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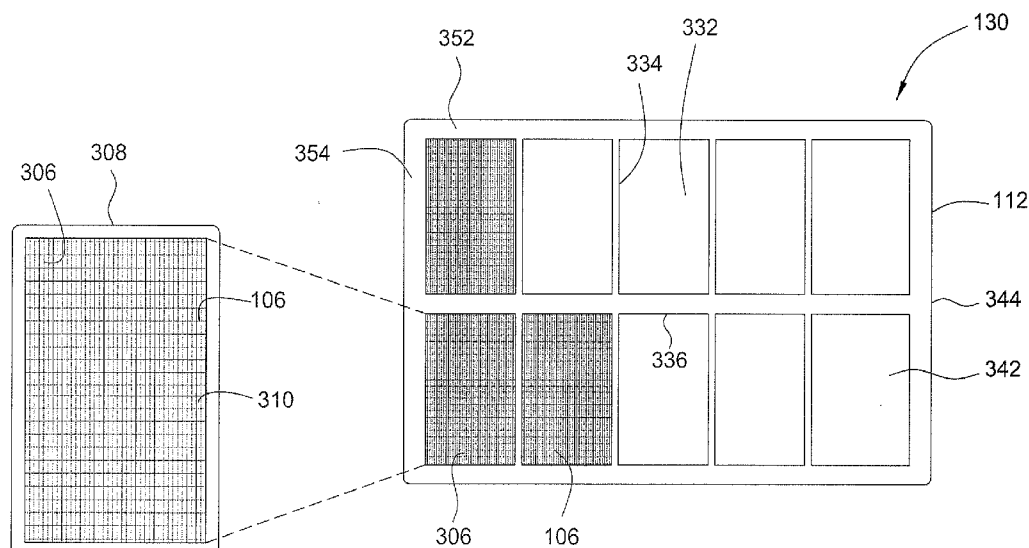


FIG. 3

(57) Abstract: A low tension fine metal mask, a tension fine metal mask assembly for electro-optic devices and a method of forming the mask assembly are provided. The low tension fine metal mask assembly 130 has a frame 112, the frame has a plurality of apertures 332, the low tension fine metal mask assembly has a plurality of mask units 306, each mask unit has a having a plurality of openings 310, each metal mask unit is coupled to the frame in a manner that maintains a tension across the mask unit of about less than about 0.4 kgf/cm.

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FINE METAL MASK FOR PRODUCING ORGANIC LIGHT-EMITTING DIODES

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] Embodiments disclosed herein generally relate to the production of electro-optic devices. More specifically, embodiments disclosed herein generally relate to forming a fine metal mask.

Description of the Related Art

[0002] Electro-optic devices that make use of organic materials are becoming increasingly desirable for a number of reasons. Many of the materials used to make such devices are relatively inexpensive, so organic electro-optic devices have the potential for cost advantages over inorganic devices. As well, the inherent properties of organic materials, such as their flexibility, may be advantageous for particular applications such as for deposition or formation on flexible substrates. Examples of organic electro-optic devices include organic light emitting devices (OLEDs), organic phototransistors, organic photovoltaic cells, and organic photodetectors.

[0003] For OLEDs, the organic materials are believed to have performance advantages over conventional materials. For example, the wavelength at which an organic emissive layer emits light may generally be readily tuned with appropriate dopants. OLEDs make use of thin organic films that emit light when voltage is applied across the device. OLEDs are becoming an increasingly interesting technology for use in applications such as flat panel displays, illumination, and backlighting.

[0004] Prior to and during evaporative deposition of OLED materials, a fine metal mask (FMM) is used to define deposition areas on a substrate. Mask manufacturing issues, mask material, small differences from run to run and changes in temperature during deposition may cause the FFM to become misaligned on a substrate. To date, these small temperature variations and changes during processing have limited the use of FMM for evaporative patterning to relatively small substrates and relatively larger defined features.

