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(71) Applicant: **HEWLETT-PACKARD DEVELOPMENT COMPANY, L.P.** [US/US]; 10300 Energy Drive, Spring, Texas 77389 (US).

(72) Inventors: **WU, Kuan-Ting**; 10F, No. 66, Jing Mao 2 Rd., NanGang District, Taipei, 11568 (TW). **CHANG, Chi Hao**; 10F, No. 66, Jing Mao 2 Rd., NanGang District, Taipei, 11568 (TW). **LIN, Chien-Ting**; 10F, No. 66, Jing Mao 2 Rd., NanGang District, Taipei, 11568 (TW).

(74) Agent: **COSTALES, Shruti et al.**; HP Inc., Intellectual Property, 3390 E. Harmony Road, Mail Stop 35, Fort Collins, Colorado 80528 (US).

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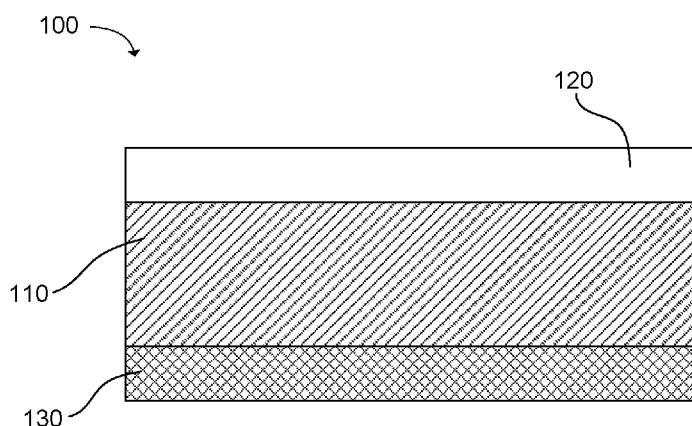


FIG. 1

(57) Abstract: The present disclosure is drawn to covers for electronic devices. In one example, a cover for an electronic device can include a light metal substrate and a dried sol-gel oxide coating on a first surface of the light metal substrate. The light metal substrate can have a density from about 0.5 g/cm³ to about 7.5 g/cm³. The light metal substrate can also include a micro-arc oxidation layer across a second surface of the light metal substrate. The first surface of the light metal substrate may not include a micro-arc oxidation layer.



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COVERS FOR ELECTRONIC DEVICES**BACKGROUND**

[0001] The use of personal electronic devices of all types continues to
10 increase. Cellular phones, including smartphones, have become nearly
ubiquitous. Tablet computers have also become widely used in recent years.
Portable laptop computers continue to be used by many for personal,
entertainment, and business purposes. For portable electronic devices in
particular, much effort has been expended to make these devices more useful
15 and more powerful while at the same time making the devices smaller, lighter,
and more durable. The aesthetic design of personal electronic devices is also of
concern in this competitive market.

BRIEF DESCRIPTION OF THE DRAWING

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[0002] FIG. 1 is a cross-sectional view illustrating an example cover for an
electronic device in accordance with examples of the present disclosure;

[0003] FIG. 2 is a cross-sectional view illustrating another example cover
for an electronic device in accordance with examples of the present disclosure;

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[0004] FIG. 3 is a cross-sectional view illustrating yet another example
cover for an electronic device in accordance with examples of the present
disclosure;

[0005] FIG. 4 is a cross-sectional view illustrating another example cover
for an electronic device in accordance with examples of the present disclosure;

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[0006] FIG. 5 is an exploded view of an example electronic device in
accordance with examples of the present disclosure; and

[0007] FIG. 6 is a flowchart illustrating an example method of making a cover for an electronic device in accordance with examples of the present disclosure.

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DETAILED DESCRIPTION

[0008] The present disclosure describes covers for electronic devices. In one example, a cover for an electronic device can include a light metal substrate having a density from about 0.5 g/cm³ to about 7.5 g/cm³. A dried sol-gel oxide coating can be on a first surface of the light metal substrate. The light metal substrate can also include a micro-arc oxidation layer across a second surface of the light metal substrate. The first surface of the light metal substrate may not include a micro-arc oxidation layer. In further examples, the light metal substrate can include aluminum, magnesium, titanium, lithium, niobium, zinc, or an alloy thereof. In still further examples, the dried sol-gel oxide coating can include aluminum oxide, silicon oxide, titanium oxide, zirconium oxide, or a combination thereof. In some examples, the dried sol-gel oxide coating can be transparent and the first surface of the light metal substrate can have a metallic luster visible through the dried sol-gel oxide coating. In other examples, the dried sol-gel oxide coating can include a pigment dispersed therein. In further examples, the cover can include a protective coating layer on the dried sol-gel oxide coating, where the protective coating layer includes a polymer resin. In certain examples, the polymer resin can include polyester, poly(meth)acrylic, polyurethane, epoxy, urethane (meth)acrylic, (meth)acrylic (meth)acrylate, epoxy (meth)acrylate, or a combination thereof. In additional examples, the protective coating layer can also include a pigment in an amount from about 0.5 wt% to about 30 wt% with respect to dry components of the protective coating layer. In some examples, the pigment can include carbon black, titanium dioxide, clay, mica, talc, barium sulfate, calcium carbonate, synthetic pigment, metallic powder, aluminum oxide, graphene, pearl pigment, or a combination thereof. In further examples, the cover can include a metal-containing physical vapor deposition layer on the dried sol-gel oxide coating.

[0009] The present disclosure also describes electronic devices. In some examples, an electronic device can include a cover. The cover can include a light metal substrate having a density from about 0.5 g/cm³ to about 7.5 g/cm³, and a dried sol-gel coating on an exterior surface of the light metal substrate, and an
5 electronic component adjacent to an interior surface of the light metal substrate. The light metal substrate can include a micro-arc oxidation layer across the interior surface of the light metal substrate. The exterior surface of the light metal substrate may not include a micro-arc oxidation layer. In another example, the electronic device can also include either a protective coating layer or a physical
10 vapor deposition layer on the dried sol-gel oxide coating. In a further example, a second protective coating layer can be applied in the form of a clear coat to the protective coating layer or the physical vapor deposition layer.

[0010] The present disclosure also describes methods of making covers for electronic devices. In some examples, a method of making a cover for an
15 electronic device can include applying a sol-gel oxide coating on a first surface of a light metal substrate having a density from about 0.5 g/cm³ to about 7.5 g/cm³. The light metal substrate can also be treated with micro-arc oxidation to form a micro-arc oxidation layer across a second surface of the light metal substrate. A micro-arc oxidation layer may not be formed on the first surface. In certain
20 examples, the sol-gel oxide coating can be applied and dried on the first surface of the light metal substrate before treating the second surface of the light metal substrate with micro-arc oxidation to form the micro-arc oxidation layer.

Covers for Electronic Devices

25 [0011] Light metal materials can be used to make covers for electronic devices. These materials can have useful properties, such as low weight, high strength, and an appealing appearance. However, some of these metals can be easily oxidized at the surface, and may be vulnerable to corrosion or other chemical reactions at the surface. For example, magnesium or magnesium alloys
30 can be used to form covers for electronic devices. Magnesium can have a somewhat porous surface that can be vulnerable to chemical reactions and corrosion at the surface. In some examples, magnesium or magnesium alloy can

be treated by micro-arc oxidation to form a layer of protective oxide at the surface. This protective oxide layer can increase the chemical resistance, hardness, and durability of the magnesium or magnesium alloy. However, micro-arc oxidation can also create a dull appearance instead of the original luster of the metal.

