. Such cameras can be placed
13 behind a lens, such as in an AR/VR device. As discussed herein, the camera can serve to
14 identify environmental information, and provide an outward facing view of a view, such as a
15 scenery view, similar to that which a user views when using the device and looking through
16 the lens.

17 **[0097]** Systems and devices can determine a color calibration based on the colored
18 coating 420. The color calibration amplifies a reflection color profile associated with the colored
19 coating. Systems and devices update received images based on the color calibration.

20 **[0098]** In certain embodiments, based on the color calibration, a third color profile
21 can be applied to received images to tune the view through the lens and compensate for the
22 colored coating 440. The color calibration can dynamically adjust the color calibration when
23 the received images indicate a change in the view through the lens 450.

24 **[0099]** Such operations can be helpful when utilizing the received images for one or
25 more operations, as discussed herein. In an example, the view through the lens, as observed
26 by the one or more cameras, may be displayed on one or more displays, such as a local
27 display, on a backside of the colored lens, or on one or more external devices. Since the
28 cameras view through the lens becomes distorted based on the colored coating on the lens,
29 the colored calibration amplifies the reflected wavelengths, to compensate for the effect of the
30 colored coating. Such operations aid in generating accurate images with realistic colors,
31 despite colored coatings. Such operations further enable various colored coatings and designs
32 to be applied onto devices, without affecting the function and operation of the device, e.g.,
33 AR/VR devices.

34 **[00100]** FIG. 5A illustrates an example transmission vs. wavelength graph for
35 various coatings on a lens, usable for various embodiments discussed herein. The graph
36 compares various lenses and demonstrates a stark difference between light transmission
37 through lenses without any coatings and configurations with specialized infrared ink coatings.

1 Lenses with coatings utilized infrared ink. Transmission data for each lens utilized a 0° angle
2 of incidence (AOI) during testing. This transmission data, with a 0° AOI, provides examples for
3 on-axis color profiles.

4 **[00101]** The two lenses without any infrared ink coating, corresponding to the curves
5 for Sample A 510 and Sample B 540, demonstrated a consistent transmission rate of over
6 90% for wavelengths between 400 nm and 900 nm. The lens corresponding to curve for
7 Sample C 530 may include infrared ink on polycarbonate/polymethylmethacrylate
8 (PC/PMMA). In other embodiments, the Sample may include any such ink and substrate
9 combination, such as an ink and transparent polymer combination. For the three curves
10 relating to lenses with infrared coating, i.e., Sample B 520, Sample C 530, and Sample D 550,
11 the lenses have a less than 20% transmission rate for wavelengths below 750 nm, and less
12 than 10% transmission rate for wavelengths below 730 nm. Above 850 nm, transmission rates
13 increase to at least 60%. In some examples, as with the curve for Sample E 550, transmission
14 rates can increase to 70% or greater for wavelengths of 800 nm and above. While the tested
15 coatings demonstrate transmission rates for infrared inks, it will be appreciated that various
16 types of coatings, directed toward particular wavelengths can be applied in a similar manner.
17 Likewise, such coatings can include discrete regions on a lens, as discussed herein, and such
18 transmission data can be applicable for determining color profiles, transmission profiles, and
19 reflection profiles for such regions.

20 **[00102]** FIG. 5B illustrates an example reflection (%) versus wavelength (nm) graph
21 for an AR coating related to a yellow/green reflected color. The reflection percentage of
22 yellow/green indicates a peak reflection of around 1-2.5% for wavelengths between 500-
23 600nm, with a peak of about 2.4% at approximately 550 nm. Secondary peaks occur between
24 400-500 nm, and between 400-450 nm. Another smaller peak occurs around 750-800 nm.
25 The reflected wavelength peaks result in a yellow/green reflected color.

26 **[00103]** FIG. 5C illustrates another example reflection (%) versus wavelength (nm)
27 graph for an AR coating, but related to a violet reflected color. Both the measured reflection
28 percentage, represented by line 570, and the simulated reflection percentage, represented by
29 line 580, demonstrates a sharp decrease between 400-450 nm. The illustrated design exhibits
30 a strong reflection at 400 nm, which corresponds to violet reflected light. After approximately
31 450 nm, both the simulated and measured examples do not exhibit a reflection percentage
32 greater than about 2.5%.

33 **[00104]** FIG. 5D illustrates an example transmission (%) versus wavelength (nm)
34 graph for an AR coating related to the violet reflected color. Both the measured transmission
35 percentage, represented by line 590, and the simulated reflection percentage, represented by
36 line 595, demonstrates a sharp increase between 400-450 nm. After approximately 450 nm,
37 both the simulated and measured examples do not exhibit a reflection percentage less than

1 about 95%. The transmission curves for the violet reflected colors have a lower transmission
2 percentage at lower wavelengths. The ISP tuning mechanisms and embodiments discussed
3 herein can account for this loss in transmission.

4 **[00105]** FIG. 6 illustrates an example material stack for lenses and coatings as
5 discussed herein. A lens, such as a colored lens, can comprise a plurality of layered materials.
6 Such materials can be stacked on an inner and outer sides of a cover window 640. In
7 embodiments, such materials can comprise PC, PMMA, a combination of PC/PMMA, and the
8 like. The layered materials can include, but are not limited to, an ink layer, a hard-coat (HC)
9 layer, and an outer anti-reflective (AR) layer. In some embodiments, an anti-fingerprint (AF)
10 layer can be applied to the outermost layer.

11 **[00106]** In embodiments the lens can be a curved lens, such that an outer portion
12 comprises a convex shape. In the example illustrated in FIG. 6 a lens can comprise an AR
13 layer 610 can comprise an innermost layer 0.35-0.4 micrometers thick, an HC layer 620 with
14 a 9-30 micrometer thickness, an ink layer 630 with a 6-28 micrometer thickness, an ~800
15 micrometer cover window 640 (e.g., PC/PMMA, PC, etc.), another HC layer 650 with a 9-10
16 micrometer thickness, another AR layer 660 with a 0.35-0.40 micrometer thickness, and an
17 outer AF layer 670 with a 0.012-0.013 micrometer thickness.

18 **[00107]** It will be appreciated that lens designs can comprise more or less material
19 layers than illustrated in FIG. 6, and the layer thicknesses may be greater or less, depending
20 on the desired optical characteristics of the lenses. In addition, such layers can extend over
21 part or all of a lens, and various layer combinations and layer thicknesses can be implemented
22 to form one or more regions on a lens. In other words, various regions on a lens can comprise
23 similar or different layer configurations, and FIG. 6 provides only one such example for
24 generating a lens in accordance with embodiments discussed herein.

25 **[00108]** FIG. 7 illustrates an example reflection profile, and FIG. 8 illustrates a
26 corresponding transmission profile. As discussed herein, lenses can be tuned to reflect
27 particular color(s) in certain regions, e.g., non camera regions, and optimized to transmit
28 known colors. Systems and methods can execute calibration operations based on the known
29 reflection profiles and transmission profiles to optimize camera performance, and any
30 operations utilizing the images received the camera.

31 **[00109]** FIG. 7 provides reflection (%) vs. wavelength (nm) from approximately 400
32 nm to 1000 nm for an example reflection profile in accordance with embodiments. FIG. 7
33 illustrates significant reflection for light in the 400-500 nm range and peaking at approximately
34 20%. Light in the 600-800 nm wavelength range also experience increased reflection, peaking
35 at around 10%. Wavelengths greater than 900 nm are reflected as well, peaking at
36 approximately 5%. The lowest reflection levels are seen between 500-600 nm and 800-900
37 nm, with less than 5% reflection. Reflection is near zero around 530-570 nm and 830-900 nm,

and at a minimum around 550 nm and 830-840 nm.

[00110] FIG. 8 illustrates a corresponding transmission profile to the reflection profile of FIG. 7, in accordance with embodiments. The example transmission profile provides transmission (%) vs. wavelength (nm) data. Wavelengths above 500 nm transmit light at levels approximately 88% and higher, peaking around 100% transmission around 800-900 nm. Light in the 400-500 nm range experience lower transmission levels, as expected, since this range experienced the greatest reflection levels in FIG. 7. The transmission levels of 400-500 nm light increase as the wavelengths increase, starting at approximately 68% at 400 nm, and reaching approximately 88% transmission at 500 nm. Light in the 500-600 nm wavelength remains constant at approximately 88-90% transmission and being to increase after 600 nm. Light in the 700-900 nm range increases and peaks at around 100% transmission between 800-900 nm, and decreases slightly, above 900 nm.

[00111] Table 1 illustrates data related to transmission profiles for a plurality of lens types and colors, ranging from green, red, blue, clear, and combinations of such colors. The following table provides transmission spectra data for various lens configurations and examples. Transmission profiles, comprising transmission data for a plurality of wavelengths and/or ranges of wavelengths, can provide a basis for color calibration operations. The coloration discussed in the following table is relevant to custom ink meant for near-infrared usage.

TABLE 1

	1	2	3	4	5	6	7	8	9
Color	Green	Green/ Clear A	Green/ Clear B	Red	Red/ Clear	Blue	Blue/ Clear	Green/ Red	Green/ Red/ Clear
T% 940nm	91.4014	90.8532	91.6532	91.2415	91.7397	89.1285	90.8275	90.3015	92.1005
T% 850nm	89.8806	91.2004	90.5094	89.9659	90.6843	86.1239	88.836	89.3295	91.3765
T% 550nm	0.5453	7.5548	10.6507	0.0101	7.7763	0.7312	7.5656	0.1692	10.8715

[00112] As discussed above, embodiments of the present invention comprise lenses having one or more regions, with each region comprising one or more color profiles. A particular region can comprise differing on-axis and off-axis color profiles, each with a transmission profile and a reflection profile. On-axis and off-axis refer to the angle of incidence (AOI) of light received at a particular region. On-axis indicates light received directly, with little to no AOI, while off-axis indicates light received at an angle. Different color profiles can exist

for different AOIs and/or ranges of AOIs.

[00113] Table 2 illustrates specific transmission requirements for embodiments of camera regions as a function of wavelength. With respect to Table 2, camera regions represent lens regions, e.g., on a lens of an artificial reality device, behind a camera is positioned and receives light. Based on camera needs for optimal functionality, minimum transmission requirements can optimize one or more cameras. Table 2 indicates specific requirements for on-axis and off-axis, e.g., 70-degree AOI, for ranges of wavelengths.

[00114] In embodiments, an on-axis color profile can transmit over 77% of light between 400-860 nm, with the greatest transmission between 500-700 nm. An off-axis color profile wherein the on-axis color profile for at least one region has greater than a 90% transmission rate for wavelengths above 500 nm. An on-axis color profile for at least one region on a lens provides over 96% transmission rate for wavelengths between 500-700 nm. Off-axis color profile in embodiments can comprise a transmission rate of greater than 64% for wavelengths above 500 nm and/or a transmission rate of greater than 73% for wavelengths between 500-700 nm.

TABLE 2

	Wavelength	Camera Regions
T% at 0 degrees	400 nm	>77%
	500 nm	>96%
	600 nm	>96%
	700 nm	>97%
	840-860 nm	>90%
T% at 70 degrees	400 nm	>59%
	500 nm	>74%
	600 nm	>73%
	700 nm	>74%
	840-860 nm	>64%

[00115] Table 3 illustrates color calibration data utilizing on-axis and off-axis color profile information for a blue colored lens. The color calibration identifies the signal to noise ratio (SNR) for red (R), green (G), blue (B), and yellow (Y) wavelengths, both on-axis and off axis, with regard to a point of reference (Cool White, CW) and Blue. The delta values for the on-axis measurements indicate a drop in SNR which can be compensated during a color calibration operation. The delta values for the off-axis measurements indicate an SNR enhancement which can also be compensated during color calibration operations. It will be appreciated that while SNR can serve as a basis for color calibration operations discussed herein, they are but one example of color profile data and measurements applicable for color

calibration operations. Exemplary embodiments can utilize other measurements and values instead of or in addition to the SNR measurements, and each are in accordance with the various embodiments discussed herein.

TABLE 3

	On-Axis			Off-Axis		
	Point of Reference (CW)	Blue	Delta %	Point of Reference (CW)	Blue	Delta %
Red	11.79	10.83	-8.1%	5.95	6.99	17.5%
Green	12.90	11.88	-7.9%	7.89	9.01	14.2%
Blue	3.98	3.77	-5.3%	2.49	2.83	13.7%
Yellow	11.55	10.64	-7.9%	6.69	7.70	15.1%

[00116] FIGs. 9-10 illustrate various color tinting fabrication processes applicable to embodiments of the present invention. Such processes can generate lenses, such as the layered device illustrated in FIG. 6. FIG. 9 illustrates a thermoform process to create 2D and 3D lenses. In the thermoform method, material sheets 910, e.g., lens material, PC, PC/PMMA, etc., can be printed and/or baked 920 to create a two-dimensional flat lens. Thermoforming 930 heats the lens to a forming temperature to allow the product to be molded into a three-dimensional shape. A hard coating 940 can be applied to the thermoformed product, and trimming process, such a computer-numerical-controlled (CNC) operation 950, can shape the product into the desired form. Additional layers and/or coatings, such as an anti-reflective (AR) layer 960 can be applied to the product. A thermoforming process generate products and lenses in accordance with embodiments, having one or more regions with particular optical characteristics and color profiles.

[00117] FIG. 10 provides a flow chart for an injection molding process to form three-dimensional products, devices, and lenses, in accordance with embodiments. Raw material 1010, such as polyethylene, polycarbonate, and/or PMMA material can be injection molded 1020 to form a 3D shape. In the injection molding process, raw material 1010 can be heated into a molten form, then injected into a mold, and cooled while in the mold. Pad printing operations 1030 can add additional colors, materials, and/or designs to the product. In an example, the lens can be colored with regions having color profiles. A hard coating 1040 can be applied to the product, along with an anti-reflective (AR) layer 1050. A trimming process, such as a CNC operation 1060, can further refine the product to its desired shape and size. Similar to thermoforming processes, injection molding processes can generate products and lenses in accordance with embodiments, having one or more regions with particular optical characteristics and color profiles.