[0005] One solution has been to do very precise alignment of masks to substrates, maintain deposition temperatures as low and constant as possible during processing, to use mask materials having low thermal coefficient of expansion, and place the mask under tension. This deposition technique has been done for many years and has reached its limits in terms of feature density, i.e., the number of features which may be formed in an area.

[0006] Another possible solution is small mask scanning (SMS). SMS involves the use of a mask which is smaller than the whole substrate or display; and which is scanned relative to the substrate, whereby the mask is used to deposit stripes of red, green and blue (RGB) material. This technique has many problems, due to the fact that clearance must be maintained between the substrate and the mask during deposition, which leads to cross contamination among the emissive RGB materials. Further, SMS can create defects due to scratching, which results from the desire to keep clearance as small as possible during the scanning to avoid the above described cross contamination.

[0007] Thus, there is a continuing need for improved masks and masking techniques for the formation of electro-optic devices.

SUMMARY OF THE INVENTION

[0008] The embodiments described herein generally relate to the formation of low tension fine metal masks for electro-optic devices. The low tension fine metal mask has a frame. The frame has a plurality of apertures. The low tension fine metal mask has a plurality of mask units. Each mask unit has a having a plurality of openings. Each metal mask unit is coupled to the frame in a manner that maintains a tension across the mask unit of about less than about 0.4 kgf/cm, such as 0.1 kgf/cm.

[0009] In another embodiment, a masking assembly is disclosed. The masking assembly has a body. The body has a frame and a plurality of supports forming apertures on at least one side of the frame. A mask unit is sized to the aperture and bonded thereto. The mask unit has a fine metal

mask having a plurality of openings. The fine metal mask is disposed within the border and at a low tension.

[0010] In yet another embodiment, a method is disclosed for forming a fine metal mask assembly. The method begins by preparing a substrate formed from a silicon-metal hybrid material. A through hole is formed in voids of a metal layer through a silicon layer of the silicon-metal hybrid material. The through hole has sidewalls formed at a first angle. A second angle is formed on a sidewall of the metal layer. The substrate is cut to a shape suitable to form a mask unit. The mask unit is then coupled into the fine metal mask assembly wherein a tension across the mask unit is about less than about 0.4 kgf/cm.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0012] Figures 1 depicts a schematic for portion of a process chamber having a mask assembly.

[0013] Figure 2 is prior art depicting a top view for a fine metal mask disposed in the mask assembly suited for use in the processing chamber of Figure 1.

[0014] Figure 3 depicts a top view for a low tension fine metal mask, according to one embodiment, disposed in the mask assembly similarly suitable for use in the processing chamber of Figure 1.

[0015] Figures 4A and 4B depict section views for the forming the low tension fine metal mask.

[0016] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

DETAILED DESCRIPTION

[0017] Embodiments disclosed herein generally relate to fine metal masks. A fine metal mask refers to masks that may be used during deposition of materials onto a substrate. The fine metal mask may be used to form features having a pattern resolution smaller than the entire active (light emitting) area of the substrate. Typically, the fine metal mask has one dimension that is of the order of the dimensions of a portion of the sub-pixels (usually of one color) that are to be disposed on the substrate. The fine metal mask is thereby typically utilized for the deposition of the emissive layer of an organic device, where the differing colors of the display are each deposited separately through the fine metal mask and designed to only allow deposition on a portion of the active OLEDs present in the display (*e.g.*, the fine metal mask through which only the red emissive layer is deposited, another fine metal mask through which only the green emissive layer is deposited, etc.).

[0018] The fine metal mask may be formed from a silicon-metal hybrid material using micro machining (Microelectromechanical systems) or plasma processing to achieve a mask pattern having accuracies of about 1 micrometer. Additionally, during the deposition process, both the substrate and the fine metal mask may be heated, and thus, both the substrate and the fine metal mask expand to some degree. As the substrate and the fine metal mask expand, the alignment of the fine metal mask with relation to the substrate must be maintained to achieve high accuracy and high resolution. For example, the fine metal mask may achieve pixels per inch (PPI) resolution of greater than 600 PPI such as between about 800 PPI and about 1200 PPI

on next generation and large substrates. By positioning the fine metal mask in a rigid frame without tensioning the fine metal mask, the fine metal mask can be aligned with the substrate during processing without shift or distortion. The embodiments disclosed herein are more clearly described with reference to the figures below.