5 [0012] In order to preserve the original luster of the light metal substrate, in some examples of the present disclosure the light metal substrate can be coated with a sol-gel oxide coating on a surface of the light metal substrate. In many cases, the surface that is coated with the sol-gel oxide coating can be the exterior surface when the cover is assembled with other components to make an
10 electronic device. The sol-gel oxide coating can be dried to make a hard, transparent protective coating over the light metal substrate. The light metal substrate can then be treated by micro-arc oxidation. The dried sol-gel oxide coating can prevent the exterior surface of the light metal substrate from being oxidized during the micro-arc oxidation process. Thus, the interior surface can be
15 oxidized by the micro-arc oxidation treatment to form a layer of protective oxide, while the exterior surface of the light metal substrate retains its metallic luster due to the dried sol-gel oxide coating on the exterior surface. Accordingly, in some examples, the cover can provide an attractive metallic appearance on the exterior surface. Additionally, in other examples the dried sol-gel coating can include
20 pigments to vary the appearance of the cover, or the dried sol-gel oxide coating can be a base layer on which additional layers are applied to further vary the appearance of the cover. These examples are explained in more detail below.

[0013] As used herein, “cover” refers to the exterior shell of an electronic device. In other words, the cover contains the internal electronic components of
25 the electronic device. The cover is an integral part of the electronic device. The term “cover” is not meant to refer to the type of removable protective cases that are often purchased separately from an electronic device (especially smartphones and tablets) and placed around the exterior of the electronic device. Covers formed of light metal materials can be used on a variety of electronic
30 devices. For example, laptop computers, smartphones, tablet computers, and other electronic devices can include light metal covers. In various examples, these covers can be formed by molding, casting, machining, bending, working, or

another process. In one example, a cover can be milled from a single block of metal. In other examples, the cover can be made from multiple panels. For example, laptop covers sometimes include four separate cover pieces forming the complete cover of the laptop. The four separate pieces of the laptop cover are often designated as cover A (back cover of the monitor portion of the laptop), cover B (front cover of the monitor portion), cover C (top cover of the keyboard portion) and cover D (bottom cover of the keyboard portion). Covers can also be made for smartphones and tablet computers with a single metal piece or multiple metal panels.

[0014] With the above description in mind, FIG. 1 shows a cross-sectional view of an example cover 100 for an electronic device in accordance with an example of the present disclosure. The cover includes a light metal substrate 110 with a dried sol-gel oxide coating 120 on a first surface of the light metal substrate. The light metal substrate also has a micro-arc oxidation layer 130 across a second surface of the light metal substrate. The first surface does not include such a micro-arc oxidation layer. In some examples, the dried sol-gel oxide coating can be transparent to allow the metallic luster of the light metal substrate to be visible. In other examples, the dried sol-gel oxide coating can be semi-transparent or opaque, and pigment can be added to the sol-gel to give the coating a particular color. In further examples, the dried sol-gel oxide coating can be a base layer onto which additional layers are applied.

[0015] FIG. 2 shows a cross-sectional view of another example cover 200 for an electronic device in accordance with an example of the present disclosure. This example includes a light metal substrate 210 with a dried sol-gel oxide coating 220 on one surface, and a micro-arc oxidation layer 230 on the opposite surface. A protective coating layer 240 is also applied on the dried sol-gel oxide coating. The protective coating layer can include a polymer resin and in some cases can also include a pigment to provide color to the protective coating layer.

[0016] FIG. 3 shows a cross-sectional view of yet another example cover 300 for an electronic device in accordance with an example of the present disclosure. This example also includes a light metal substrate 310 with a dried sol-gel coating 320 and a micro-arc oxidation layer 330. A physical vapor

deposition layer 340 is deposited on the dried sol-gel coating. The physical vapor deposition layer can include a metal in some examples. As used herein, "physical vapor deposition" refers to processes that involve converting a material from a condensed phase to a vapor phase and then back to a condensed phase as a thin film on the deposition surface.

[0017] FIG. 4 shows a cross-sectional view of a further example cover 400 for an electronic device in accordance with an example of the present disclosure. This cover includes a light metal substrate 410. A dried sol-gel oxide coating 420 has been applied to the top surface of the substrate. The substrate has been treated by micro-arc oxidation to form a micro-arc oxidation layer 430 on the bottom surface of the substrate. A physical vapor deposition layer 440 is deposited on the dried sol-gel oxide coating. Then, a clear coat layer 450 is applied over the physical vapor deposition layer. In some examples, the clear coat layer can provide an additional protective layer over the physical vapor deposition layer. In further examples, a clear coat layer can be applied over a first protective layer, such as the protective layer 240 shown in FIG. 2.

[0018] The figures described above show particular examples of the present disclosure. Other examples can include additional features, different features, or a portion of the features shown in the figures. Accordingly, the present disclosure is not limited to the specific examples shown in the figures.

[0019] It is noted that when discussing covers for electronic devices, the electronic devices themselves, or methods of making covers for electronic devices, such discussions can be considered applicable to one another whether or not they are explicitly discussed in the context of that example. Thus, for example, when discussing the light substrate in the context of one of the example covers, such disclosure is also relevant to and directly supported in the context of the electronic devices and/or methods, and *vice versa*. It is also understood that terms used herein will take on their ordinary meaning in the relevant technical field unless specified otherwise. In some instances, there are terms defined more specifically throughout or included at the end of the present disclosure, and thus, these terms are supplemented as having a meaning described herein.

[0020] In further detail, it is noted that the spatial relationship between layers is often described herein as positioned or applied “on” or “over” another layer. These terms do not infer that this layer is positioned directly in contact with the layer to which it refers, but could have intervening layers therebetween. That
5 being stated, a layer described as being positioned on or over another layer can be positioned directly on that other layer, and thus such a description finds support herein for being positioned directly on the referenced layer.

[0021] *Light Metal Substrate*

10 [0022] As mentioned above, in some examples covers for electronic devices can include a light metal substrate. In certain examples, the light metal substrate can have a density from about 0.5 g/cm³ to about 7.5 g/cm³. In other examples, the light metal substrate can have a density from about 0.5 g/cm³ to about 7 g/cm³, from about 0.5 g/cm³ to about 5.5 g/cm³, from about 0.5 g/cm³ to about 4 g/cm³, or from about 1 g/cm³ to about 2 g/cm³. These “light metals” can
15 thus have a lower density than some heavier metals, such as steel for example. In some examples, the light metal substrate can be made of a pure metallic element, while in other examples the light metal substrate can be made of an alloy. The pure metallic element or alloy can have a density in the ranges described above.
20 In certain examples, heavier elements may be alloyed with lighter elements to produce a light metal alloy that has a density in the ranges described above.

[0023] Non-limiting examples of metals that can be included in the light metal substrate include aluminum, magnesium, titanium, lithium, niobium, zinc, or an alloy thereof. In some examples, alloys of these metals can include additional
25 metals, such as bismuth, copper, cadmium, iron, thorium, strontium, zirconium, manganese, nickel, lead, silver, chromium, silicon, tin, gadolinium, yttrium, calcium, antimony, cerium, lanthanum, or others. In a particular example, the substrate can be pure magnesium or an alloy including 99% magnesium or greater. In another particular example, the substrate can be made of an alloy
30 including magnesium and aluminum. Examples of magnesium-aluminum alloys can include alloys made up of from about 91% to about 99% magnesium by weight and from about 1% to about 9% aluminum by weight, and alloys made up

of about 0.5% to about 13% magnesium by weight and 87% to 99.5% aluminum by weight. Specific examples of magnesium-aluminum alloys can include AZ63, AZ81, AZ91, AM50, AM60, AZ31, AZ31B, AZ61, AZ80, AE44, AJ62A, ALZ391, AMCa602, LZ91, and Magnox. Specific examples of aluminum-magnesium
5 alloys can include 1050, 1060, 1199, 2014, 2024, 2219, 3004, 4041, 5005, 5010, 5019, 5024, 5026, 5050, 5052, 5056, 5059, 5083, 5086, 5154, 5182, 5252, 5254, 5356, 5454, 5456, 5457, 5557, 5652, 5657, 5754, 6005, 6005A, 6060, 6061, 6063, 6066, 6070, 6082, 6105, 6162, 6262, 6351, 6463, 7005, 7022, 7068, 7072, 7075, 7079, 7116, 7129, and 7178. In a particular example, the substrate can be
10 made from AZ31 or AZ91.