1 **[00118]** FIGS. 11-12 illustrate apparatuses for various film coating methods, usable
2 to create colored lenses for embodiments of the present invention. Various processing
3 methods utilize physical vapor deposition (PVD) for coating products and devices, such as the
4 lenses discussed herein. FIG. 11 illustrates a sputter deposition apparatus in accordance with
5 embodiments. In a sputter deposition coating process, a target cathode 1110 is secured to
6 one or more magnets 1130, and electrically charged 1140 to cause material 1150 to eject from
7 the target cathode 1110 and transfer to a substrate 1120. The substrate can be a lens or other
8 desired device to be coated. The sputtering process is advantageous for providing a strong,
9 uniform coating on the substrate surface. Sputtering further enables deposition of a variety of
10 materials, and a plurality of layers with desired thicknesses, as in various embodiments
11 discussed herein.

12 **[00119]** FIG. 12 illustrates an Electron-Beam (E-Beam) Evaporation apparatus in
13 accordance with embodiments. In an E-Beam Evaporation process, an apparatus 2000
14 comprising a filament 2002, accelerator 2004, magnetic field 2006, shutter 2008, and vacuum
15 pump 2010, generates an electron beam 2012 directed toward a target material source 2014.
16 The interaction causes target material to evaporate and convert into a gaseous vapor state
17 2016, where it can be deposited onto a substrate 2018, such as a lens or other device to be
18 coated. One or more sensors 2020, such as a quartz crystal microbalance (QCM) sensor can
19 analyze the thickness of the deposited target material in real-time, thus enabling precise and
20 accurate layers.

21 **[00120]** It will be appreciated that while PVD processing methods can form products,
22 devices, and lenses in accordance with embodiments, formation of such embodiments are not
23 limited to such processing methods. A plurality of processing methods, systems, devices, and
24 apparatuses can generate one or more layers and aspects of products and devices in
25 accordance with embodiments.

26 **[00121]** FIG. 13 illustrates an example artificial reality system 1300. The artificial
27 reality system 1300 may include a head-mounted display (HMD) 1310 (e.g., glasses)
28 comprising a frame 1312, one or more displays 1314, and a computing device 1308 (also
29 referred to herein as computer 1308). The displays 1314 may be transparent or translucent
30 allowing a user wearing the HMD 1310 to look through the displays 1314 to see the real world
31 and displaying visual artificial reality content to the user at the same time. The HMD 1310 may
32 include an audio device 1306 (e.g., speaker/microphone 38 of FIG. 6) that may provide audio
33 artificial reality content to users. The HMD 1310 may include one or more cameras 1316 which
34 can capture images and videos of environments. The HMD 1310 may include an eye tracking
35 system to track the vergence movement of the user wearing the HMD 1310. In one example
36 embodiment, the camera 1316 may be the eye tracking system. The HMD 1310 may include
37 a microphone of the audio device 1306 to capture voice input from the user. The augmented

1 reality system 1300 may further include a controller 1318 (e.g., processor 32 of FIG. 14)
2 comprising a trackpad and one or more buttons. The controller may receive inputs from users
3 and relay the inputs to the computing device 1308. The controller may also provide haptic
4 feedback to users. The computing device 1308 may be connected to the HMD 1310 and the
5 controller through cables or wireless connections. The computing device 1308 may control the
6 HMD 1310 and the controller to provide the augmented reality content to and receive inputs
7 from one or more users. In some example embodiments, the controller 1318 may be a
8 standalone controller or integrated within the HMD 1310. The computing device 1308 may be
9 a standalone host computer device, an on-board computer device integrated with the HMD
10 1310, a mobile device, or any other hardware platform capable of providing artificial reality
11 content to and receiving inputs from users. In some exemplary embodiments, HMD 1310 may
12 include an artificial reality system/virtual reality system (e.g., artificial reality system 100).

13 **[00122]** FIG. 14 illustrates another example of an artificial reality system including a
14 head-mounted display (HMD) 1400, image sensors 1402 mounted to (e.g., extending from)
15 HMD 1400, according to at least one exemplary embodiment of the present disclosure. In
16 some embodiments, image sensors 1402 are mounted on and protruding from a surface (e.g.,
17 a front surface, a corner surface, etc.) of HMD 1400. In some exemplary embodiments, HMD
18 1400 may include an artificial reality system/virtual reality system (e.g., artificial reality system
19 100). In an exemplary embodiment, image sensors 102 may include, but are not limited to,
20 one or more sensors (e.g., camera 1316, a display 1314, an audio device 1306, etc.). In
21 exemplary embodiments, a compressible shock absorbing device may be mounted on image
22 sensors 1402. The shock absorbing device may be configured to substantially maintain the
23 structural integrity of image sensors 1402 in case an impact force is imparted on image
24 sensors 1402. In some embodiments, image sensors 1402 may protrude from a surface (e.g.,
25 the front surface) of HMD 1400 so as to increase a field of view of image sensors 1402. In
26 some examples, image sensors 1402 may be pivotally and/or translationally mounted to HMD
27 100 to pivot image sensors 1402 at a range of angles and/or to allow for translation in multiple
28 directions, in response to an impact. For example, image sensors 1402 may protrude from the
29 front surface of HMD 1400 so as to give image sensors 1402 at least a 180 degree field of
30 view of objects (e.g., a hand, a user, a surrounding real-world environment, etc.).

31 **[00123]** FIG. 15 illustrates a block diagram of an exemplary hardware/software
32 architecture of a UE 30. As shown in FIG. 15, the UE 30 (also referred to herein as node 30)
33 may include a processor 32, non-removable memory 44, removable memory 46, a
34 speaker/microphone 38, a keypad 40, a display, touchpad, and/or indicators 42, a power
35 source 48, a global positioning system (GPS) chipset 50, and other peripherals 52. The UE
36 30 may also include a camera 54. In an exemplary embodiment, the camera 54 is a smart
37 camera configured to sense images appearing within one or more bounding boxes. The UE

30 may also include communication circuitry, such as a transceiver 34 and a transmit/receive element 36. It will be appreciated the UE 30 may include any sub-combination of the foregoing elements while remaining consistent with an embodiment.

[00124] The processor 32 may be a special purpose processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Array (FPGAs) circuits, any other type of integrated circuit (IC), a state machine, and the like. In general, the processor 32 may execute computer-executable instructions stored in the memory (e.g., memory 44 and/or memory 46) of the node 30 in order to perform the various required functions of the node. For example, the processor 32 may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the node 30 to operate in a wireless or wired environment. The processor 32 may run application-layer programs (e.g., browsers) and/or radio access-layer (RAN) programs and/or other communications programs. The processor 32 may also perform security operations such as authentication, security key agreement, and/or cryptographic operations, such as at the access-layer and/or application layer for example.

[00125] The processor 32 is coupled to its communication circuitry (e.g., transceiver 34 and transmit/receive element 36). The processor 32, through the execution of computer executable instructions, may control the communication circuitry in order to cause the node 30 to communicate with other nodes via the network to which it is connected.

[00126] The transmit/receive element 36 may be configured to transmit signals to, or receive signals from, other nodes or networking equipment. For example, in an embodiment, the transmit/receive element 36 may be an antenna configured to transmit and/or receive radio frequency (RF) signals. The transmit/receive element 36 may support various networks and air interfaces, such as wireless local area network (WLAN), wireless personal area network (WPAN), cellular, and the like. In yet another embodiment, the transmit/receive element 36 may be configured to transmit and receive both RF and light signals. It will be appreciated that the transmit/receive element 36 may be configured to transmit and/or receive any combination of wireless or wired signals.

[00127] The transceiver 34 may be configured to modulate the signals that are to be transmitted by the transmit/receive element 36 and to demodulate the signals that are received by the transmit/receive element 36. As noted above, the node 30 may have multi-mode capabilities. Thus, the transceiver 34 may include multiple transceivers for enabling the node 30 to communicate via multiple radio access technologies (RATs), such as universal terrestrial radio access (UTRA) and Institute of Electrical and Electronics Engineers (IEEE 802.11), for example.

[00128] The processor 32 may access information from, and store data in, any type

1 of suitable memory, such as the non-removable memory 44 and/or the removable memory
2 46. For example, the processor 32 may store session context in its memory, as described
3 above. The non-removable memory 44 may include RAM, ROM, a hard disk, or any other type
4 of memory storage device. The removable memory 46 may include a subscriber identity
5 module (SIM) card, a memory stick, a secure digital (SD) memory card, and the like. In other
6 embodiments, the processor 32 may access information from, and store data in, memory that
7 is not physically located on the node 30, such as on a server or a home computer.

8 **[00129]** The processor 32 may receive power from the power source 48, and may
9 be configured to distribute and/or control the power to the other components in the node 30.
10 The power source 48 may be any suitable device for powering the node 30. For example, the
11 power source 48 may include one or more dry cell batteries (e.g., nickel-cadmium (NiCd),
12 nickel-zinc (NiZn), nickel metal hydride (NiMH), lithium-ion (Li-ion), etc.), solar cells, fuel cells,
13 and the like.

14 **[00130]** The processor 32 may also be coupled to the GPS chipset 50, which may
15 be configured to provide location information (e.g., longitude and latitude) regarding the
16 current location of the node 30. It will be appreciated that the node 30 may acquire location
17 information by way of any suitable location-determination method while remaining consistent
18 with an exemplary embodiment.

19 **[00131]** FIG. 16 is a block diagram of an exemplary computing system 1600 which
20 may also be used to implement components of the system or be part of the UE 30. The
21 computing system 1600 may comprise a computer or server and may be controlled primarily
22 by computer readable instructions, which may be in the form of software, wherever, or by
23 whatever means such software is stored or accessed. Such computer readable instructions
24 may be executed within a processor, such as central processing unit (CPU) 91, to cause
25 computing system 200 to operate. In many workstations, servers, and personal computers,
26 central processing unit 91 may be implemented by a single-chip CPU called a microprocessor.
27 In other machines, the central processing unit 91 may comprise multiple processors.
28 Coprocessor 81 may be an optional processor, distinct from main CPU 91, that performs
29 additional functions or assists CPU 91.

30 **[00132]** In operation, CPU 91 fetches, decodes, and executes instructions, and
31 transfers information to and from other resources via the computer's main data-transfer path,
32 system bus 80. Such a system bus connects the components in computing system 200 and
33 defines the medium for data exchange. System bus 80 typically includes data lines for sending
34 data, address lines for sending addresses, and control lines for sending interrupts and for
35 operating the system bus. An example of such a system bus 80 is the Peripheral Component
36 Interconnect (PCI) bus.

37 **[00133]** Memories coupled to system bus 80 include RAM 82 and ROM 93. Such

1 memories may include circuitry that allows information to be stored and retrieved. ROMs 93
2 generally contain stored data that cannot easily be modified. Data stored in RAM 82 may be
3 read or changed by CPU 91 or other hardware devices. Access to RAM 82 and/or ROM 93
4 may be controlled by memory controller 92. Memory controller 92 may provide an address
5 translation function that translates virtual addresses into physical addresses as instructions
6 are executed. Memory controller 92 may also provide a memory protection function that
7 isolates processes within the system and isolates system processes from user processes.
8 Thus, a program running in a first mode may access only memory mapped by its own process
9 virtual address space; it cannot access memory within another process's virtual address space
10 unless memory sharing between the processes has been set up.

11 **[00134]** In addition, computing system 200 may contain peripherals controller 83
12 responsible for communicating instructions from CPU 91 to peripherals, such as printer 94,
13 keyboard 84, mouse 95, and disk drive 85.

14 **[00135]** Display 86, which is controlled by display controller 96, is used to display
15 visual output generated by computing system 200. Such visual output may include text,
16 graphics, animated graphics, and video. Display 86 may be implemented with a cathode-ray
17 tube (CRT)-based video display, a liquid-crystal display (LCD)-based flat-panel display, gas
18 plasma-based flat-panel display, or a touch-panel. Display controller 96 includes electronic
19 components required to generate a video signal that is sent to display 86.

20 **[00136]** Further, computing system 1600 may contain communication circuitry, such
21 as for example a network adaptor 97, that may be used to connect computing system 200 to
22 an external communications network, such as network 12 of FIG. 6, to enable the computing
23 system 200 to communicate with other nodes (e.g., UE 30) of the network.

24 **[00137]** FIG. 17 illustrates an example computer system 1700. In exemplary
25 embodiments, one or more computer systems 1700 perform one or more steps of one or more
26 methods described or illustrated herein. In particular embodiments, one or more computer
27 systems 1700 provide functionality described or illustrated herein. In exemplary embodiments,
28 software running on one or more computer systems 1700 performs one or more steps of one
29 or more methods described or illustrated herein or provides functionality described or
30 illustrated herein. Exemplary embodiments include one or more portions of one or more
31 computer systems 1700. Herein, reference to a computer system may encompass a
32 computing device, and vice versa, where appropriate. Moreover, reference to a computer
33 system may encompass one or more computer systems, where appropriate.