[0019] Figure 1 depicts a schematic diagram of a portion of a processing chamber 100 having a fine metal mask assembly 130. The processing chamber 100 can be a process chamber adapted for use with the embodiments described below. In one embodiment, the processing chamber 100 can be a chamber available from AKT America, Inc., a subsidiary of Applied Materials, Inc., Santa Clara, California. It is to be understood that the embodiments discussed herein may be practiced on other chambers, including those chambers sold by other manufacturers.

[0020] A substrate 102 can be positioned in the processing chamber 100 in connection with an electrostatic chuck (not shown). The substrate 102 can be a substrate suitable for forming an organic light-emitting diode (OLED) thereon. Additionally, the substrate 102 may be a flexible material. The OLED may be composed of a layer of organic materials situated between two electrodes, the anode and cathode, all deposited on the substrate 102. In one embodiment, the substrate 102 is substantially composed of glass. The substrate can be of a broad range of dimensions (e.g. length, width, shape, thickness, etc.). In one embodiment, the substrate 102 is approximately 1 meter long and 1 meter wide. In this embodiment, the substrate 102 is depicted with a cathode 104 formed over a lower surface 103. The cathode 104 may comprise indium tin oxide (ITO). In other embodiments, the cathode 104 is discontinuous and is formed on the substrate 102 in conjunction with the formation of the OLED layers (not shown).

[0021] A source 108 is positioned adjacent the substrate 102 and the cathode 104. Generally, the source 108 can be a source boat or other container or receptacle capable of producing a vapor of organic material 110. The vapor of organic material 110 can be configured to deposit further layers over the cathode 104, such as an emission layer, a hole transport layer, a

color change layer or further layers (not shown) as required or desired for the formation of the OLED structure. In one embodiment, the source 108 produces a vapor of organic material 110 to form a white emission layer (not shown) over the cathode 104 and a color change layer over the white emission layer. In another embodiment, the source 108 produces a vapor of organic material 110 to form a color emission layer (not shown) over the cathode 104. One or more additional layers may be formed over the cathode 104, such as an electron transport layer (not shown).

[0022] The fine metal mask assembly 130 is positioned between the substrate 102 and the source 108. It is understood that the fine metal mask assembly 130 is not depicted to scale and may be smaller or larger than shown, in length, width or height with comparison to the related structures. The fine metal mask assembly 130 includes a fine metal mask 106 and a frame 112. The fine metal mask 106 can be positioned in the frame 112. The fine metal mask 106 may be at least partially composed of one or more magnetic or non-magnetic metals. For example, the fine metal mask may be formed from a silicon-metal hybrid material. Suitable materials for the fine metal mask 106 or components thereof include, but are not limited to silicon-nickel hybrid material, INVAR (64FeNi), ASTM Grade 5 titanium (Ti-6Al-4V), titanium, aluminum, molybdenum, copper, 440 stainless steel, HASTELLOY® alloy C-276, nickel, chrome-molybdenum steel, 304 stainless steel, other iron containing compositions, or combinations thereof. The frame 112 can be composed of a material similar to that of the fine metal mask 106. In one embodiment, the frame 112 is composed of INVAR.

[0023] The fine metal mask 106 can be of a size and shape which allows for coverage of at least a portion of the substrate. In one embodiment, the fine metal mask 106 is from 1 meters and 1.5 meters in length and from 750 millimeters to 925 millimeters in height. The fine metal mask 106 can have a thickness of less than 80 micrometer, such as about 40 micrometer or about 20 micrometer. In one embodiment, the fine metal mask 106 has a thickness of less than 40 micrometer.