[0024] Thus, magnesium or magnesium alloys can be used as the light metal substrate in certain examples. Magnesium can be selected as a material for an electronic device cover because of its high strength to weight ratio. However, magnesium can present certain difficulties. Magnesium tends to oxidize easily on
15 the surface, which prevents a metallic luster appearance. Additionally, magnesium can have poor color stability, hardness, and chemical resistance. Adding the dried sol-gel oxide coating on a surface of the light metal substrate and treating other surfaces of the light metal substrate with micro-arc oxidation can give a magnesium or magnesium alloy cover an attractive finish with good
20 hardness, chemical resistance, and durability. Specifically, the micro-arc oxidation treatment can form a layer of protective oxide on some surfaces of the light metal substrate while the dried sol-gel oxide coating can preserve the metallic luster of the surface on which the coating is applied.

[0025] In various examples, the light metal substrate can be formed by
25 molding, casting, machining, bending, working, or another process. In certain examples, the substrate can be a cover for an electronic device that is milled from a single block of metal or metal alloy. In other examples, an electronic device cover can be made from multiple panels. As an example, laptops sometimes include four separate pieces forming the chassis or cover of the laptop, with the
30 electronic components of the laptop protected inside the chassis. The four separate pieces of the laptop chassis are often designated as cover A (back cover of the monitor portion of the laptop), cover B (front cover of the monitor

portion), cover C (top cover of the keyboard portion) and cover D (bottom cover of the keyboard portion). In certain examples, one of these covers or more than one of these covers can include a light metal substrate as described herein. These covers can be made by machining, casting, molding, bending, stamping, or by
5 other forming methods. Other types of electronic device covers can also include a light metal substrate, such as a smartphone, tablet, or television cover. The light metal substrates for these applications can be made using the same forming methods.

[0026] The light metal substrate is not particularly limited with respect to
10 thickness. However, when used as a panel for an electronic device, such as for a housing or chassis, the thickness of the substrate can be chosen with regard to the density of the material (for purposes of controlling weight, for example), the hardness of the material, the malleability of the material, the material aesthetic, etc. In some examples, however, the thickness of the substrate can be from about
15 0.5 mm to about 2 cm, from about 1 mm to about 1.5 cm, from about 1.5 mm to about 1.5 cm, from about 2 mm to about 1 cm, from about 3 mm to about 1 cm, from about 4 mm to about 1 cm, or from about 1 mm to about 5 mm, though thicknesses outside of these ranges can be used.

20 [0027] *Dried Sol-gel Oxide Coating*

[0028] A sol-gel coating can be applied to a surface of the light metal substrate and dried to form a dried sol-gel coating. As used herein, “sol-gel” refers to materials made by converting monomers into a colloidal solution, or “sol,” that acts as a precursor for an integrated network, or “gel.” The gel can be dried to
25 remove solvent from the gel, leaving a dried sol-gel coating. In some examples, the sol-gel coatings used with the covers described herein can include a metal oxide or silicon oxide. Specific examples of oxides that can be included in the dried sol-gel oxide coating can include aluminum oxide, silicon oxide, titanium oxide, zirconium oxide, or a combination thereof. In some examples, the dried
30 sol-gel oxide coating can consist of one of these oxides or a combination of these oxides. In other examples, the dried sol-gel oxide coating can include one of

these oxides or a combination of these oxides in an amount from about 50 wt% to about 99 wt% of the dried sol-gel oxide coating.

[0029] The dried sol-gel coating can be formed from a variety of monomers, depending on the type of sol-gel oxide material desired. In some examples, metal oxide sol-gels can be formed from metal alkoxide monomers and silicon oxide sol-gels can be formed from silicon alkoxide monomers. In a particular example, a silicon oxide sol-gel can be formed by polymerizing tetraethyl orthosilicate (TEOS) to form a network of siloxane bonds. The TEOS can be polymerized, for example, by mixing the TEOS with water or alcohol and an acid or base to catalyze hydrolysis and condensation of the TEOS monomers. The Stöber process is one non-limiting example of a process that can be used to form this type of sol-gel. The siloxane network in the reaction solvent forms a gel, and the solvent can then be removed by drying to leave a dry siloxane network.

[0030] In other examples, monomers used to form the sol-gel coating can include TEOS, tetramethyl orthosilicate (TMOS), titanium n-butoxide, titanium isopropoxide, aluminum isopropoxide, zirconium n-propoxide, zirconium tert-butoxide, zinc isopropoxide, or combinations thereof. Non-limiting examples of catalysts that can be used to polymerize the monomers can include hydrochloric acid, sulfuric acid, nitric acid, carboxylic acids, oxalic acid, carbonic acid, ammonium hydroxide, sodium hydroxide, or combinations thereof. Solvents can include water, ethanol, n-propanol, isopropyl alcohol, ethyl acetate, butyl acetate, propylene glycol monomethyl ether, ethylene glycol mono tert-butyl ether, or combinations thereof.

[0031] A variety of methods can be used to coat a surface of the light metal substrate with the sol-gel coating. In some examples, the surface can be coated by dip coating, spin coating, spray coating, casting, or other methods. In certain examples, the sol-gel material can be coated on the light metal substrate in the sol stage, i.e., before the gel has formed. For example, the sol can be coated soon after mixing the monomers with a solvent and catalyst, before the gel has time to form. In other examples, the coating can be applied in multiple parts, such as a first coating composition that includes the monomer and a second coating composition that includes the catalyst. The catalyst may then catalyze the

formation of the gel when the two coating compositions are combined on the substrate.

[0032] One consideration related to micro-arc oxidation of light metal substrates is the extremely high temperature at the surface of the substrate during micro-arc oxidation. In some cases, the plasma arcs formed at the surface can reach temperatures higher than about 5,000 °C. Some coatings used on light metal substrates such as polymeric coatings or paint layers can have difficulty withstanding the high temperatures encountered during micro-arc oxidation. For examples, paint coatings may crack or peel off due to the high temperature. However, the dried sol-gel oxide coatings can withstand the high temperatures without peeling or degrading. In some cases, the adhesion of the sol-gel coating to the light metal substrate can actually be strengthened by the high temperatures.

[0033] In certain examples, the dried sol-gel oxide coating can be transparent. This can allow the metallic luster of the light metal substrate to show through the coating. In other examples, the dried sol-gel oxide coating can be colored with a pigment or other colorant. Colored oxide coatings may be partially transparent to provide a colored metallic appearance. Alternatively, the dried sol-gel oxide coating can be opaque. In particular examples, the dried sol-gel oxide coating can include a pigment to make the coating opaque and to impart a particular color to the coating. This can give the exterior of the cover a stone-like appearance, for example. In certain examples, the dried sol-gel oxide coating can include a pigment in an amount from about 0.5 wt% to about 30 wt% with respect to the dry weight of the dried sol-gel oxide coating. In other examples, the amount of pigment can be from about 1 wt% to about 25 wt% or from about 2 wt% to about 15 wt% of the dry weight of the dried sol-gel oxide coating. Non-limiting examples of pigments that can be included in the dried sol-gel oxide coating can include carbon black, titanium dioxide, clay, mica, talc, barium sulfate, calcium carbonate, synthetic pigment, metallic powder, aluminum oxide, graphene, pearl pigment, or a combination thereof.