34 **[00138]** This disclosure contemplates any suitable number of computer systems
35 1700. This disclosure contemplates computer system 1700 taking any suitable physical form.
36 As example and not by way of limitation, computer system 1700 may be an embedded
37 computer system, a system-on-chip (SOC), a single-board computer system (SBC) (such as,

1 for example, a computer-on-module (COM) or system-on-module (SOM)), a desktop computer
2 system, a laptop or notebook computer system, an interactive kiosk, a mainframe, a mesh of
3 computer systems, a mobile telephone, a personal digital assistant (PDA), a server, a tablet
4 computer system, or a combination of two or more of these. Where appropriate, computer
5 system 1700 may include one or more computer systems 1700; be unitary or distributed; span
6 multiple locations; span multiple machines; span multiple data centers; or reside in a cloud,
7 which may include one or more cloud components in one or more networks. Where
8 appropriate, one or more computer systems 1700 may perform without substantial spatial or
9 temporal limitation one or more steps of one or more methods described or illustrated herein.
10 As an example and not by way of limitation, one or more computer systems 1700 may perform
11 in real time or in batch mode one or more steps of one or more methods described or illustrated
12 herein. One or more computer systems 1700 may perform at different times or at different
13 locations one or more steps of one or more methods described or illustrated herein, where
14 appropriate.

15 **[00139]** In exemplary embodiments, computer system 1700 includes a processor
16 1702, memory 1704, storage 1706, an input/output (I/O) interface 1708, a communication
17 interface 1710, and a bus 1712. Although this disclosure describes and illustrates a particular
18 computer system having a particular number of particular components in a particular
19 arrangement, this disclosure contemplates any suitable computer system having any suitable
20 number of any suitable components in any suitable arrangement.

21 **[00140]** In exemplary embodiments, processor 1702 includes hardware for
22 executing instructions, such as those making up a computer program. As an example and not
23 by way of limitation, to execute instructions, processor 1702 may retrieve (or fetch) the
24 instructions from an internal register, an internal cache, memory 1704, or storage 1706;
25 decode and execute them; and then write one or more results to an internal register, an internal
26 cache, memory 1704, or storage 1706. In particular embodiments, processor 1702 may
27 include one or more internal caches for data, instructions, or addresses. This disclosure
28 contemplates processor 1702 including any suitable number of any suitable internal caches,
29 where appropriate. As an example and not by way of limitation, processor 1702 may include
30 one or more instruction caches, one or more data caches, and one or more translation
31 lookaside buffers (TLBs). Instructions in the instruction caches may be copies of instructions
32 in memory 1704 or storage 1706, and the instruction caches may speed up retrieval of those
33 instructions by processor 1702. Data in the data caches may be copies of data in memory
34 1704 or storage 1706 for instructions executing at processor 1702 to operate on; the results
35 of previous instructions executed at processor 1702 for access by subsequent instructions
36 executing at processor 1702 or for writing to memory 1704 or storage 1706; or other suitable
37 data. The data caches may speed up read or write operations by processor 1702. The TLBs

1 may speed up virtual-address translation for processor 1702. In particular embodiments,
2 processor 1702 may include one or more internal registers for data, instructions, or addresses.
3 This disclosure contemplates processor 1702 including any suitable number of any suitable
4 internal registers, where appropriate. Where appropriate, processor 1702 may include one or
5 more arithmetic logic units (ALUs); be a multi-core processor; or include one or more
6 processors 1702. Although this disclosure describes and illustrates a particular processor, this
7 disclosure contemplates any suitable processor.

8 **[00141]** In exemplary embodiments, memory 1704 includes main memory for storing
9 instructions for processor 1702 to execute or data for processor 1702 to operate on. As an
10 example and not by way of limitation, computer system 1700 may load instructions from
11 storage 1706 or another source (such as, for example, another computer system 1700) to
12 memory 1704. Processor 1702 may then load the instructions from memory 1704 to an internal
13 register or internal cache. To execute the instructions, processor 1702 may retrieve the
14 instructions from the internal register or internal cache and decode them. During or after
15 execution of the instructions, processor 1702 may write one or more results (which may be
16 intermediate or final results) to the internal register or internal cache. Processor 1702 may
17 then write one or more of those results to memory 1704. In particular embodiments, processor
18 1702 executes only instructions in one or more internal registers or internal caches or in
19 memory 1704 (as opposed to storage 1706 or elsewhere) and operates only on data in one
20 or more internal registers or internal caches or in memory 1704 (as opposed to storage 1706
21 or elsewhere). One or more memory buses (which may each include an address bus and a
22 data bus) may couple processor 1702 to memory 1704. Bus 1712 may include one or more
23 memory buses, as described below. In exemplary embodiments, one or more memory
24 management units (MMUs) reside between processor 1702 and memory 1704 and facilitate
25 accesses to memory 1704 requested by processor 1702. In particular embodiments, memory
26 1704 includes random access memory (RAM). This RAM may be volatile memory, where
27 appropriate. Where appropriate, this RAM may be dynamic RAM (DRAM) or static RAM
28 (SRAM). Moreover, where appropriate, this RAM may be single-ported or multi-ported RAM.
29 This disclosure contemplates any suitable RAM. Memory 1704 may include one or more
30 memories 1704, where appropriate. Although this disclosure describes and illustrates
31 particular memory, this disclosure contemplates any suitable memory.

32 **[00142]** In exemplary embodiments, storage 1706 includes mass storage for data or
33 instructions. As an example and not by way of limitation, storage 1706 may include a hard disk
34 drive (HDD), a floppy disk drive, flash memory, an optical disc, a magneto-optical disc,
35 magnetic tape, or a Universal Serial Bus (USB) drive or a combination of two or more of these.
36 Storage 1706 may include removable or non-removable (or fixed) media, where appropriate.
37 Storage 1706 may be internal or external to computer system 1700, where appropriate. In

1 exemplary embodiments, storage 1706 is non-volatile, solid-state memory. In particular
2 embodiments, storage 1706 includes read-only memory (ROM). Where appropriate, this ROM
3 may be mask-programmed ROM, programmable ROM (PROM), erasable PROM (EPROM),
4 electrically erasable PROM (EEPROM), electrically alterable ROM (EAROM), or flash memory
5 or a combination of two or more of these. This disclosure contemplates mass storage 1706
6 taking any suitable physical form. Storage 1706 may include one or more storage control units
7 facilitating communication between processor 1702 and storage 1706, where appropriate.
8 Where appropriate, storage 1706 may include one or more storages 1706. Although this
9 disclosure describes and illustrates particular storage, this disclosure contemplates any
10 suitable storage.

11 **[00143]** In exemplary embodiments, I/O interface 1708 includes hardware, software,
12 or both, providing one or more interfaces for communication between computer system 1700
13 and one or more I/O devices. Computer system 1700 may include one or more of these I/O
14 devices, where appropriate. One or more of these I/O devices may enable communication
15 between a person and computer system 1700. As an example and not by way of limitation, an
16 I/O device may include a keyboard, keypad, microphone, monitor, mouse, printer, scanner,
17 speaker, still camera, stylus, tablet, touch screen, trackball, video camera, another suitable
18 I/O device or a combination of two or more of these. An I/O device may include one or more
19 sensors. This disclosure contemplates any suitable I/O devices and any suitable I/O interfaces
20 1708 for them. Where appropriate, I/O interface 1708 may include one or more device or
21 software drivers enabling processor 1702 to drive one or more of these I/O devices. I/O
22 interface 1708 may include one or more I/O interfaces 1708, where appropriate. Although this
23 disclosure describes and illustrates a particular I/O interface, this disclosure contemplates any
24 suitable I/O interface.

25 **[00144]** In exemplary embodiments, communication interface 1710 includes
26 hardware, software, or both providing one or more interfaces for communication (such as, for
27 example, packet-based communication) between computer system 1700 and one or more
28 other computer systems 1700 or one or more networks. As an example and not by way of
29 limitation, communication interface 1710 may include a network interface controller (NIC) or
30 network adapter for communicating with an Ethernet or other wire-based network or a wireless
31 NIC (WNIC) or wireless adapter for communicating with a wireless network, such as a WI-FI
32 network. This disclosure contemplates any suitable network and any suitable communication
33 interface 1710 for it. As an example and not by way of limitation, computer system 1700 may
34 communicate with an ad hoc network, a personal area network (PAN), a local area network
35 (LAN), a wide area network (WAN), a metropolitan area network (MAN), or one or more
36 portions of the Internet or a combination of two or more of these. One or more portions of one
37 or more of these networks may be wired or wireless. As an example, computer system 1700

1 may communicate with a wireless PAN (WPAN) (such as, for example, a BLUETOOTH
2 WPAN), a WI-FI network, a WI-MAX network, a cellular telephone network (such as, for
3 example, a Global System for Mobile Communications (GSM) network), or other suitable
4 wireless network or a combination of two or more of these. Computer system 1700 may include
5 any suitable communication interface 1710 for any of these networks, where appropriate.
6 Communication interface 1710 may include one or more communication interfaces 1710,
7 where appropriate. Although this disclosure describes and illustrates a particular
8 communication interface, this disclosure contemplates any suitable communication interface.

9 **[00145]** In particular embodiments, bus 1712 includes hardware, software, or both
10 coupling components of computer system 1700 to each other. As an example and not by way
11 of limitation, bus 1712 may include an Accelerated Graphics Port (AGP) or other graphics bus,
12 an Enhanced Industry Standard Architecture (EISA) bus, a front-side bus (FSB), a
13 HYPERTRANSPORT (HT) interconnect, an Industry Standard Architecture (ISA) bus, an
14 INFINIBAND interconnect, a low-pin-count (LPC) bus, a memory bus, a Micro Channel
15 Architecture (MCA) bus, a Peripheral Component Interconnect (PCI) bus, a PCI-Express
16 (PCIe) bus, a serial advanced technology attachment (SATA) bus, a Video Electronics
17 Standards Association local (VLB) bus, or another suitable bus or a combination of two or
18 more of these. Bus 1712 may include one or more buses 1712, where appropriate. Although
19 this disclosure describes and illustrates a particular bus, this disclosure contemplates any
20 suitable bus or interconnect.

21 **[00146]** Herein, a computer-readable non-transitory storage medium or media may
22 include one or more semiconductor-based or other integrated circuits (ICs) (such, as for
23 example, field-programmable gate arrays (FPGAs) or application-specific ICs (ASICs)), hard
24 disk drives (HDDs), hybrid hard drives (HHDs), optical discs, optical disc drives (ODDs),
25 magneto-optical discs, magneto-optical drives, floppy diskettes, floppy disk drives (FDDs),
26 magnetic tapes, solid-state drives (SSDs), RAM-drives, SECURE DIGITAL cards or drives,
27 any other suitable computer-readable non-transitory storage media, or any suitable
28 combination of two or more of these, where appropriate. A computer-readable non-transitory
29 storage medium may be volatile, non-volatile, or a combination of volatile and non-volatile,
30 where appropriate.

31 **[00147]** Herein, “or” is inclusive and not exclusive, unless expressly indicated
32 otherwise or indicated otherwise by context. Therefore, herein, “A or B” means “A, B, or both,”
33 unless expressly indicated otherwise or indicated otherwise by context. Moreover, “and” is
34 both joint and several, unless expressly indicated otherwise or indicated otherwise by context.
35 Therefore, herein, “A and B” means “A and B, jointly or severally,” unless expressly indicated
36 otherwise or indicated otherwise by context.

37 **[00148]** The scope of this disclosure encompasses all changes, substitutions,

1 variations, alterations, and modifications to the example embodiments described or illustrated
2 herein that a person having ordinary skill in the art would comprehend within the scope of the
3 appended claims. The scope of this disclosure is not limited to the example embodiments
4 described or illustrated herein, the invention being defined in the appended claims. Moreover,
5 although this disclosure describes and illustrates respective embodiments herein as including
6 particular components, elements, feature, functions, operations, or steps, any of these
7 embodiments may include any combination or permutation of any of the components,
8 elements, features, functions, operations, or steps described or illustrated anywhere herein
9 that a person having ordinary skill in the art would comprehend. Furthermore, reference in the
10 appended claims to an apparatus or system or a component of an apparatus or system being
11 adapted to, arranged to, capable of, configured to, enabled to, operable to, or operative to
12 perform a particular function encompasses that apparatus, system, component, whether or
13 not it or that particular function is activated, turned on, or unlocked, as long as that apparatus,
14 system, or component is so adapted, arranged, capable, configured, enabled, operable, or
15 operative. Additionally, although this disclosure describes or illustrates particular
16 embodiments as providing particular advantages, particular embodiments may provide none,
17 some, or all of these advantages.

18

1 **CLAIMS:**

2 1. A device, comprising:

3 a lens;

4 a plurality of cameras positioned behind the lens, wherein a first camera
5 processes visible light, and a second camera processes infrared light;

6 a colored coating on the lens comprising a plurality of regions, each region
7 comprising a color profile for selectively transmitting light, wherein a first region is positioned
8 in front of the first camera, and a second region is positioned in front of the second camera;
9 and

10 a processor and a non-transitory memory including computer-executable
11 instructions, which when executed by the processor, cause the device to at least:

12 receive light information indicative of at least one of: visible light received at the
13 first camera or infrared light received at the second camera, wherein the received light
14 information provides environmental information for executing an operation on the device;

15 identify wavelengths reflected by the color profile positioned in front of each
16 camera;

17 determine a color calibration for the light information based on the color profile,
18 wherein the color calibration amplifies the wavelengths reflected by the color profile;

19 update the environmental information based on the color calibration; and
20 execute the operation on the device based on the updated environmental information.

21 2. The device of claim 1, and one or more of the following:

22 wherein a laser emitter is positioned behind the lens; and a third region on the colored
23 coating, the third region comprising a color profile for selectively transmitting infrared light;

24 wherein the colored coating comprises two first regions for selectively transmitting
25 visible light, and the second region for selectively transmitting infrared light is centrally
26 positioned between the two first regions;

27 wherein the first camera identifies at least one of red, green, blue, or yellow wavelength
28 values;

29 wherein each color profile comprises a transmission profile and a reflection profile;

30 wherein the operation on the device is generating an image on a display;

31 wherein the operation on the device is executing a simultaneous location and mapping
32 (SLAM) function;

33 wherein the colored coating comprises a plurality of ink layers, and each ink layer
34 reflects a range of wavelengths;

35 wherein the colored coating is applied to the lens using at least one of a pad printing
36 technique, a thermoformed technique, an injection molding technique, sputter deposition, and
37 e-beam evaporation.