[0024] The fine metal mask 106 is positioned in the processing chamber 100. The processing chamber is pumped down, wherein the temperature is stabilized and made ready to receive the substrate 102. The substrate 102 can then be brought into the processing chamber 100 and the alignment marks on the fine metal mask 106 is brought into alignment with corresponding features on the substrate 102.

[0025] To better understand and appreciate the fine metal mask 106, the fine metal mask assembly 130 will first be discussed relative to a conventional fine metal mask 206. Figure 2 depicts a top view for a conventional fine metal mask 206, disposed in the fine metal mask assembly 130, suited for use in the processing chamber 100 of Figure 1. The conventional fine metal mask 206 is connected to the frame 112. In one example, the conventional fine metal mask 206 uses microactuators 214 to attach to the frame 112. In another example, the conventional fine metal mask 206 is stretched and welded to the frame 112.

[0026] Stretching the conventional fine metal mask 206, or alternately the microactuators 214, apply a force which aligns and/or stretches the conventional fine metal mask 206. The mask opening 216 and the frame opening 218 are depicted as holes in the conventional fine metal mask 206 and the frame 112 respectively. However, other connections may be used, such as a hook or bolt attaching the microactuator 214 or welding the microactuator 214 to the frame 112, the conventional fine metal mask 206, or both. In operation, the conventional fine metal mask 206 is tensioned so as to bring the conventional fine metal mask 206 and pattern-defining features 220 to the final desired size and position relative to the substrate 102. For example, the fine metal mask 206 may be tensioned normally in a range between about 0.7 to about 0.9 kgf/cm. The fine metal mask assembly 130 would then be loaded into the processing chamber 100.

[0027] The conventional fine metal mask 206 may include sizes of about 750 mm x 650 mm that is tensioned in one or more dimensions to above 0.8 kgf/cm. Larger sizes for the conventional fine metal mask 206 include about 920 mm x about 730 mm, GEN 6 half-cut (about 1500 mm x about 900 mm).

[0028] The conventional fine metal mask 206 is formed from a piece of low thermal expansion sheet metal which is stretched and then attached in a stretched state to a heavy frame. The heavy frame is generally required to maintain the high stretching, i.e., tensioning, of the fine metal mask and can be on the order of thousands of pounds. For example, the conventional fine metal mask 206 having 16 actuators may be formed from INVAR, which has a coefficient of thermal expansion (CTE) of $1.3 \mu\text{m}/\text{m}^\circ\text{C}$, a yield strength of 70 ksi, and a Young's modulus of 21500 ksi. With a temperature rise of 50°C , the thermal expansion is $162.5 \mu\text{m}$. The strain and stress necessary to correct for the expansion is 0.0065% requiring each of the 16 actuators to employ a force of 27.1 lbs. Likewise, the fine metal mask (FMM) may be formed from: Ti-6Al-4V requiring a force per actuator of 137.5 lbs; titanium requiring a force per actuator of 144.8 lbs; Al requiring a force per actuator of 222.8 lbs; molybdenum titanium requiring a force per actuator of 248.3 lbs; copper requiring a force per actuator of 254.2 lbs; stainless steel requiring a force per actuator of 286.6 lbs; HASTELLOY® requiring a force per actuator of 322.2 lbs; nickel, requiring a force per actuator of 347.3 lbs; and chrome-molybdenum steel requiring a force per actuator of 351.7 lbs. However, the tensioning force applied to the conventional fine metal mask 206 limits the resolution and causes shift and skewing of the mask at high temperatures. Consequentially the conventional fine metal mask provides a poor roadmap for extendibility to high resolution and larger sizes.