[0034] In further examples, the thickness of the dried sol-gel oxide coating can be from about 3 μm to about 20 μm . In still further examples, the thickness can be from about 5 μm to about 20 μm or from about 5 μm to about 15 μm .

5 [0035] *Micro-arc Oxidation Layer*

[0036] The light metal substrate can be treated with micro-arc oxidation to form a micro-arc oxidation layer on surfaces of the light metal substrate. In some examples, the micro-arc oxidation can be performed after the dried sol-gel oxide coating is applied to a surface of the light metal substrate so that the dried sol-gel
10 oxide coating can prevent that surface from being oxidized during micro-arc oxidation.

[0037] Micro-arc oxidation (MAO) can also be referred to as plasma electrolytic oxidation. Micro-arc oxidation is an electrochemical process in which the surface of a metal is oxidized using micro-discharges of compounds on the
15 surface of the substrate when immersed in a chemical or electrolytic bath, for example. The electrolytic bath may include predominantly water with about 1 wt% to about 5 wt% electrolytic compound(s), e.g., alkali metal silicates, alkali metal hydroxide, alkali metal fluorides, alkali metal phosphates, alkali metal aluminates, the like, and combinations thereof. The electrolytic compounds may likewise be
20 included at from about 1.5 wt% to about 3.5 wt% or from about 2 wt% to about 3 wt%, though these ranges are not considered limiting. In one example, a high-voltage alternating current can be applied to the substrate to create plasma on the surface of the substrate. In this process, the substrate can act as one electrode immersed in the electrolyte solution, and the counter electrode can be
25 any other electrode that is also in contact with the electrolyte. In some examples, the counter electrode can be an inert metal such as stainless steel. In certain examples, the bath holding the electrolyte solution can be conductive and the bath itself can be used as the counter electrode. A high direct current or alternating voltage can be applied to the substrate and the counter electrode. In
30 some examples, the voltage can be about 200 V or higher, such as about 200 V to about 600 V, about 250 V to about 600 V, about 250 V to about 500 V, or about 200 V to about 300 V. Temperatures can be from about 20 $^{\circ}\text{C}$ to about 40 $^{\circ}\text{C}$, or

from about 25 °C to about 35 °C, for example, though temperatures outside of these ranges can be used. This process can oxidize the surface to form an oxide layer from the substrate material. The oxidation can extend below the surface to form thick layers, as thick as 30 μm or more. In some examples the oxide layer
5 can have a thickness from about 1 μm to about 25 μm, from about 1 μm to about 22 μm, or from about 2 μm to about 20 μm. Thickness can likewise be from about 2 μm to about 15 μm, from about 3 μm to about 10 μm, or from about 4 μm to about 7 μm. The oxide layer can, in some instances, increase resistance to wear and corrosion and impart useful mechanical, thermal, and dielectric properties to
10 the substrate. The electrolyte solution can include a variety of electrolytes, such as a solution of potassium hydroxide.

[0038] In certain examples, the light metal substrate can have a dried sol-gel oxide coating applied to a surface before the micro-arc oxidation treatment. The dried sol-gel oxide coating can prevent that surface from being
15 oxidized during micro-arc oxidation. In a particular example, the dried sol-gel oxide coating can be applied on the surface that is to be the exterior surface of the cover. The opposite surface, which is to be the interior surface of the cover, can be oxidized by micro-arc oxidation. Because of the dried sol-gel oxide coating on the exterior surface, no micro-arc oxidation layer forms on the exterior surface.

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[0039] *Protective Coating Layer*

[0040] In some examples, a protective coating layer can be applied over the dried sol-gel oxide coating. The protective coating layer can include a polymer resin. In certain examples, the polymer resin can be transparent and the
25 protective coating layer can be a clear coat layer that allows the color of the underlying materials to show through. In examples having a transparent dried sol-gel oxide coating, a clear coat can be applied over the dried sol-gel oxide coating and the metallic luster of the light metal substrate can be visible through both the dried sol-gel oxide coating and the clear coat. In further examples, the
30 dried sol-gel oxide coating may be colored and a clear coat can be applied to allow the color of the dried sol-gel oxide coating to show through. In some examples, the polymer resin of the clear coat layer can be clear poly(meth)acrylic,

clear polyurethane, clear urethane (meth)acrylate, clear (meth)acrylic (meth)acrylate, or clear epoxy (meth)acrylate coating. The thickness of the clear coat layer can be from about 1 μm to about 100 μm in some examples. In further examples, the thickness can be from about 5 μm to about 20 μm . In certain
5 examples, the clear coat layer can be a layer of polyacrylic with a thickness from about 1 μm to about 50 μm , from about 2 μm to about 30 μm , or from about 5 μm to about 15 μm . In other examples, the clear coat layer can be a polyurethane with a thickness from about 5 μm to about 100 μm , from about 10 μm to about 75 μm , or from about 10 μm to about 50 μm .

10 [0041] In further examples, the protective coating over the dried sol-gel oxide coating can be colored. The protective coating can include fillers such as pigment dispersed in an organic polymer resin. Non-limiting examples of pigments used in the protective coating layer can include carbon black, titanium dioxide, clay, mica, talc, barium sulfate, calcium carbonate, synthetic pigment,
15 metallic powder, aluminum oxide, graphene, pearl pigment, or a combination thereof. The pigment can be present in the protective coating layer in an amount from about 0.5 wt% to about 30 wt% with respect to dry components of the protective coating layer, in some examples. In other examples, the amount of pigment can be from about 1 wt% to about 25 wt% or from about 2 wt% to about
20 15 wt% with respect to dry components of the protective coating layer.

[0042] The polymer resin included in the protective coating layer with the pigment can include polyester, poly(meth)acrylic, polyurethane, epoxy, urethane (meth)acrylic, (meth)acrylic (meth)acrylate, epoxy (meth)acrylate, or a combination thereof. As used herein, a "combination" of multiple different
25 polymers can refer to a blend of homopolymers, a copolymer made up of the different polymers or monomers thereof, or adjacent layers of the different polymers. In certain examples, the polymer resin of the protective coating layer can have a weight-average molecular weight from about 100 g/mol to about 6,000 g/mol.

30 [0043] The thickness of the colored protective coating layer can be from about 1 μm to about 100 μm in some examples. In further examples, the thickness can be from about 5 μm to about 20 μm .

[0044] In certain examples, the protective coating layer can include a base coat that is colored and a top coat that is clear. Thus, the colored layer and the clear coat layer described above can be used together in certain examples. The overall thickness of the base coat with the top coat can be from about 2 μm to about 100 μm , from about 5 μm to about 60 μm , or from about 10 μm to about 40 μm , in some examples.

[0045] In further examples, the colored base coat layer, the top clear coat layer, or both, can be radiation curable. The polymer resin used in these layers can be curable using heat and/or radiation. For example, a heat curing polymer resin can be used and then cured in an oven for a sufficient curing time. A radiation curing polymer resin can be exposed to sufficient radiation energy to cure the polymer resin. The protective coating layer can be cured after applying the layer to the cover. In certain examples, curing can include heating the protective coating layer at a temperature from about 50 °C to about 80 °C or from about 50 °C to about 60 °C or from about 60 °C to about 80 °C. The layer can be heated for a curing time from about 5 minutes to about 40 minutes, or from about 5 minutes to about 10 minutes, or from about 20 minutes to about 40 minutes. In other examples, curing can include exposing the layer to radiation energy at an intensity from about 500 mJ/cm^2 to about 2,000 mJ/cm^2 or from about 700 mJ/cm^2 to about 1,300 mJ/cm^2 . The layer can be exposed to the radiation energy for a curing time from about 5 seconds to about 30 seconds, or from about 10 seconds to about 30 seconds.