1 3. The device of claim 1 or claim 2, wherein the colored coating comprises a first plurality
2 of layers on an inner face of the lens, and a second plurality of layers on an outer face of the
3 lens;

4 optionally, wherein the first plurality of layers comprises an inner ink layer, a middle
5 hard-coat (HC) layer, and an outer anti-reflective (AR) layer; optionally, wherein the inner ink
6 layer is 6-28 micrometers, the middle HC layer is 9-30 micrometers, and the outer AR layer is
7 0.35-0.4 micrometers;

8 optionally, wherein the second plurality of layers comprises an inner hard-coat (HC)
9 layer, a middle anti-reflective (AR) layer, and an outer anti-fingerprint (AF) layer; optionally,
10 wherein the inner HC layer is 9-10 micrometers, the middle AR layer is 0.35-0.4 micrometers,
11 and the outer AF layer is 0.012-0.013 micrometers.

12 4. The device of any preceding claim, and one of the following:

13 wherein the second region has less than a 20% transmission rate for wavelengths
14 below 750 nm;

15 wherein the second region has less than a 10% transmission rate for wavelengths
16 below 730 nm;

17 wherein the second region has less than a 5% transmission rate for wavelengths below
18 700 nm;

19 wherein the second region has greater than a 60% transmission rate for wavelengths
20 above 850 nm.

21 5. The device of any preceding claim, wherein each region comprises an on-axis color
22 profile, and an off-axis color profile;

23 optionally, wherein the on-axis color profile for at least one region has greater than a
24 90% transmission rate for wavelengths above 500 nm;

25 optionally, wherein the on-axis color profile for the at least one region has greater than
26 a 96% transmission rate for wavelengths between 500-700 nm;

27 optionally, wherein the off-axis color profile for at least one region has a transmission
28 rate of greater than 64% for wavelengths above 500 nm;

29 optionally, wherein the off-axis color profile for the at least one region has a
30 transmission rate of greater than 73% for wavelengths between 500-700 nm.

31 6. A computer-implemented method, comprising:

32 receiving light information at a plurality of cameras positioned behind a lens comprising
33 a colored coating, wherein the colored coating comprises a plurality of regions each having a
34 color profile, and wherein the light information is indicative of at least one of visible light or
35 infrared light, and the light information provides environmental information for executing an
36 operation on a computing device;

37 identifying wavelengths reflected by the color profile of a first region positioned

1 in front of a first camera, and a second region positioned in front of a second camera;
2 determining a color calibration for the light information received at each
3 camera, based on the color profile, wherein the color calibration amplifies wavelengths
4 reflected by the color profile;

5 updating the environmental information based on the color calibration; and
6 executing the operation on the computing device based on the updated
7 environmental information.

8 7. The computer-implemented method of claim 6, further comprising one or more of the
9 following:

10 transmitting light through a third region on the colored coating using a laser emitter,
11 the third region comprising a color profile for selectively transmitting infrared light;

12 receiving visible light transmitted through two first regions configured to selectively
13 transmit visible light, and receiving infrared light through the second region configured to
14 selectively transmit infrared light, wherein the second region is centrally positioned between
15 the two first regions.

16 8. The computer-implemented method of claim 6 or claim 7, and one or more of the
17 following:

18 wherein the operation on the computing device comprises generating an image on a display;
19 wherein the operation on the computing device comprises executing a simultaneous location
20 and mapping (SLAM) function.

21 9. The computer-implemented method of any one of claims 6 to 8, and one of the
22 following:

23 wherein the second region has less than a 20% transmission rate for wavelengths
24 below 750 nm;

25 wherein the second region transmits less than 10% of wavelengths below 730 nm;

26 wherein the second region transmits greater than 60% of wavelengths above 850 nm.

27 10. The computer-implemented method of any one of claims 6 to 9, wherein each region
28 comprises an on-axis color profile, and an off-axis color profile;

29 optionally, wherein the on-axis color profile for at least one region transmits greater
30 than 90% of wavelengths above 500 nm;

31 optionally, wherein the off-axis color profile for at least one region transmits greater
32 than 64% of wavelengths above 500 nm.

33 11. A system, comprising:

34 a lens;

35 a camera positioned behind the lens;

36 a colored coating on the lens, wherein the colored coating comprises at least
37 one region comprising a reflection color profile and a transmission color profile; and

1 a camera module, associated with a device, comprising at least one processor
2 and a non-transitory memory including computer-executable instructions, which when
3 executed by the processor, cause the device to at least:

4 receive images from the camera, the images indicative of a view through the
5 lens;

6 determine a color calibration based on the colored coating on the lens, wherein
7 the color calibration amplifies the reflection color profile; and

8 update the received images based on the color calibration.

9 12. The system of claim 11, and one or more of the following:

10 wherein the coating comprises at least one of a printed ink or a film;

11 wherein the printed ink is infrared transparent ink;

12 wherein the camera positioned behind the lens comprises an infrared camera and a
13 visible spectrum camera.

14 wherein the lens is a curved lens;

15 wherein the device is a wearable headset;

16 wherein each region is positioned in front of the camera;

17 wherein the camera module further comprises instructions to at least:

18 based on the color calibration, apply a third color profile from a light source, wherein the third
19 color profile tunes the received images to compensate for the colored coating; and

20 dynamically adjust the color calibration when the received images indicate a change in the
21 view through the lens.

22 13. The system of claim 11 or claim 12, wherein the transmission color profile and the
23 reflection color profile each comprises a plurality of wavelengths;

24 optionally, wherein each of the plurality of wavelengths comprises a set of red, green,
25 blue or yellow color values.

26 14. The system of any one of claims 11 to 13, further comprising one or more of the
27 following:

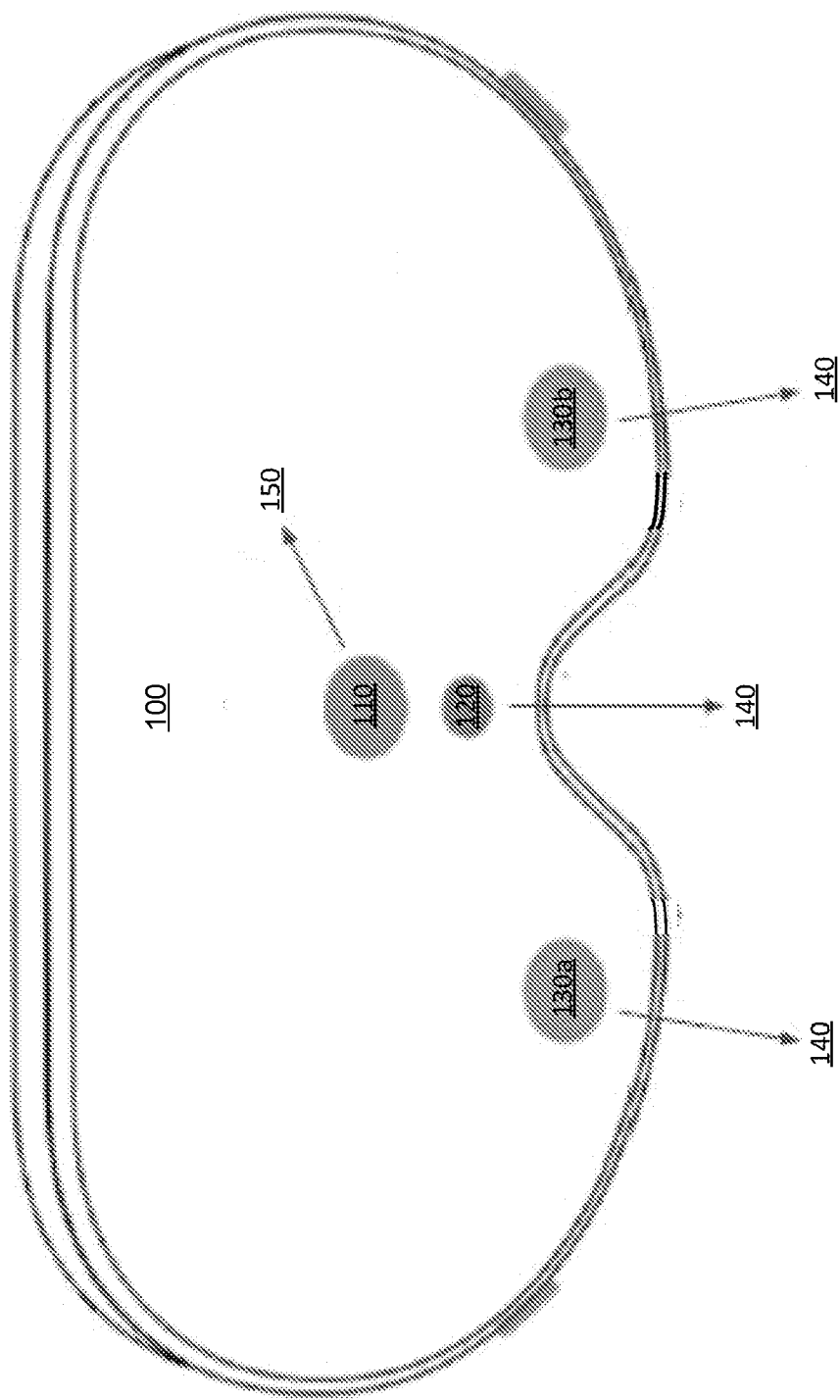
28 means for adjusting a white balance of the received images;

29 three cameras positioned behind the lens, and three regions positioned in front of each
30 camera.

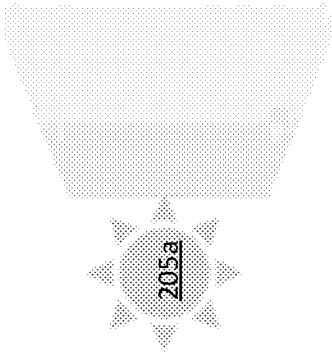
31 15. The system of any one of claims 11 to 14, wherein the colored coating on the lens
32 includes at least two regions with different transmission color profiles and reflection color
33 profiles;

34 optionally, wherein the transmission color profiles and the reflection color profiles each
35 comprise on-axis color values and off-axis color values.

FIGURE 1



2100



2200

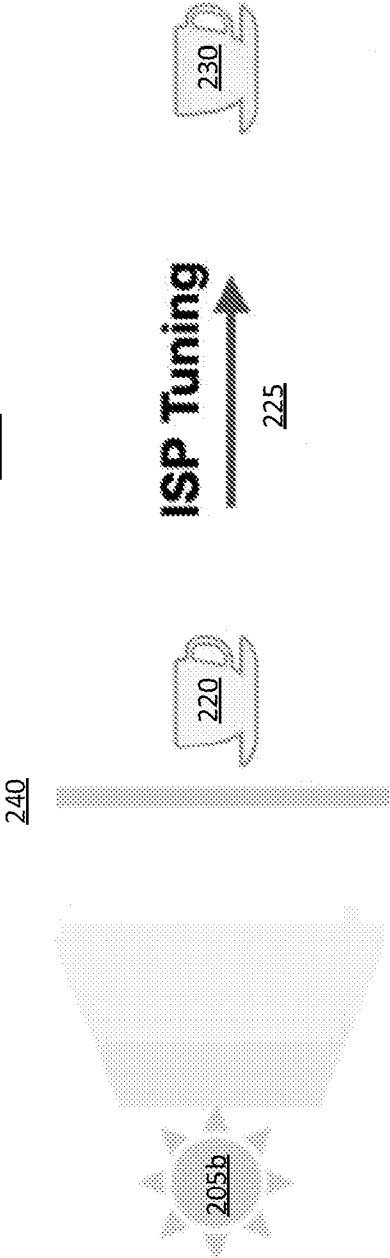
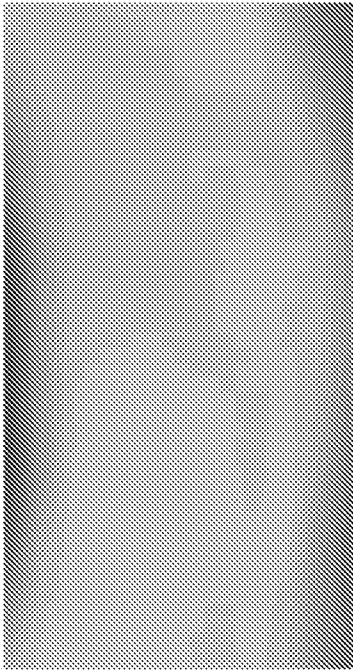