[0029] Figure 3 depicts a top view for a fine metal mask 106, according to one embodiment, disposed in the fine metal mask assembly 130 suitable for use in the processing chamber of Figure 1. The fine metal mask 106 is not subject to the tensioning forces utilized in the conventional fine metal mask 206 discussed above in relation to Figure 2. The fine metal mask 106 may include sizes of about 750 mm x 650 mm that is tensioned in one or more dimensions to less than about 0.4 kgf/cm, such as 0.1 kgf/cm or less. Larger sizes for the fine metal mask 106 include about 920 mm x about 730 mm, GEN 6 half-cut (about 1500 mm x about 900 mm), and extends to even larger sizes such as GEN 6 (about 1500 mm x about 1800 mm), GEN 8.5 (about 2200 mm x about 2500 mm) and GEN 10 (about 2800 mm x about 3200 mm).

[0030] The frame 112 of the fine metal mask assembly 130 has a body 352. The body 352 may be formed from INVAR (64FeNi), ASTM Grade 5 titanium (Ti-6Al-4V), titanium, aluminum, molybdenum, copper, 440 stainless steel, HASTELLOY® alloy C-276, nickel, chrome-molybdenum steel, 304 stainless steel, other iron containing compositions, or combinations thereof. The body 352 has a casing 354. The casing 354 may be shaped in a band having an interior portion 342 and an outer perimeter 344. Examples of band shapes for the casing 354 may encompass a circular ring shape, an oblong ring shape, a rectangular ring shape or other suitable polynomial band/ring shape having a central hollow area.

[0031] The body 352 may additionally have one or more supports 336. The body 352 may also have a plurality of secondary supports 334. The supports 336, 334 divide the interior portion 342 of the casing 354 into a plurality of apertures 332. The supports 336, 334 may be integral to the casing 354. For example, the apertures 332 and supports 336, 334 may be formed by removing material from the casing 354 or during the manufacture of the casing 354 through an additive manufacturing process like 3D printing such that the casing 354 and the supports 336, 334 are formed from one solid homogenous piece of material. Alternately, the supports 336, 334 may be a singular unit or separate members attached to the casing 354 in forming the body 352. For example, the supports 336, 334 may be welded, glued, fastened or attached with or without tensioning by other techniques to the casing 354. In one embodiment, the frame 112 has ten (10) apertures 332. The apertures 332 may be shaped in a rectangular, square, round, triangular, pie, or other suitable shaped. For example, the ten apertures 332 may have a substantially rectangular shape.

[0032] A mask unit 306 is configured to be disposed in the apertures 332. The mask unit 306 may have an outer support 308. The fine metal mask 106 may be formed in or supported by the outer support 308 to form the mask unit 306. Alternately, the mask unit 306 may be formed solely from the fine metal mask 106. The mask unit 306 may be shaped to be held by the combination of supports 336, 334 and the casing 354. The outer support 308 may

substantially, or partially, align with one or more of the supports 336, 334 and casing 354 forming the apertures 332. One or more mask units 306 may be configured to cover one of the apertures 332. In one embodiment, each aperture 332 has one respective mask unit 306. In another embodiment, each aperture 332 has two or more mask units 306. In yet another embodiment, the apertures 332 may contain a plurality of mask units 306 disposed therein.

[0033] The fine metal mask 106 is disposed in each mask unit 306. Suitable materials for the fine metal mask 106, or components thereof include, are not limited to a silicon-metal hybrid such as silicon-nickel, INVAR 36 (64FeNi), ASTM Grade 5 titanium (Ti-6Al-4V), titanium, aluminum, molybdenum, copper, 440 stainless steel, HASTELLOY® alloy C-276, nickel, chrome-molybdenum steel, 304 stainless steel, other iron containing compositions, or combinations thereof.