[0046] *Physical Vapor Deposition Layer*

[0047] In further examples, a physical vapor deposition layer can be deposited over the dried sol-gel oxide coating. Physical vapor deposition can be used to deposit thin layers of materials such as metals and graphite. Non-limiting examples of materials that can be deposited to form the physical vapor deposition layer can include titanium, chromium, nickel, zinc, zirconium, manganese, copper, aluminum, indium, tin, molybdenum, tantalum, tungsten, hafnium, gold, palladium, vanadium, silver, platinum, graphite, stainless steel, or alloys thereof. These materials can be deposited by a variety of physical vapor deposition

processes. In certain examples, the physical vapor deposition process used can be ion-beam sputtering (IBS), reactive sputtering, ion-assisted deposition (IAD), high-target-utilization sputtering, high-power impulse magnetron sputtering (HIPIMS), gas flow sputtering, chemical vapor deposition, and others.

5 [0048] In some examples, the physical vapor deposition layer can have a thickness from about 10 nm to about 1,000 nm, or from about 20 nm to about 500 nm, or from about 30 nm to about 100 nm. In further examples, a clear coat layer can be applied over the physical vapor deposition layer to protect the physical vapor deposition layer from scratching. The clear coat layer can include any of the
10 clear coat layer components described above.

[0049] *Electronic Devices*

[0050] The present disclosure also extends to electronic devices that include a cover as described above. In some examples, an electronic device can
15 include a light metal substrate having a density from about 0.5 g/cm³ to about 7.5 g/cm³. A dried sol-gel coating can be on an exterior surface of the light metal substrate. The light metal substrate can have a micro-arc oxidation layer across an interior surface of the light metal substrate. The exterior surface of the light metal substrate may not include a micro-arc oxidation layer. The electronic device
20 can also include an electronic component adjacent to the interior surface of the light metal substrate. The electronic component can be any internal component used in an electronic device, such as a processor, motherboard, memory, battery, display screen, and so on.

[0051] FIG. 5 shows an exploded view of an example electronic device 500
25 in accordance with an example of the present disclosure. In this example, the electronic device is a laptop. The laptop includes a top cover 510 and a bottom cover 520. The bottom cover has an interior surface 522 and an exterior surface 524. The top cover has an exterior surface 514 and an interior surface that is not visible in the figure. As explained above, the top cover and bottom cover can both
30 include a light metal substrate that has a dried sol-gel oxide coating on the exterior surface and a micro-arc oxidation layer on the interior surface. Electronic components 530 are placed between the top cover and the bottom cover. When

the top cover and bottom are assembled together, the electronic components are held inside adjacent to the interior surfaces of the top and bottom covers. The electronic components in this laptop may include a motherboard, processor, memory, hard drive, and other components.

5 [0052] In further examples, electronic devices can include covers that have any of the layers and materials described above. In certain examples, an electronic device can have a cover with a protective coating layer or a physical vapor deposition layer on the dried sol-gel coating. In additional examples, the electronic device can have a second protective coating layer in the form of a clear
10 coat. The clear coat can be applied over the first protective coating layer or over the physical vapor deposition layer.

[0053] *Methods of Making Covers for Electronic Devices*

[0054] The present disclosure also extends to methods of making covers
15 for electronic devices. FIG. 6 is a flowchart of an example method 600 of making a cover for an electronic device. The method includes: applying 610 a sol-gel oxide coating on a first surface of a light metal substrate having a density from about 0.5 g/cm³ to about 7.5 g/cm³; and treating 620 the light metal substrate with micro-arc oxidation to form a micro-arc oxidation layer across a second surface of
20 the light metal substrate, wherein a micro-arc oxidation layer is not formed on the first surface.

[0055] In certain examples, the sol-gel oxide coating can be applied and dried before treating the light metal substrate with micro-arc oxidation. Thus, the dried sol-gel oxide coating can prevent the first surface of the substrate from
25 being oxidized. In further examples, methods of making covers for electronic devices can include applying any of the other layers and materials described above. For example, methods in accordance with the present disclosure can include applying a protective coating layer over the dried sol-gel oxide coating, or applying a physical vapor deposition layer over the dried sol-gel oxide coating. In
30 some examples, the protective coating layer applied over the dried sol-gel coating can be a clear coat layer, while in other examples the protective coating layer can be a colored base coat layer. In further examples, a clear coat layer can be

applied over the colored base coat layer. In still further examples, a clear coat layer can be applied over the physical vapor deposition layer.

[0056] The methods described herein can include drying and/or curing the layers as well. In some examples, the sol-gel coating can be dried by heating the cover at a temperature from about 60 °C to about 120 °C, or in other examples from about 80 °C to about 100 °C. In further examples, the sol-gel coating can be dried for a time from about 10 minutes to about 60 minutes, or in other examples from about 30 minutes to about 40 minutes. Protective coating layers can be heated at a temperature from about 50 °C to about 80 °C, from about 50 °C to about 60 °C, or from about 60 °C to about 80 °C, for a time from about 5 minutes to about 40 minutes, from about 5 minutes to about 10 minutes, or from about 20 minutes to about 40 minutes. The protective coating layer can also be irradiated with ultraviolet radiation at an intensity from about 500 mJ/cm² to about 2,000 mJ/cm², or in some examples from about 700 mJ/cm² to about 1,300 mJ/cm². The irradiation can be performed for a time from about 5 seconds to about 30 seconds, or from about 10 seconds to 30 seconds.

[0057] *Definitions*

[0058] It is noted that, as used in this specification and the appended claims, the singular forms "a," "an," and "the" include plural referents unless the content clearly dictates otherwise.

[0059] The term "about" as used herein, when referring to a numerical value or range, allows for a degree of variability in the value or range, for example, within 5% or other reasonable added range breadth of a stated value or of a stated limit of a range. The term "about" when modifying a numerical range is also understood to include the exact numerical value indicated, e.g., the range of about 1 wt% to about 5 wt% includes 1 wt% to 5 wt% as an explicitly supported sub-range.

[0060] As used herein, a plurality of items, structural elements, compositional elements, and/or materials may be presented in a common list for convenience. However, these lists should be construed as though the individual members of the list is individually identified as a separate and unique member.

Thus, no individual member of such list should be construed as a *de facto* equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary.

[0061] Concentrations, dimensions, amounts, and other numerical data may be presented herein in a range format. It is to be understood that such range format is used merely for convenience and brevity and should be interpreted flexibly to include the numerical values explicitly recited as the limits of the range, and also to include all the individual numerical values or sub-ranges encompassed within that range as if individual numerical values and sub-ranges are explicitly recited. For example, a layer thickness from about 0.1 μm to about 0.5 μm should be interpreted to include the explicitly recited limits of 0.1 μm to 0.5 μm , and to include thicknesses such as about 0.1 μm and about 0.5 μm , as well as subranges such as about 0.2 μm to about 0.4 μm , about 0.2 μm to about 0.5 μm , about 0.1 μm to about 0.4 μm etc.

[0062] The following illustrates an example of the present disclosure. However, it is to be understood that the following is illustrative of the application of the principles of the present disclosure. Numerous modifications and alternative compositions, methods, and systems may be devised without departing from the spirit and scope of the present disclosure. The appended claims are intended to cover such modifications and arrangements.