FIGURE 2A

255



250



FIGURE 2B

4/19

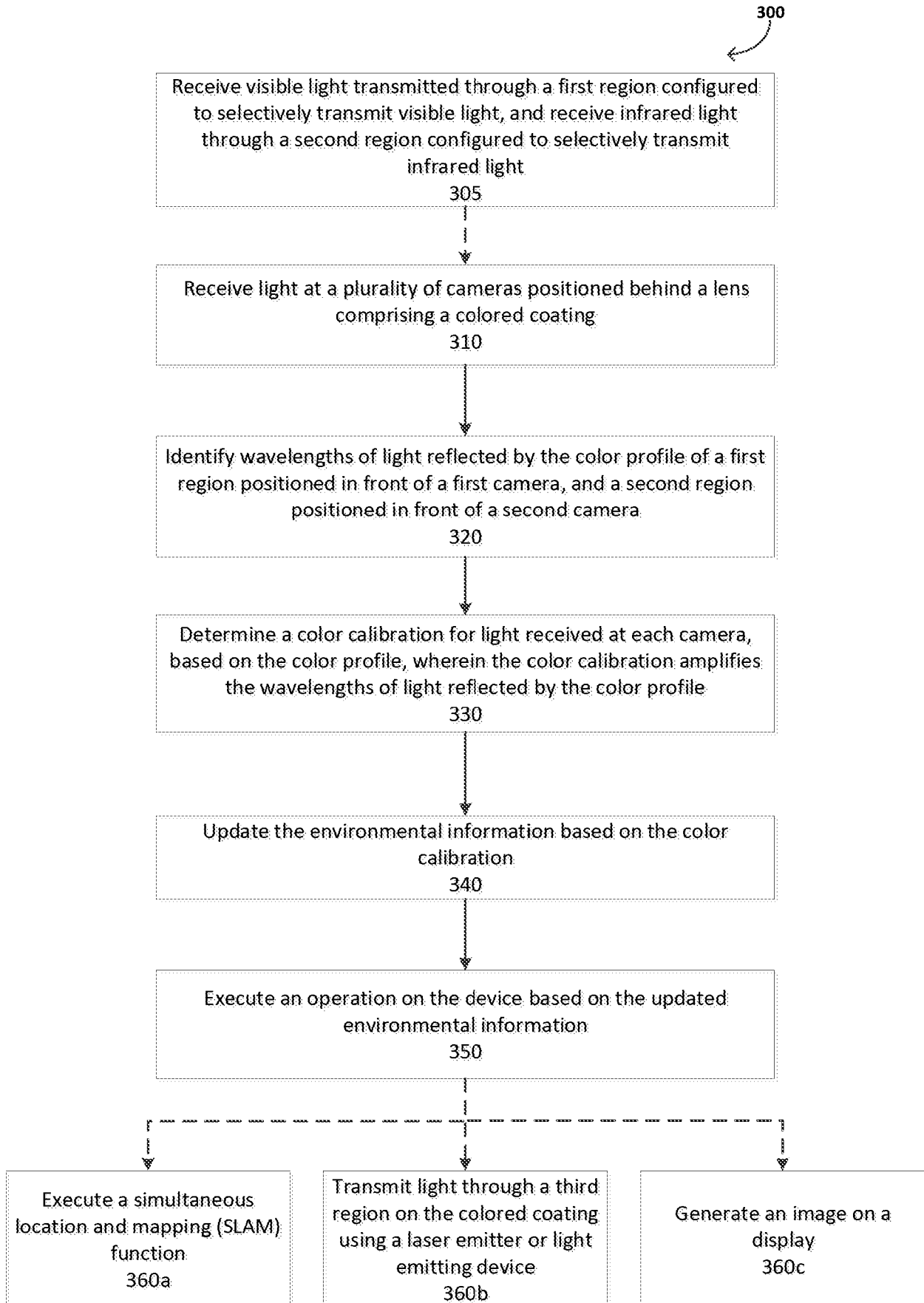
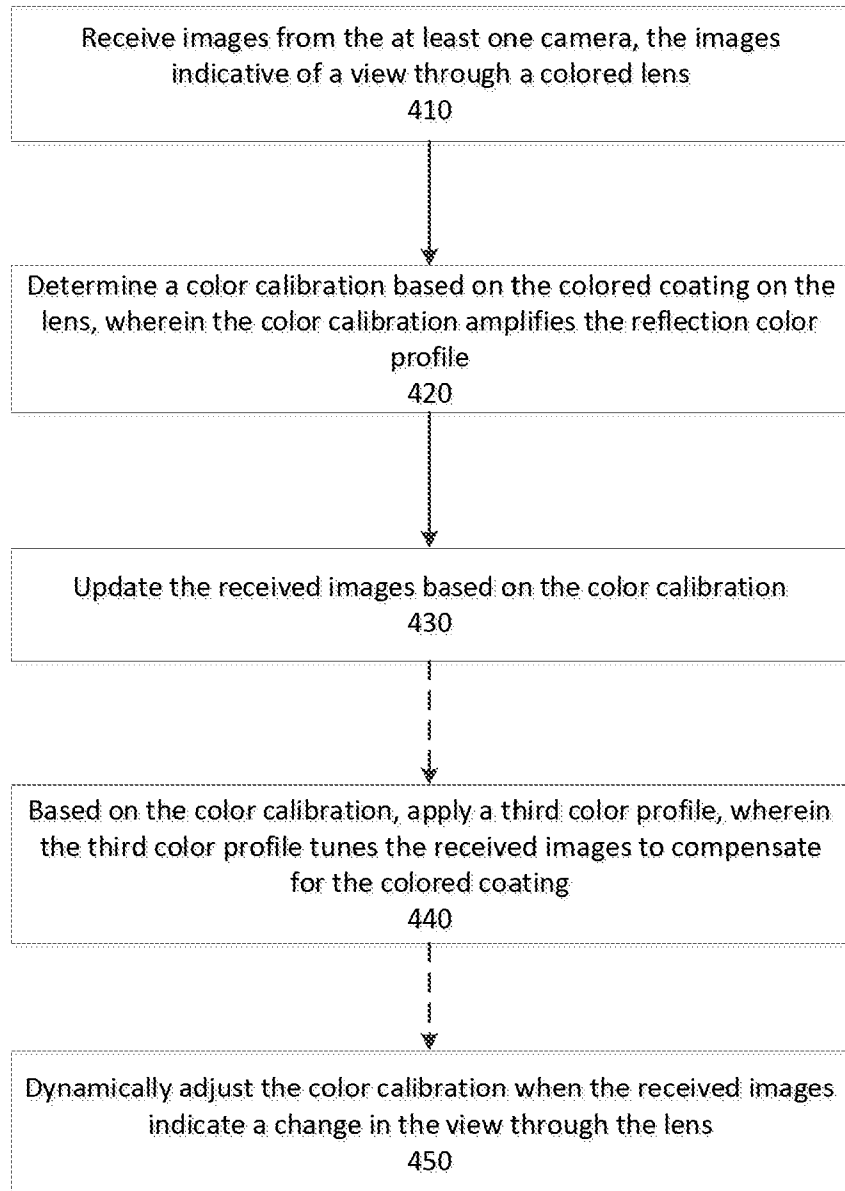