[0034] The fine metal mask 106 may be formed by an electroforming process or MEMS technique such as molding and plating, wet etching, dry etching, electro discharge machining (EDM), silicon wafer thinning by grinding, and other technologies suitable for manufacturing small devices. The fine metal mask 106 may have a plurality of small openings 310. The small openings 310 are suitable for forming features such as a device or pixel, on a surface of the substrate exposed to the fine metal mask 106. The openings 310 may have an area sized between about 1 micrometer to about 100 micrometer (i.e. about 0.001 mm to about 0.1 mm), such as about 25 micrometer. The small openings 310 in the fine metal mask may be suitable to form the features at a density of about 300 features per inch or greater such as 800 features per inch or 1000 features per inch. For example, the fine metal mask 106 may have small openings 310 configured to generate between about 250 pixels per inch (PPI) and about 1200 PPI such as between about 600 PPI and 900 PPI, such as about 800 PPI. The small openings 310 may have variations in sizes of less than about 1 micrometer, such as about 0.2 micrometer, and a pitch, i.e. center to center distance

between small openings 310, of less than about $\pm 3 \mu\text{m}$ per a 160 mm of distance.

[0035] A number of mask units 306 may be bonded to the body 352 in forming the fine metal mask assembly 130. The bonding to the body 352 may be performed by welding, such as laser welding, gluing, such as by epoxy or acrylic, forming integrally with the body 352 or by other suitable means. The bonding of the fine metal mask 106 to either the outer support 308 or directly to the body 352 of the fine metal mask assembly 130 is performed such that the fine metal mask 106 is at a low tension, such as a tension force between about zero kg/cm and about 0.1 kg/cm. The low tension of the mask unit 306 is formed without any substantially sag and has a flatness of between 2 microns and about 5 microns. Bonding of the fine metal mask 106 at low temperatures, such as by epoxy, prevents deformation of the fine metal mask 106 due to temperature changes. In one embodiment, the mask units 306 are bonded to the body 352 of the fine metal mask assembly 130 with epoxy to form pixels over an area of about 900 mm to about 1500 mm at a density greater than about 800 PPI. The mask units 306 may have an alignment accuracy of about 1 micrometer to about 5 micrometers, i.e., the actual position of the mask units 306, openings 310, alignment marks (not shown), etc., versus the designed position, is accurate to within about 1 micrometer.

[0036] Advantageously, the fine metal mask assembly 130 described above can be positioned in the processing chamber in connection with a substrate. The fine metal mask assembly 130 can be aligned and positioned in connection with the substrate for deposition. The low tension of the fine metal mask 106 significantly prevents shifts or distortions in the alignment of the fine metal mask assembly 130 with the substrate at high temperatures. Thus, the low tension of the fine metal mask 106 in the fine metal mask assembly 130 can be of a higher resolution and operate at higher temperatures than conventional metal masks such as that shown and described in Figure 2.

[0037] An additional advantage is that the mask units 306 may be easily replaced by unbinding, or debonding, the mask units 306 from the body 352 of

the fine metal mask assembly 130. As the mask units 306 become obstructed, dirty, damaged, or worn, the individual mask units 306 may be replaced or repaired, thus, minimizing expense and operational downtime.

[0038] Figures 4A and 4B depict section views for forming the low tension fine metal mask. The figures depict one opening 310. However, it should be appreciated that the fine metal mask 106 has a plurality of openings and may have over 250 openings per square inch or more.

[0039] A silicon layer 402 has a top surface 472. The silicon wafer 402 may have a thickness between about 700 micrometer and about 40 micrometer, such as about 65 micrometer. A seed layer 404 may be disposed on the silicon layer 402. The seed layer 404 may be titanium (Ti), copper (Cu) or other suitable material. A metal layer 432 may be disposed on the seed layer 404. The metal layer 432 may be formed from nickel (Ni) or nickel alloy such as nickel-cobalt (NiCo) or other appropriate material.

[0040] The silicon layer 402 may be thinned, such as by etching in and around the opening 310 such that the silicon layer 402 is about 30 micrometer thick. For example, thinning may be performed by chemical etching or grinding the bottom of the silicon layer 402 prior to etching the top surface 472. Alternately the etching can be performed in a single step with two-directional chemical etching of the silicon layer 402.