EXAMPLES

Example 1 - *Cover for Electronic Device with Transparent Sol-gel Coating and Clear Coat*

[0063] An example cover for an electronic device is prepared as follows:

- 1) A panel made from magnesium-aluminum-zinc alloy panel (AZ31, which is 3 wt% aluminum, 1 wt% zinc, and 96 wt% magnesium) is coated on one surface with a sol. The sol is made up of tetraethyl orthosilicate (TEOS), water, and carbonic acid catalyst. The sol is coated on the panel by spray coating. The sol is then allowed to

form a gel and dried in an oven at 80 °C for 40 minutes, forming a dried silica coating.

2) The panel is then treated with micro-arc oxidation to form an oxide layer about 10 µm in thickness on the opposite surface from the dried sol-gel oxide coating. No micro-arc oxidation layer forms on the side with the dried sol-gel coating.

3) A clear coat composition made up of an ultraviolet curable polyacrylic polymer resin is applied onto the dried sol-gel silica coating to form a layer about 10 µm thick. The clear coat is heated at 50 °C for 10 minutes and then irradiated with ultraviolet radiation at an intensity of 700 mJ/cm² for 30 seconds.

[0064] The finished cover has the appearance of metallic luster of the magnesium alloy panel, which shows through the transparent silica coating and the clear top coat.

Example 2 - Cover for Electronic Device with Base Coat and Clear Coat

[0065] A second example cover for an electronic device is prepared as follows:

1) A panel made from magnesium-aluminum-zinc alloy panel (AZ31, which is 3 wt% aluminum, 1 wt% zinc, and 96 wt% magnesium) is coated on one surface with a sol. The sol is made up of tetraethyl orthosilicate (TEOS), water, and carbonic acid catalyst. The sol is coated on the panel by spray coating. The sol is then allowed to form a gel and dried in an oven at 80 °C for 40 minutes, forming a dried silica coating.

2) The panel is then treated with micro-arc oxidation to form an oxide layer about 10 µm in thickness on the opposite surface from the dried sol-gel oxide coating. No micro-arc oxidation layer forms on the side with the dried sol-gel coating.

3) A colored base coat layer is applied to the dried sol-gel silica coating. The base coat includes a polyacrylic polymer resin and titanium dioxide pigment dispersed in the polymer resin. The base coat is

applied to form a layer about 10 μm thick. The base coat is then heated to 60 °C for about 40 minutes.

- 4) A clear coat composition made up of an ultraviolet curable polyacrylic polymer resin is applied onto the base coat layer to form a layer about 10 μm thick. The clear coat is heated at 50 °C for 10 minutes and then irradiated with ultraviolet radiation at an intensity of 700 mJ/cm^2 for 30 seconds.

[0066] The finished cover has a glossy white appearance due to the pigment in the base coat and the clear top coat.

Example 3 - *Cover for Electronic Device with Physical Vapor Deposition Layer and Clear Coat*

[0067] A third example cover for an electronic device is prepared as follows:

- 1) A panel made from magnesium-aluminum-zinc alloy panel (AZ31, which is 3 wt% aluminum, 1 wt% zinc, and 96 wt% magnesium) is coated on one surface with a sol. The sol is made up of tetraethyl orthosilicate (TEOS), water, and carbonic acid catalyst. The sol is coated on the panel by spray coating. The sol is then allowed to form a gel and dried in an oven at 80 °C for 40 minutes, forming a dried silica coating.
- 2) The panel is then treated with micro-arc oxidation to form an oxide layer about 10 μm in thickness on the opposite surface from the dried sol-gel oxide coating. No micro-arc oxidation layer forms on the side with the dried sol-gel coating.
- 3) A physical vapor deposition layer is applied by ion beam sputtering to deposit a layer of chromium onto the dried sol-gel coating. The physical vapor deposition layer is about 50 nm thick.
- 4) A clear coat composition made up of an ultraviolet curable polyacrylic polymer resin is applied onto the physical vapor deposition layer to form a layer about 10 μm thick. The clear coat is heated at 50 °C for

10 minutes and then irradiated with ultraviolet radiation at an intensity of 700 mJ/cm² for 30 seconds.

[0068] The finished cover has a chrome appearance due to the physical vapor deposition layer and the clear top coat.

5 [0069] What has been described and illustrated herein is an example of the disclosure along with some of its variations. The terms, descriptions, and figures used herein are set forth by way of illustration and are not meant as limitations. Many variations are possible within the spirit and scope of the disclosure, which is intended to be defined by the following claims -- and their equivalents -- in which
10 all terms are meant in their broadest reasonable sense unless otherwise indicated.

CLAIMS

What is claimed is:

- 5 1. A cover for an electronic device comprising:
a light metal substrate having a density from about 0.5 g/cm³ to about 7.5 g/cm³; and
a dried sol-gel oxide coating on a first surface of the light metal substrate,
wherein the light metal substrate comprises a micro-arc oxidation layer
10 across a second surface of the light metal substrate, and wherein the first surface of the light metal substrate does not include a micro-arc oxidation layer.
2. The cover of claim 1, wherein the light metal substrate comprises aluminum, magnesium, titanium, lithium, niobium, zinc, or an alloy thereof.
- 15 3. The cover of claim 1, wherein the dried sol-gel oxide coating comprises aluminum oxide, silicon oxide, titanium oxide, zirconium oxide, or a combination thereof.
- 20 4. The cover of claim 1, wherein the dried sol-gel oxide coating is transparent and the first surface of the light metal substrate has a metallic luster visible through the dried sol-gel oxide coating.
- 25 5. The cover of claim 1, wherein the dried sol-gel oxide coating comprises a pigment dispersed therein.
6. The cover of claim 1, further comprising a protective coating layer on the dried sol-gel oxide coating, wherein the protective coating layer comprises a polymer resin.

7. The cover of claim 6, wherein the polymer resin comprises polyester, poly(meth)acrylic, polyurethane, epoxy, urethane (meth)acrylic, (meth)acrylic (meth)acrylate, epoxy (meth)acrylate, or a combination thereof.

5 8. The cover of claim 6, wherein the protective coating layer further comprises a pigment in an amount from about 0.5 wt% to about 30 wt% with respect to dry components of the protective coating layer.

9. The cover of claim 8, wherein the pigment comprises carbon black,
10 titanium dioxide, clay, mica, talc, barium sulfate, calcium carbonate, synthetic pigment, metallic powder, aluminum oxide, graphene, pearl pigment, or a combination thereof.

10. The cover of claim 1, further comprising a metal-containing physical
15 vapor deposition layer on the dried sol-gel oxide coating.

11. An electronic device comprising:

a cover including:

20 a light metal substrate having a density from about 0.5 g/cm³ to about 7.5 g/cm³, and
 a dried sol-gel oxide coating on an exterior surface of the light metal substrate, wherein the light metal substrate comprises a micro-arc oxidation layer across an interior surface of the light metal substrate, and wherein the exterior surface of the
25 light metal substrate does not include a micro-arc oxidation layer; and

an electronic component adjacent to the interior surface of the light metal substrate.

30 12. The electronic device of claim 11, wherein the electronic device further comprises either a protective coating layer or a physical vapor deposition layer on the dried sol-gel oxide coating.

13. The electronic device of claim 12, further comprising a second protective coating layer in the form of a clear coat on the protective coating layer or the physical vapor deposition layer.

5

14. A method of making a cover for an electronic device comprising:
applying a sol-gel oxide coating on a first surface of a light metal substrate having a density from about 0.5 g/cm³ to about 7.5 g/cm³;
treating the light metal substrate with micro-arc oxidation to form a
10 micro-arc oxidation layer across a second surface of the light metal substrate, wherein a micro-arc oxidation layer is not formed on the first surface.