FIGURE 3

5/19

400

**FIGURE 4**

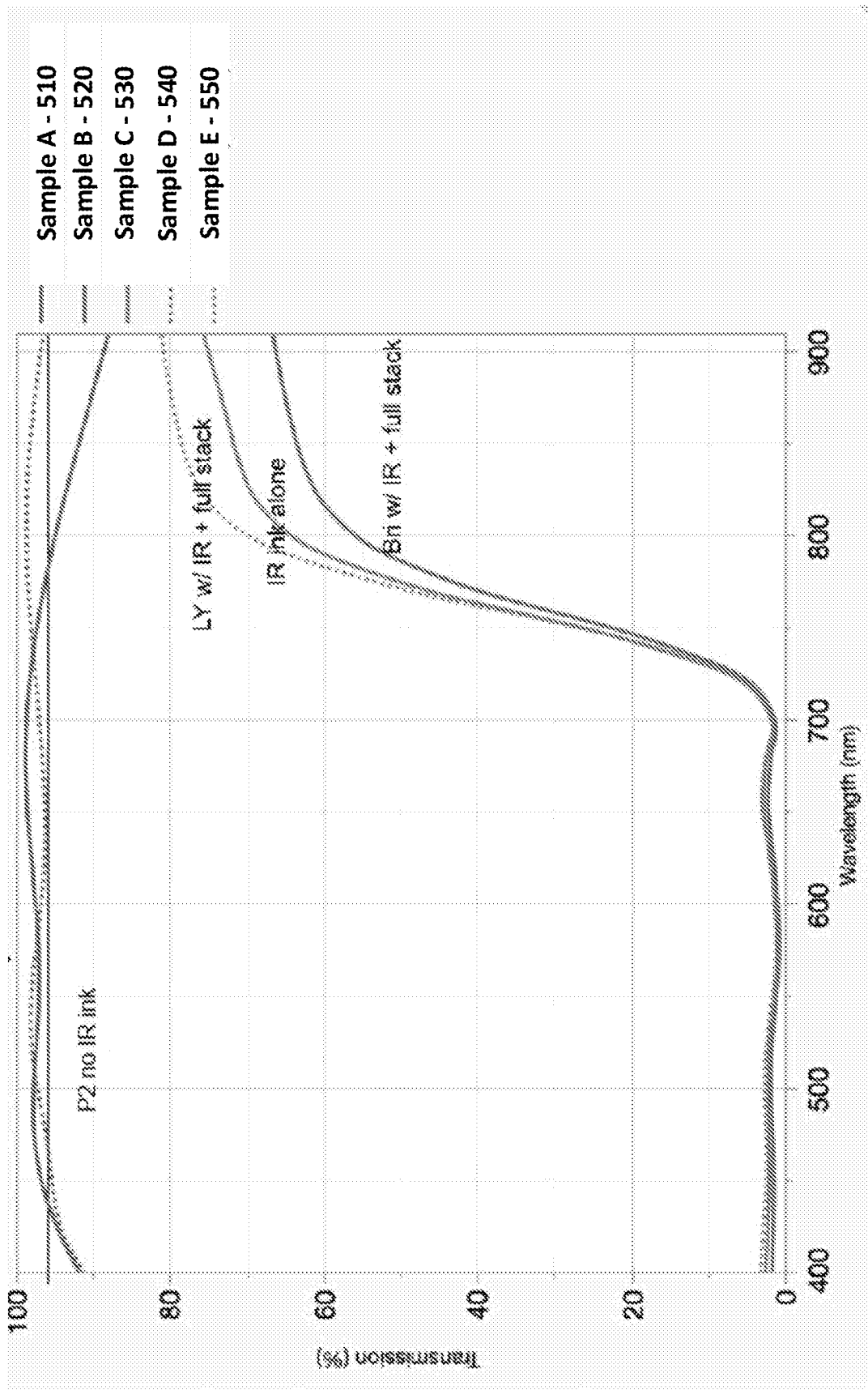


FIGURE 5A

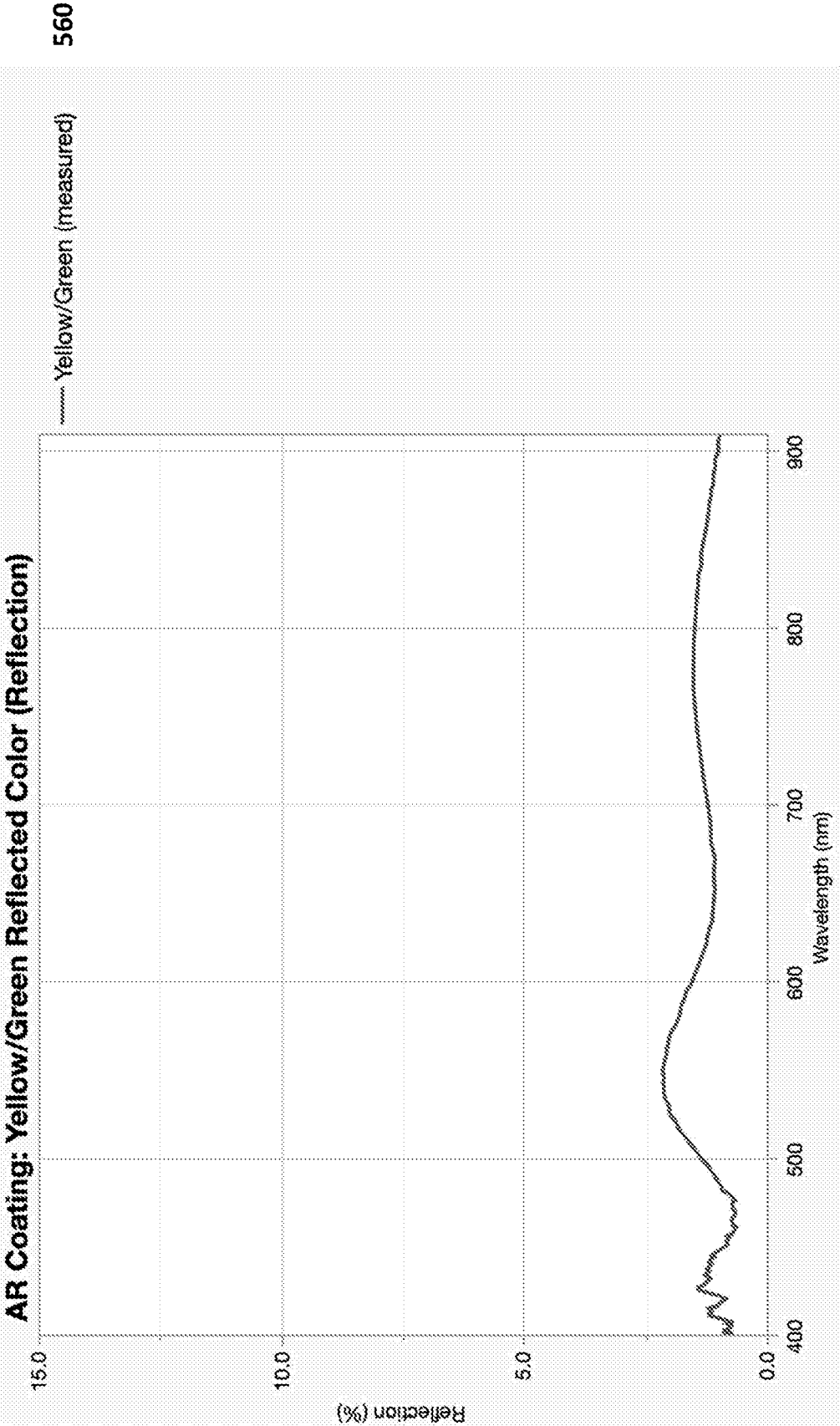


FIGURE 5B

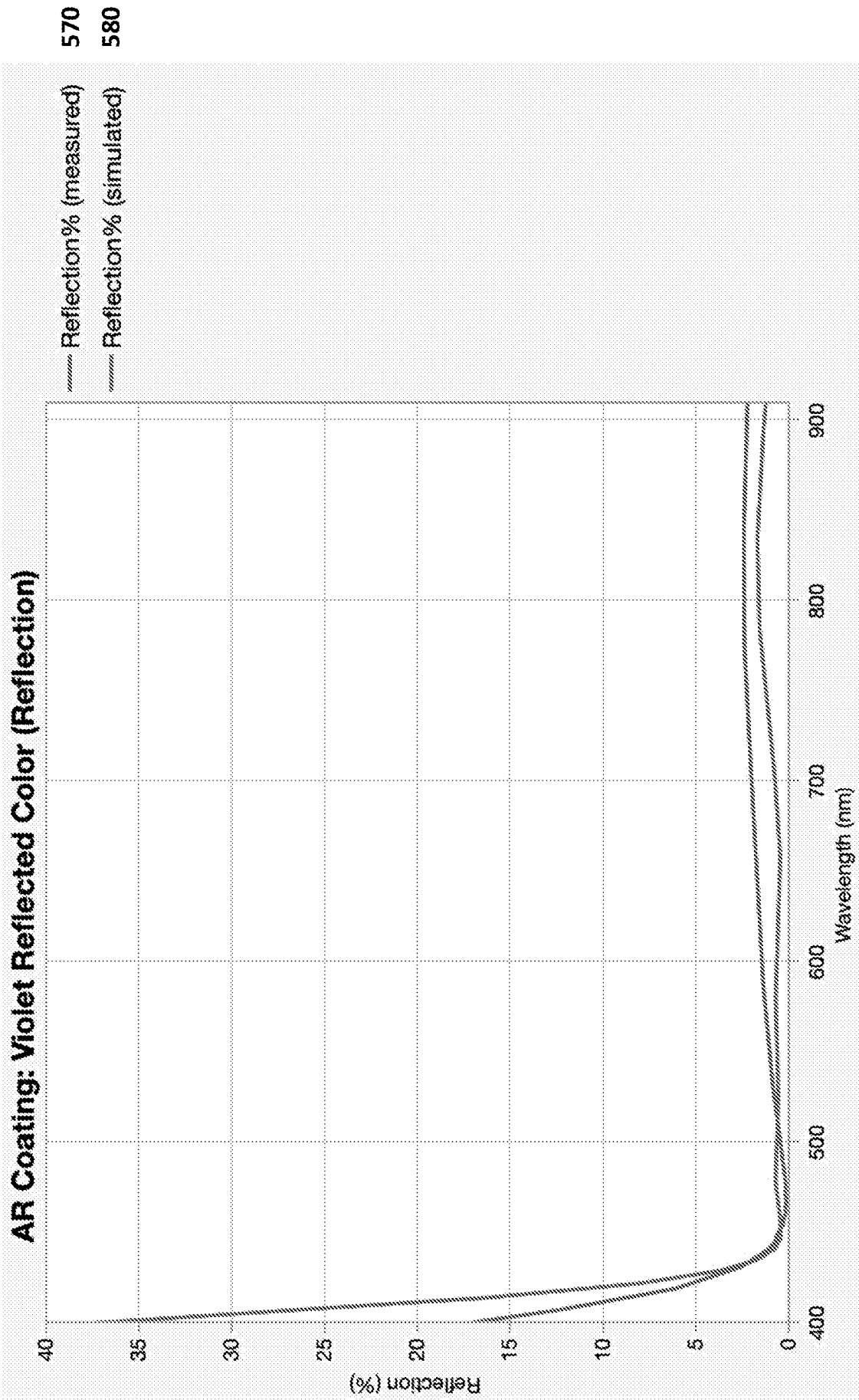


FIGURE 5C

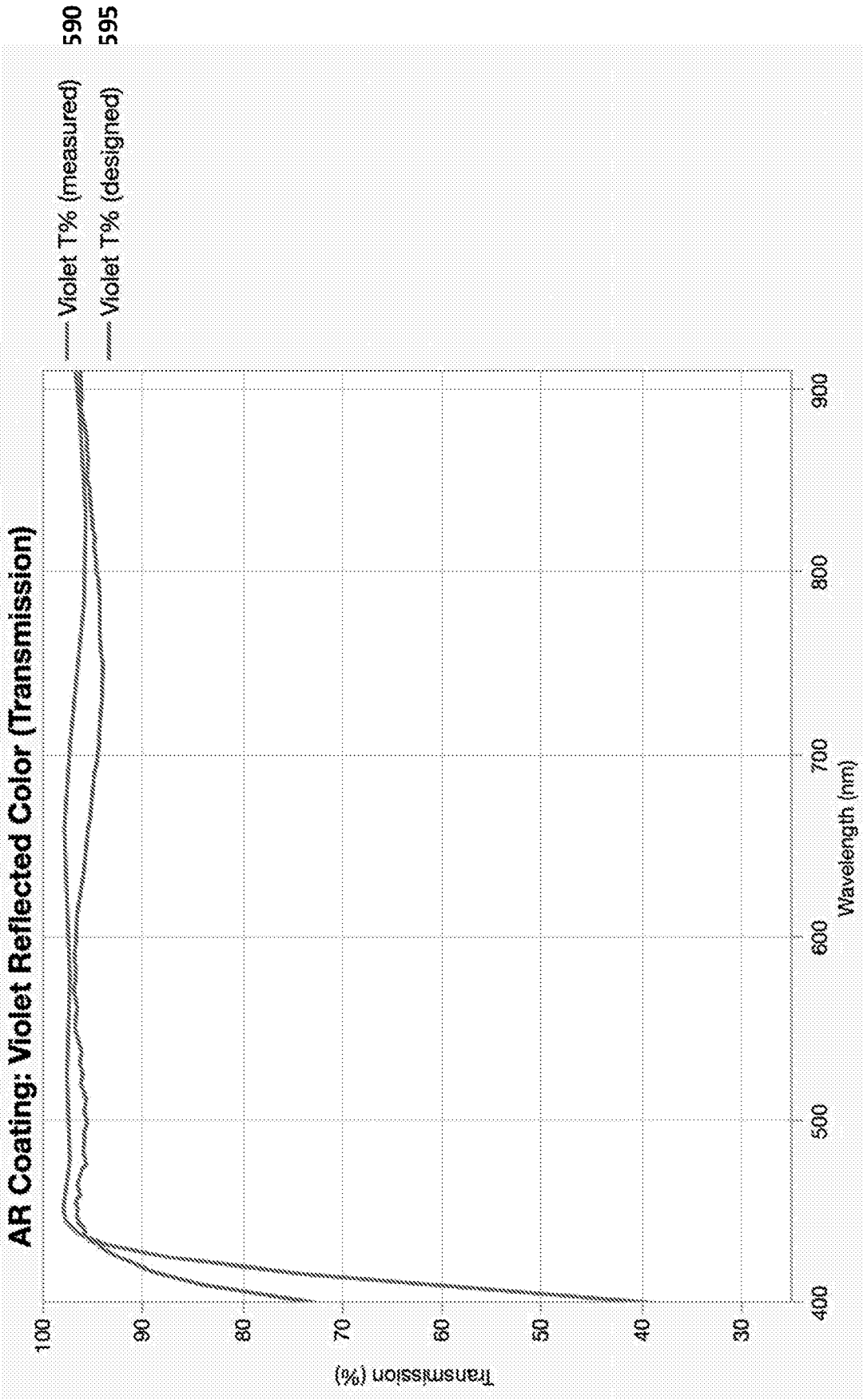


FIGURE 5D

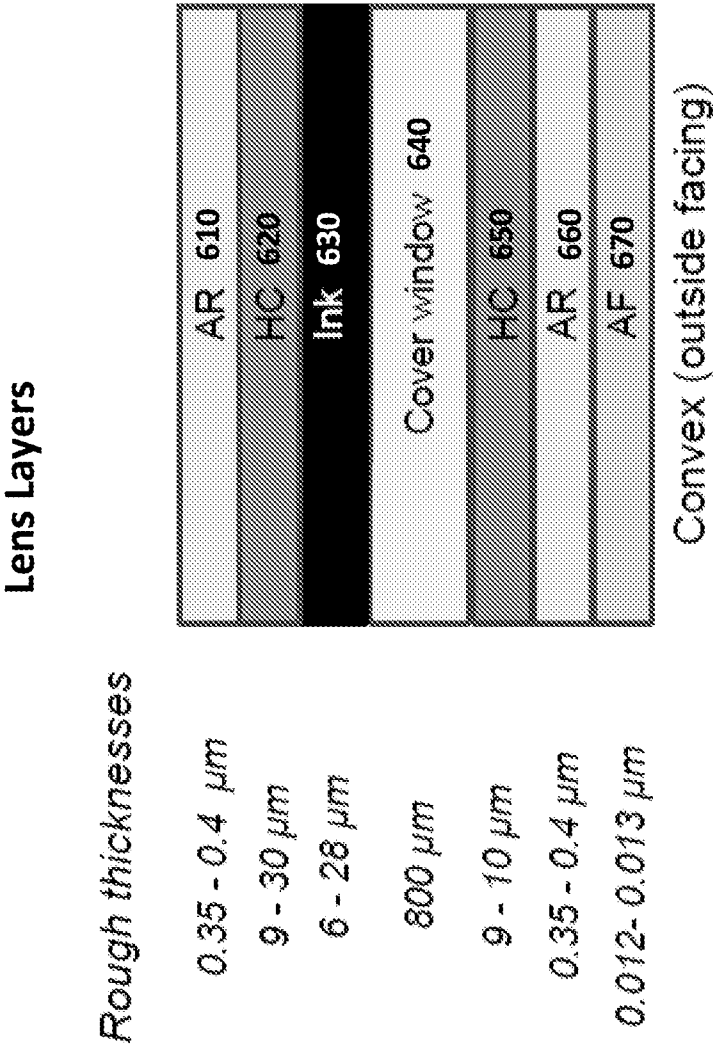


FIGURE 6

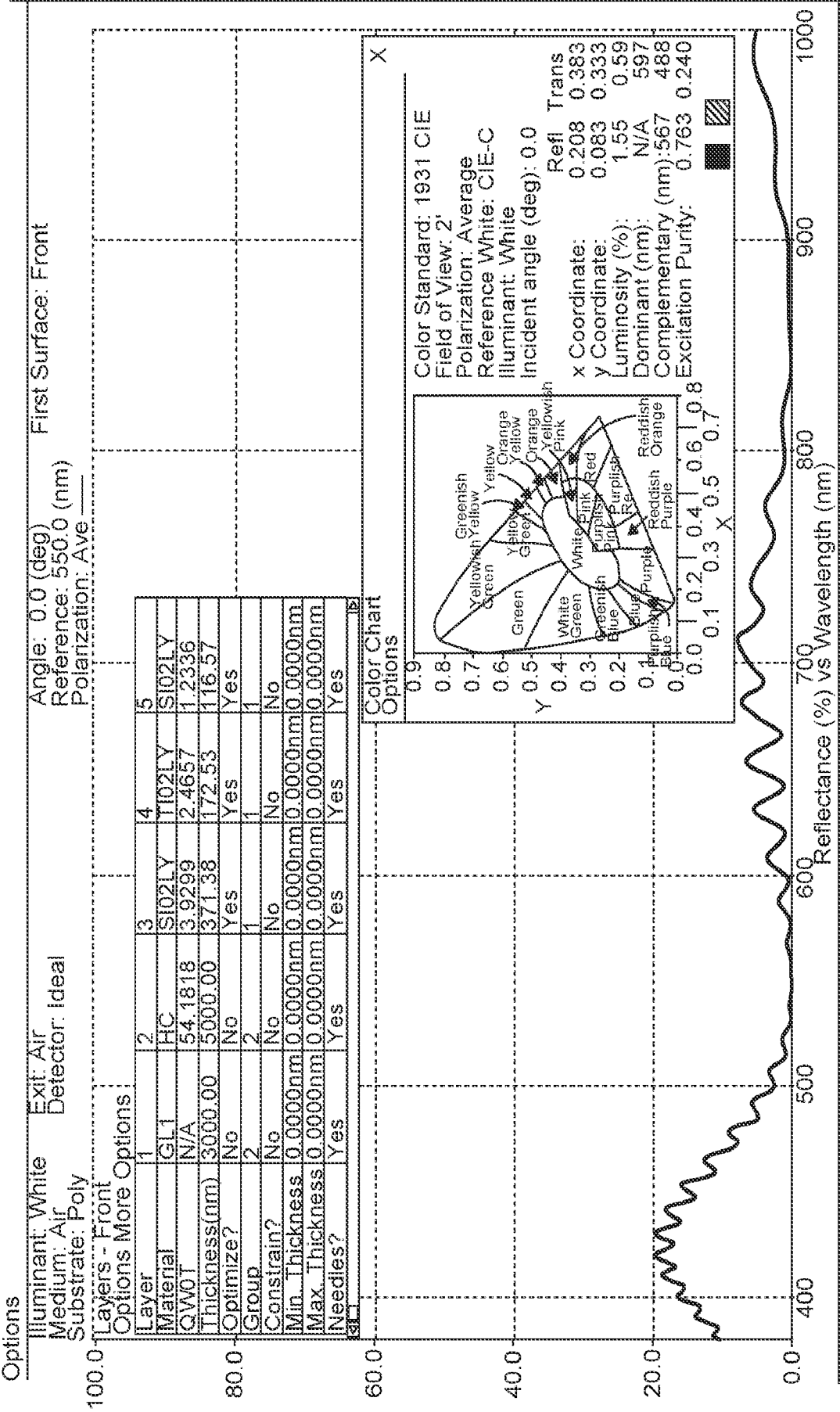


FIG. 7

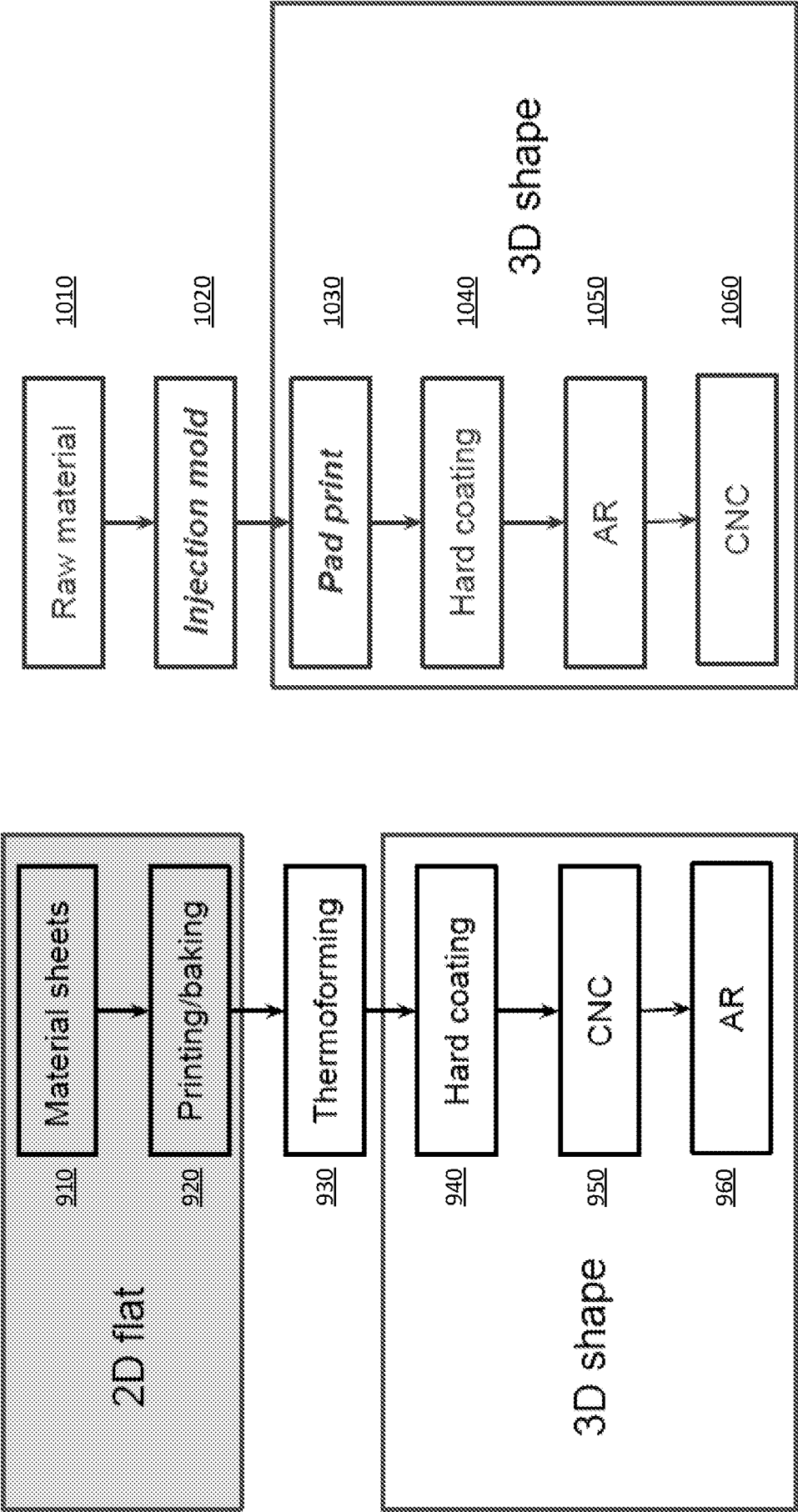


FIGURE 10

FIGURE 9

Sputter Deposition

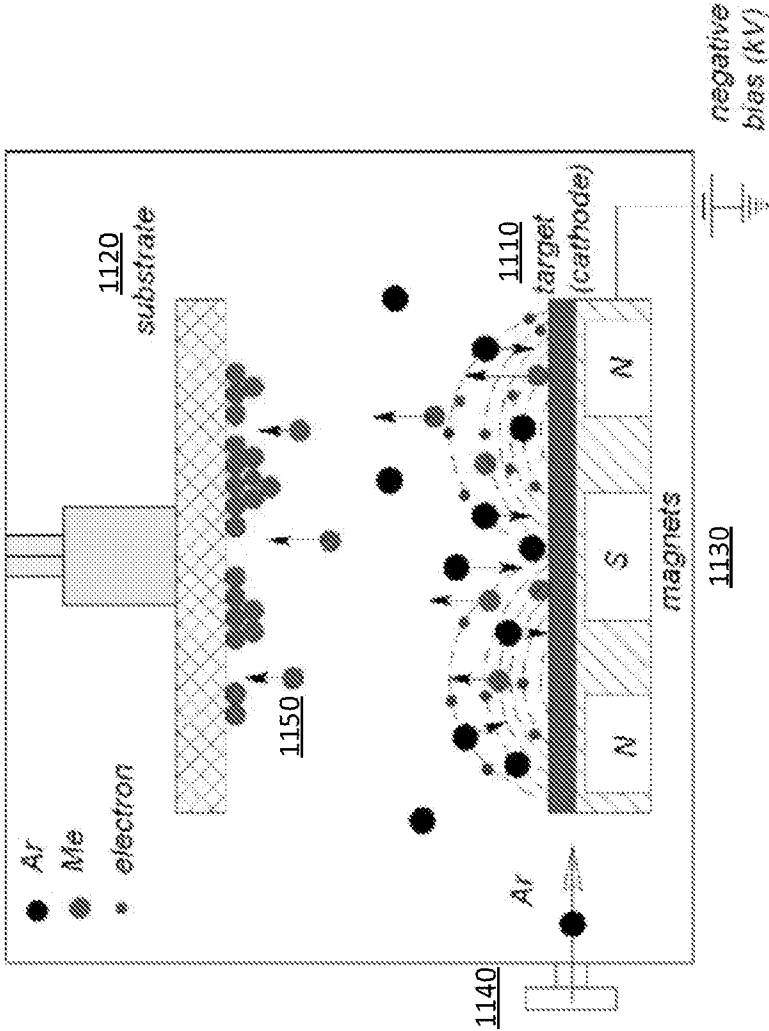


FIGURE 11

E-Beam Evaporation

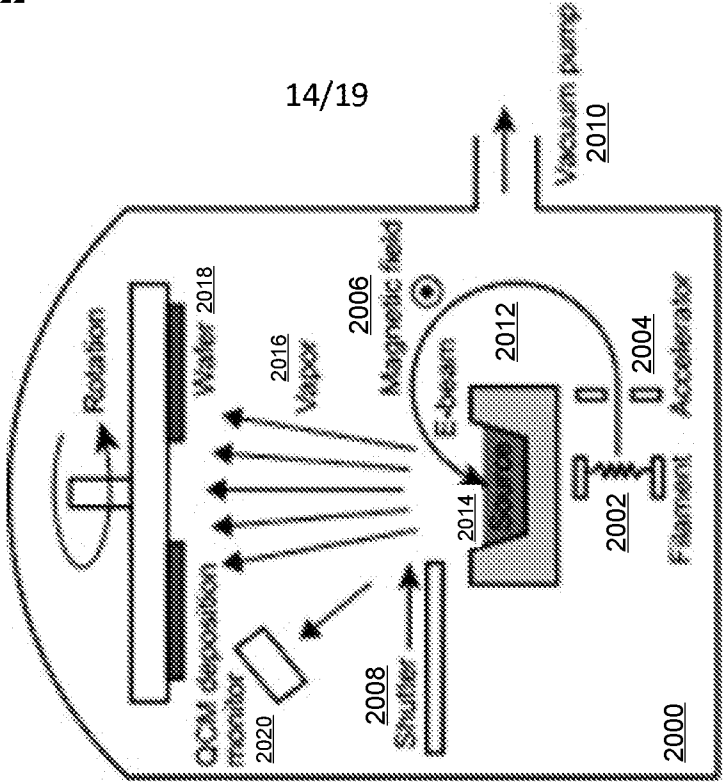


FIGURE 12

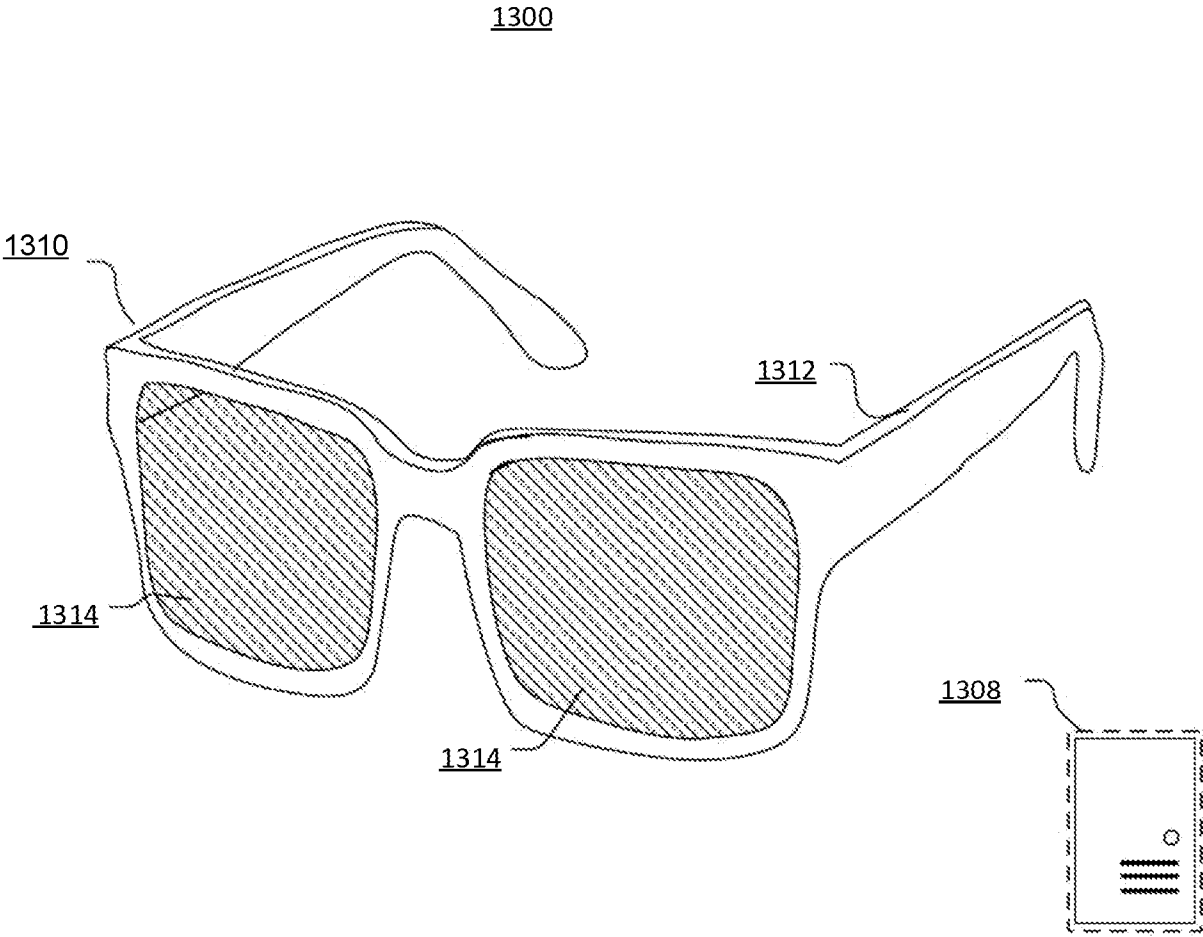


FIGURE 13

16/19

1400

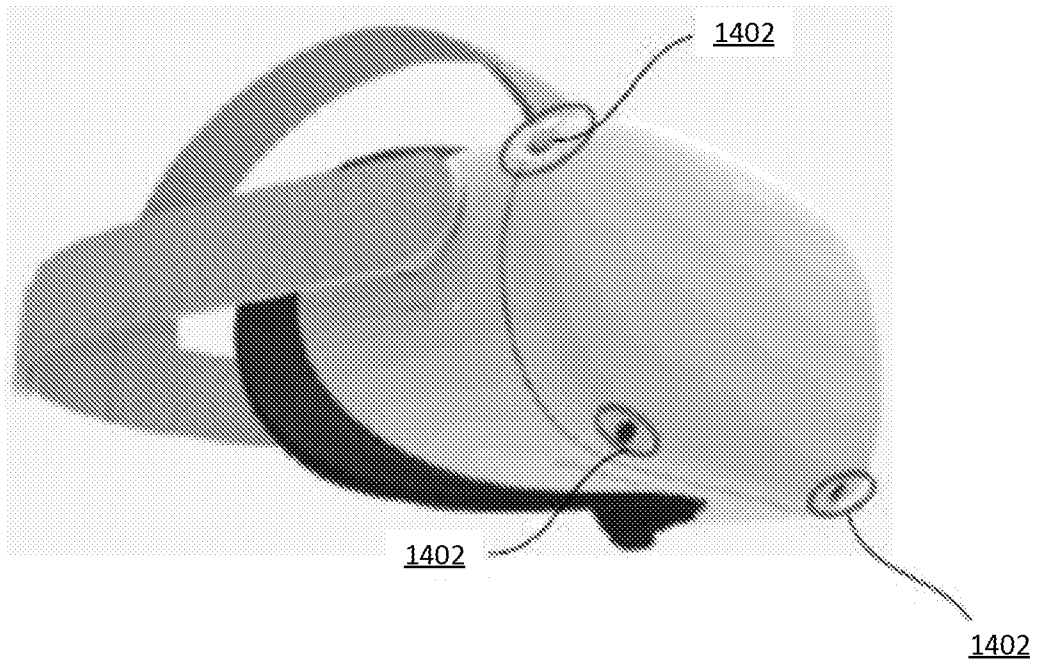


FIGURE 14

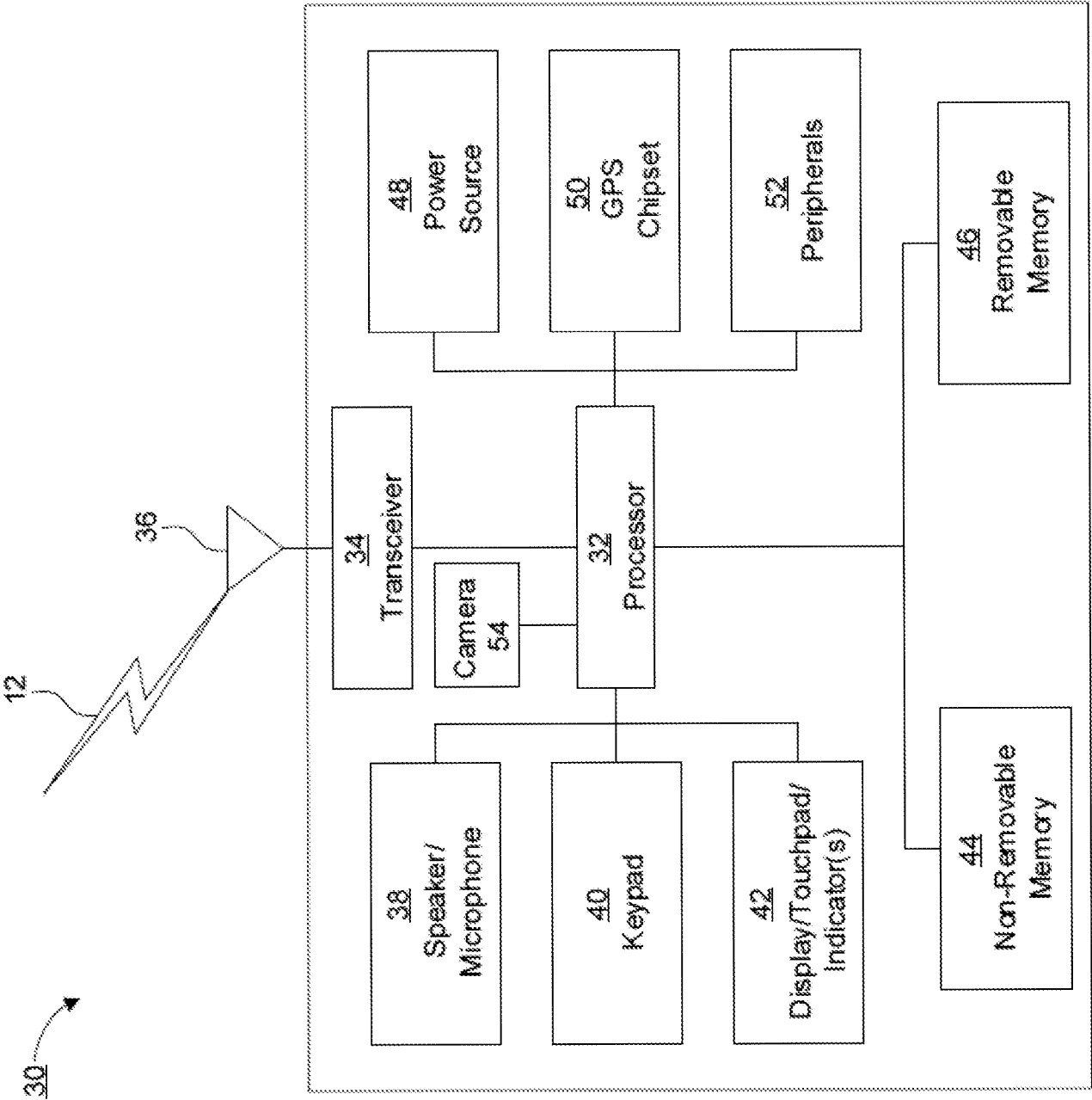


FIGURE 15

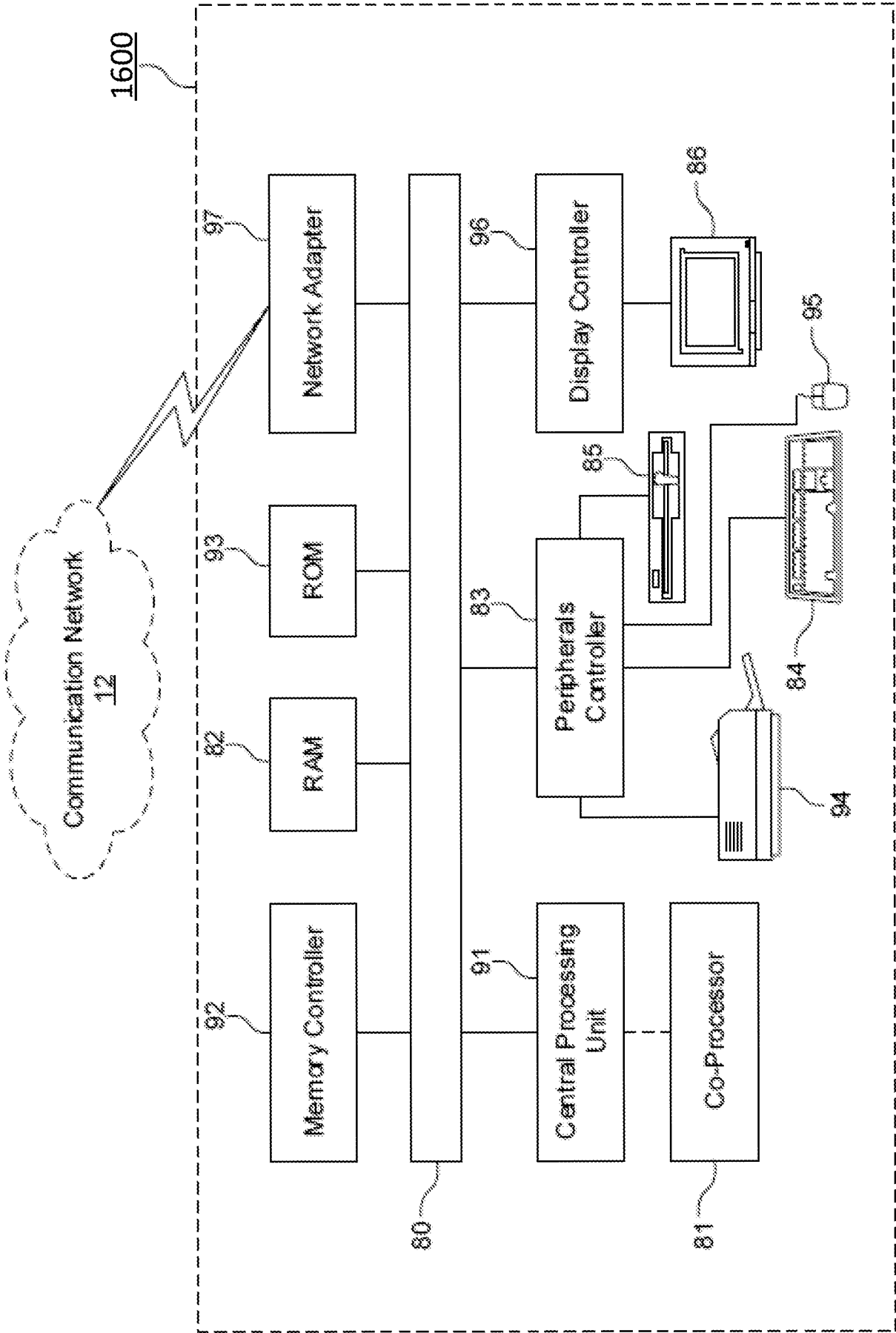