[0041] In Figure 6A, a through hole 422 is formed in the silicon layer 402 as part of forming the opening 464. The through hole 422 may have sidewalls 415 which extend from a bottom surface 411 of the silicon layer 402 to the a surface 472. The through hole 422 may be form by anisotropic chemical etching, such as a potassium hydroxide (KOH) etch, or other suitable techniques in the silicon layer 402. The etch rate may be controlled to narrow a width, such as bottom width 408, of the through hole 422 as the depth 482 of the through hole 422 increases from the top surface 472 of the silicon layer 402. The sidewalls 415 of the through hole 422 extend at an angle 406 such that the opening of the through hole 422 at the top surface 472 is larger than that of the bottom surface 611, i.e., the bottom width 608. The angle 406 may

be between about 40 degrees and about 60 degrees, such as about 54.7 degrees. The angle 406 may be precisely controlled by anisotropic etching allowing the bottom width 408 to be maintained with an accuracy of about 1 micrometer and the angle 406 for the sidewalls 415 of about 54.7 degrees. The bottom width 408 of the through hole 422 may be about 38 micrometer. The width of the through hole 422 at the top surface may be about 94 micrometer. Thus, a corresponding portion 409 of the bottom surface 411 adjacent the bottom width 408 of the opening 310 may be about 28 micrometer.

[0042] In Figure 4B a metal layer 432 is rounded. The metal layer 432 may be rounded by grinding, etching, or by other suitable techniques. For example, an iron III chloride (FeCl_3) etches may be used to round the nickel material of the metal layer 432. A sidewall 425 of the metal layer 432 may be similarly aligned with the sidewall 415 of the silicon wafer. That is, the sidewall 425 may be angled between about 40 degrees and about 50 degrees, such as about 54.7 degrees to match the angle 406 of the sidewall 415 of the silicon layer 401. Each opening for the through holes 422 corresponds to the small openings 310 (shown in Figure 3) in the finished low tension fine metal mask. Thus, the through holes 422 may be formed in a suitable density for forming a plurality of features in a substrate with the low tension fine metal mask. The silicon layer 402 may now be cut to fit in each mask unit 306 for forming the low tension fine metal mask 106. A tension across the low tension fine metal mask 106 is less than about 0.4 kgf/cm. The low tension fine metal mask 106 may be bonded and de-bonded to the mask assembly for use and unit replacement. For example, the low tension fine metal mask 106 may be bonded by epoxy at a temperature of about 25 degrees Celsius or room temperature.

[0043] Advantageously, the sidewalls 415, 425 of the through hole 422 are angled to minimize shadow and promote evaporative performance. The silicon-metal hybrid material of the low tension fine metal mask may be biased to the substrate by magnetism for tighter processing control. The silicon-metal hybrid material also enhances durability of the low tension fine metal

mask. The material and method of manufacture for the low tension fine metal mask allows a higher density of openings coupled with an alignment accuracy of less than about 1 micrometer to form a density of features on substrates with minimal skew.

[0044] While the foregoing is directed to embodiments of the invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof.

Claims:

1. A low tension fine metal mask, comprising:
a frame having a plurality of apertures; and
a plurality of fine metal mask units, each fine metal mask unit disposed in a respective one of the apertures, each fine metal mask unit having a plurality of openings wherein each fine metal mask unit is coupled to the frame in a manner that maintains a tension across the mask unit of less than about 0.4 kgf/cm.
2. The low tension fine metal mask of claim 1, wherein the openings have a density of between about 250 per inch and 1200 per inch.
3. The low tension fine metal mask of claim 1, wherein the openings in the mask unit have an alignment accuracy of about 1 micrometer with the substrate.
4. The low tension fine metal mask of claim 1, wherein the openings have sidewalls angled at between about 40 degrees and about 60 degrees.
5. The low tension fine metal mask of claim 1, wherein the tension across the mask unit is about 0.1 kgf/cm.
6. A masking assembly, comprising:
a body having a frame and a plurality of supports forming apertures on at least one side of the frame; and
a plurality of mask units sized to the aperture, wherein the mask unit comprises:
a fine metal mask having a plurality of openings, wherein each mask unit is bonded to a respective one of the apertures in a manner that maintains a tension across the fine metal mask of less than about 0.4 kgf/cm.
7. The mask assembly of claim 6 and low tension fine metal mask of claim 2, wherein the openings have a density of between 600 per inch and 900 per inch.