15. The method of claim 14, further comprising applying and drying the sol-gel oxide coating to the first surface of the light metal substrate before treating
15 the second surface of the light metal substrate with micro-arc oxidation to form the micro-arc oxidation layer.

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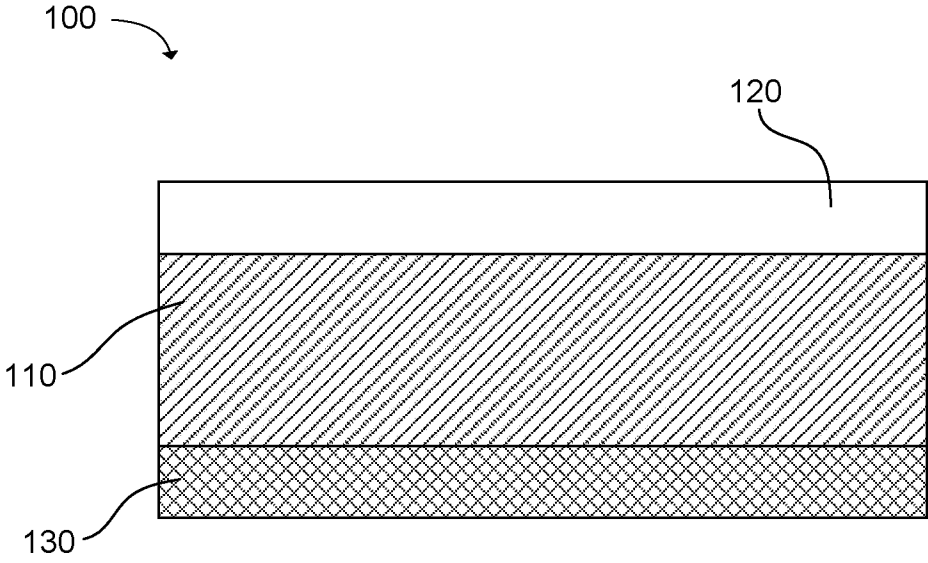