FIGURE 16

19/19

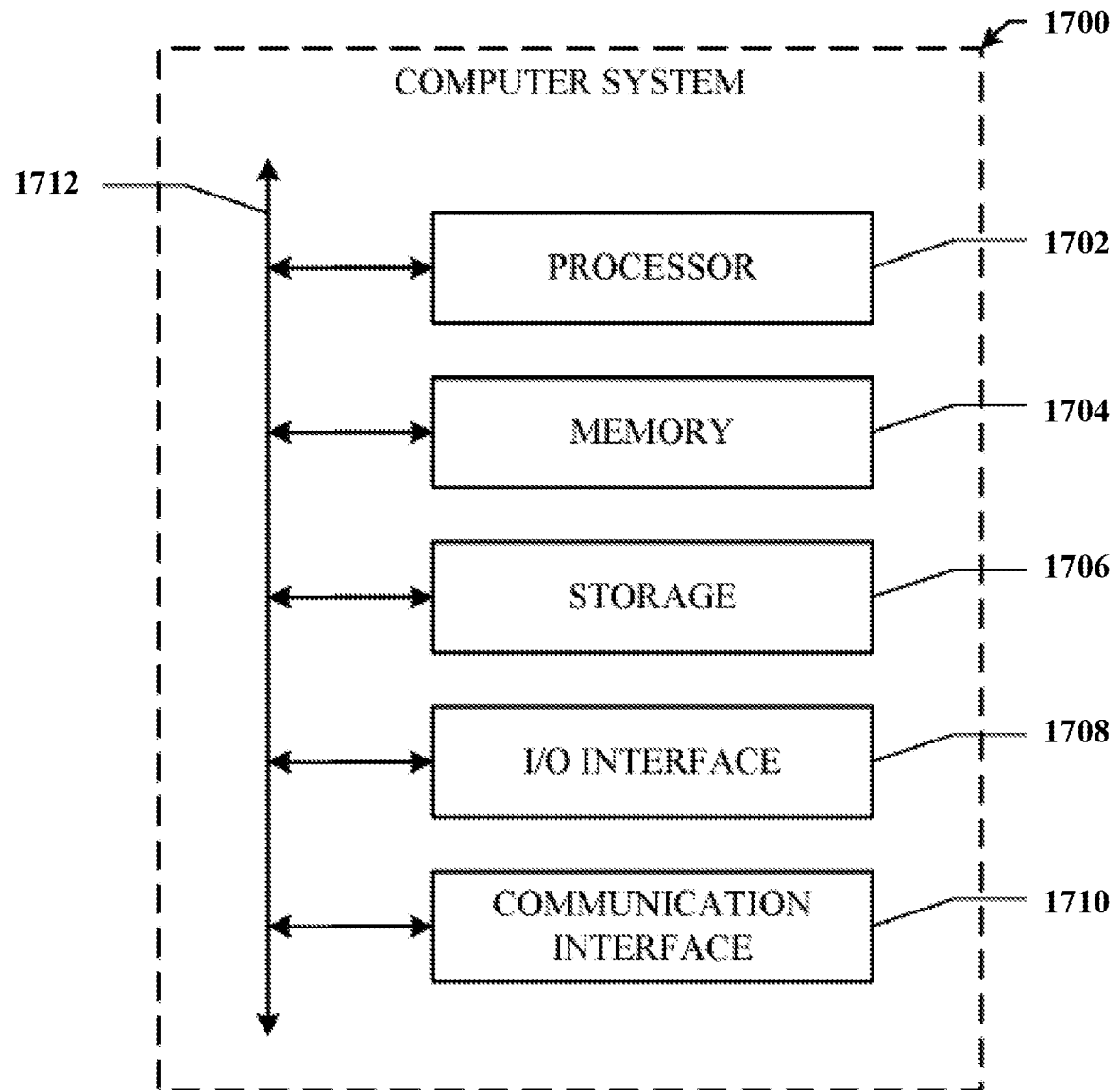


FIGURE 17

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2023/012354

A. CLASSIFICATION OF SUBJECT MATTER

INV. G02B27/01 G02B5/22

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)

G02B

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, INSPEC, WPI Data**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2021/215940 A1 (FREESE PETER [US] ET AL) 15 July 2021 (2021-07-15) paragraph [0021] - paragraph [0038]; figures 1, 2A -----	1-15
A	US 2018/239171 A1 (WOLD CHAD R [US] ET AL) 23 August 2018 (2018-08-23) abstract paragraph [0074] -----	1, 6, 11
A	US 2021/358187 A1 (KUANG JIANGTAO [US] ET AL) 18 November 2021 (2021-11-18) paragraph [0051] -----	1, 6, 11



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

12 May 2023

Date of mailing of the international search report

24/05/2023

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

Lehtiniemi, Henry

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2023/012354

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2021215940 A1	15-07-2021	NONE	
US 2018239171 A1	23-08-2018	CN 108139613 A	08-06-2018
		EP 3356882 A1	08-08-2018
		JP 6883570 B2	09-06-2021
		JP 2018530783 A	18-10-2018
		KR 20180059866 A	05-06-2018
		TW 201727280 A	01-08-2017
		US 2018239171 A1	23-08-2018
		WO 2017058562 A1	06-04-2017
US 2021358187 A1	18-11-2021	CN 115552317 A	30-12-2022
		EP 4150396 A1	22-03-2023
		US 11069104 B1	20-07-2021
		US 2021358187 A1	18-11-2021
		WO 2021231032 A1	18-11-2021