FIG. 1

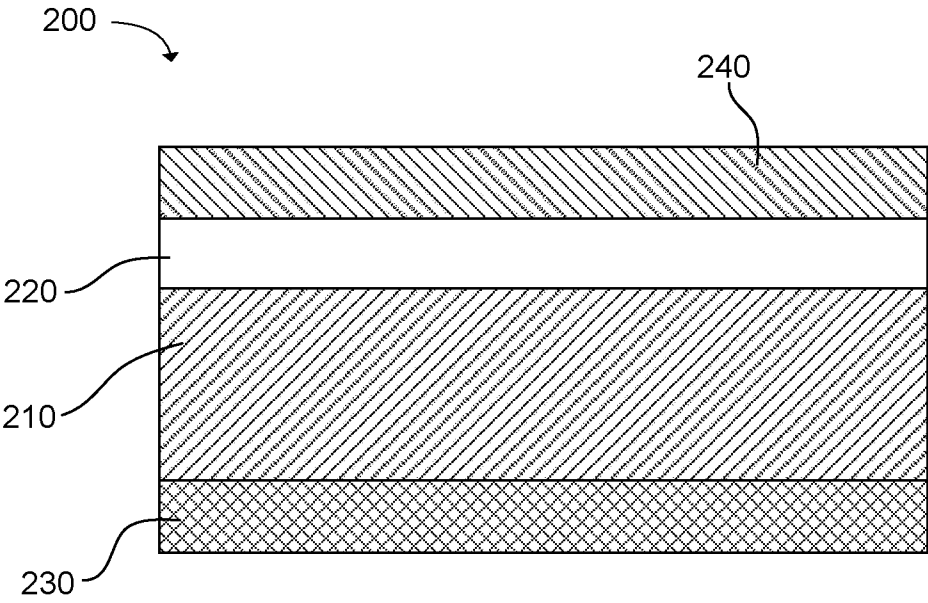


FIG. 2

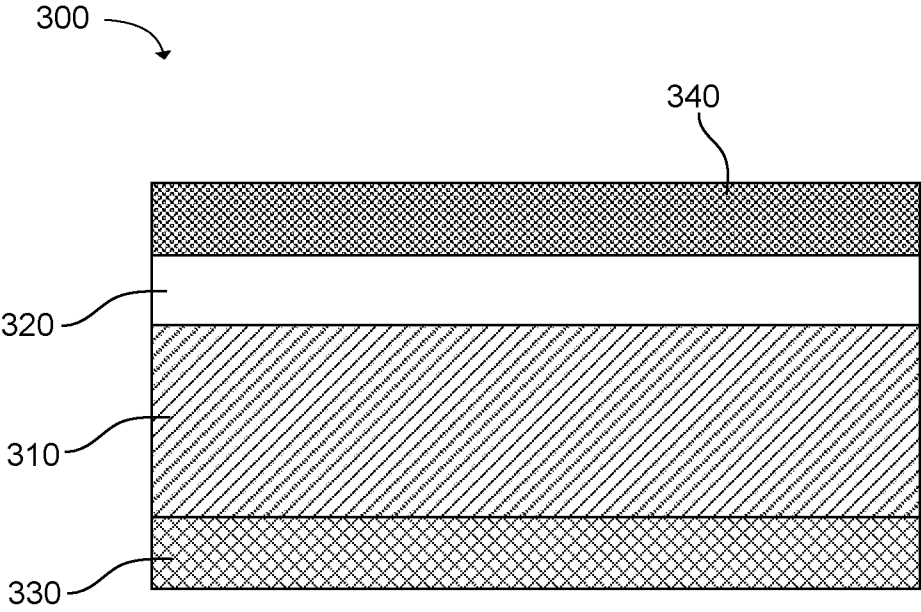


FIG. 3

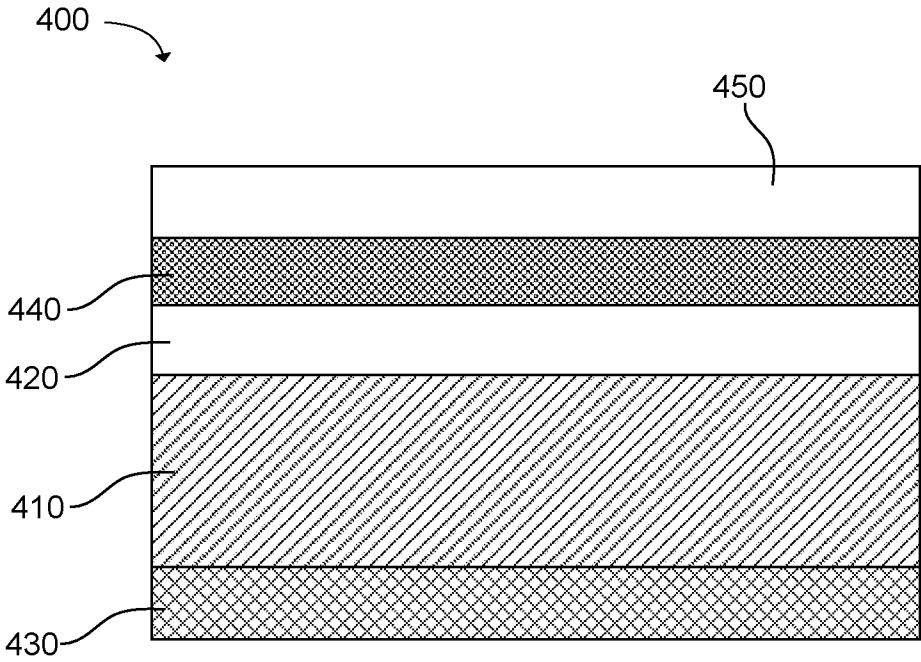


FIG. 4

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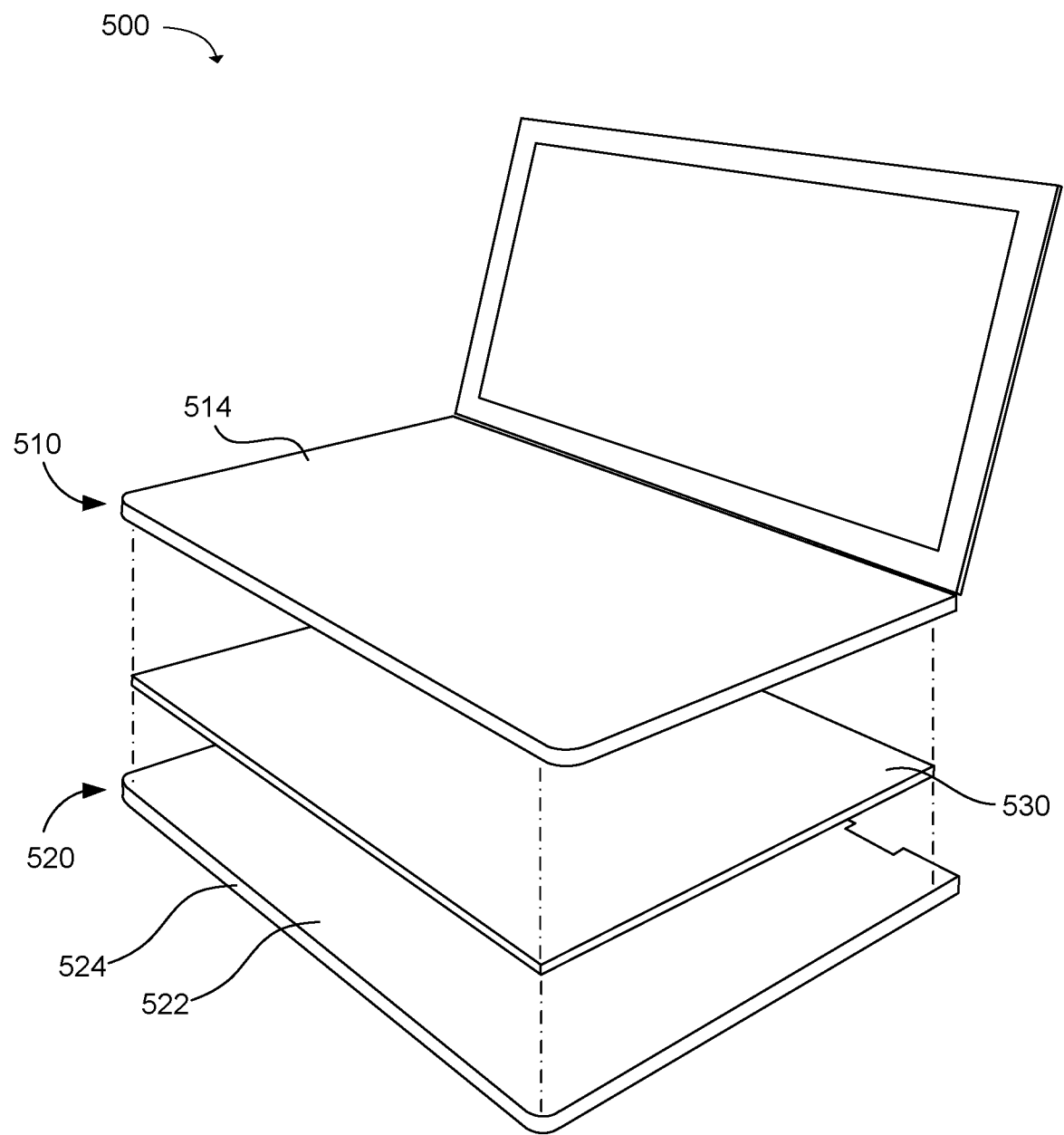


FIG. 5

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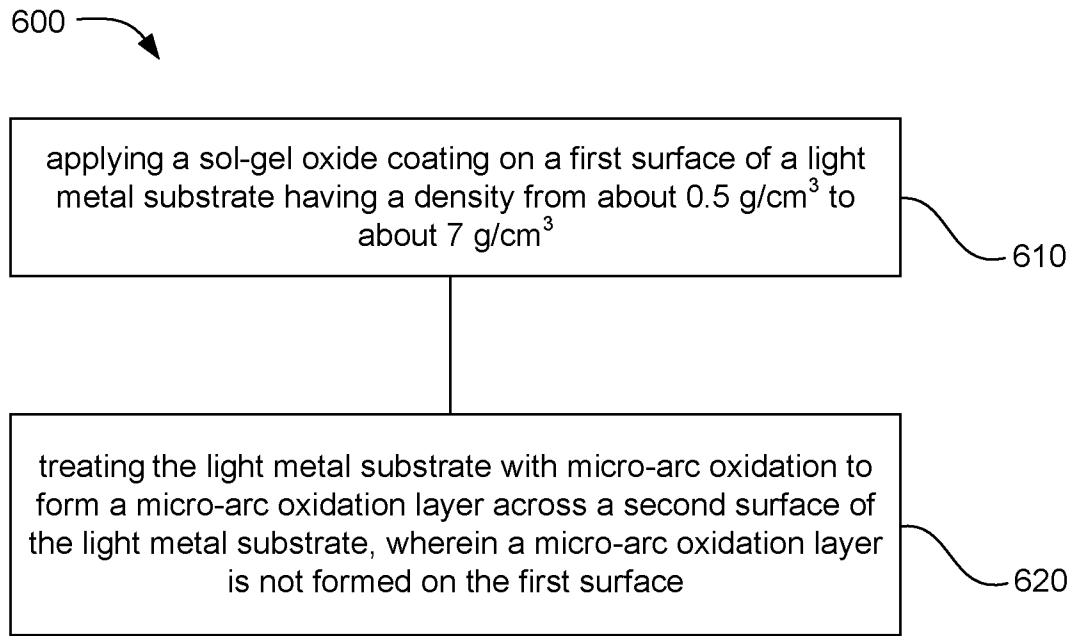


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2018/059464

A. CLASSIFICATION OF SUBJECT MATTER
C23C 4/04 (2006.01)

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)

C23C 4/00-4/04, B29C 70/00-70/78, B29D 99/00, G06F 1/00-1/18, G03F 7/00, H05K 1/00-1/11, C03C 8/00-8/18, B41C 1/00-1/10, B41N 1/00-1/14

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)

PatSearch (RUPTO internal), USPTO, PAJ, Esp@cenet, Information Retrieval System of FIPS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 2481556 A1 (HISHIDA, IWAO) 01.08.2012, paragraphs [0008], [0031]	1-15
A	US 2017/0060192 A1 (APPLE INC) 02.03.2017	1-15
A	US 2016/0130174 A1 (TENEDORA NEMAK SA DE CV) 12.05.2016	1-15
A	JP 2000318332 A (FUJI PHOTO FILM CO LTD) 21.11.2000	1-15

☐

Further documents are listed in the continuation of Box C.

☐

See patent family annex.

* Special categories of cited documents:

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“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

02 July 2019 (02.07.2019)

Date of mailing of the international search report

11 July 2019 (11.07.2019)

Name and mailing address of the ISA/RU:

Federal Institute of Industrial Property,
Berezhkovskaya nab., 30-1, Moscow, G-59,
GSP-3, Russia, 125993

Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37

Authorized officer

T. Mamedov

Telephone No. (495) 531-64-81