8. The mask assembly of claim 6 and low tension fine metal mask of claim 2, wherein the openings have a density of about 800 per inch.
9. The mask assembly of claim 6 and low tension fine metal mask of claim 1, wherein the fine metal mask is bonded to the frame by epoxy.
10. The mask assembly of claim 6, openings has sidewalls angled at about 54.7 degrees.
11. The mask assembly of claim 6 and low tension fine metal mask of claim 1, wherein the fine metal mask is formed from a silicon-nickel hybrid material.
12. A method of forming a fine metal mask assembly, comprising:
 - preparing a substrate formed from a silicon-metal hybrid material;
 - forming a through hole in voids of a metal layer through a silicon layer of the silicon-metal hybrid material, wherein the through hole has sidewalls formed at a first angle;
 - forming a second angle on a sidewall of the metal layer
 - cutting the substrate to a shape suitable to form a mask unit; and
 - coupling the mask unit into the fine metal mask assembly wherein a tension across the mask unit is less than about 0.4 kgf/cm.
13. The method of claim 12, wherein the metal layer is one of nickel (Ni), a nickel cobalt alloy (NiCo), a stainless steel, or nickel-iron alloy.
14. The method of claim 12, preparing the substrate further comprises:
 - anisotropic etching the silicon metal hybrid material to a thickness of about 30 micrometers, wherein the first angle of the sidewalls in the silicon layer is about 54.7 degrees.
15. The method of claim 12, wherein the coupling is performed with an epoxy at a temperature of about 25 degrees Celsius

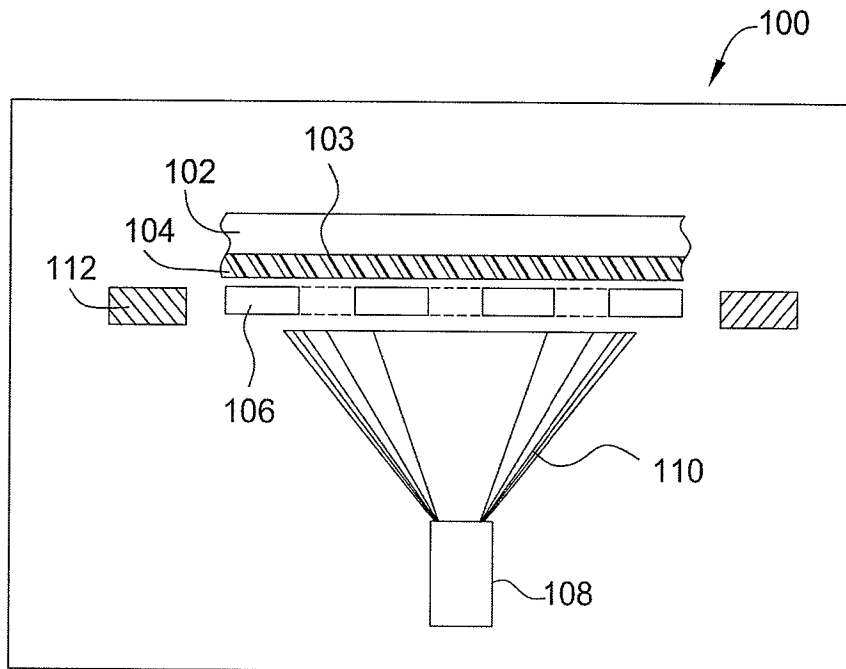


FIG. 1

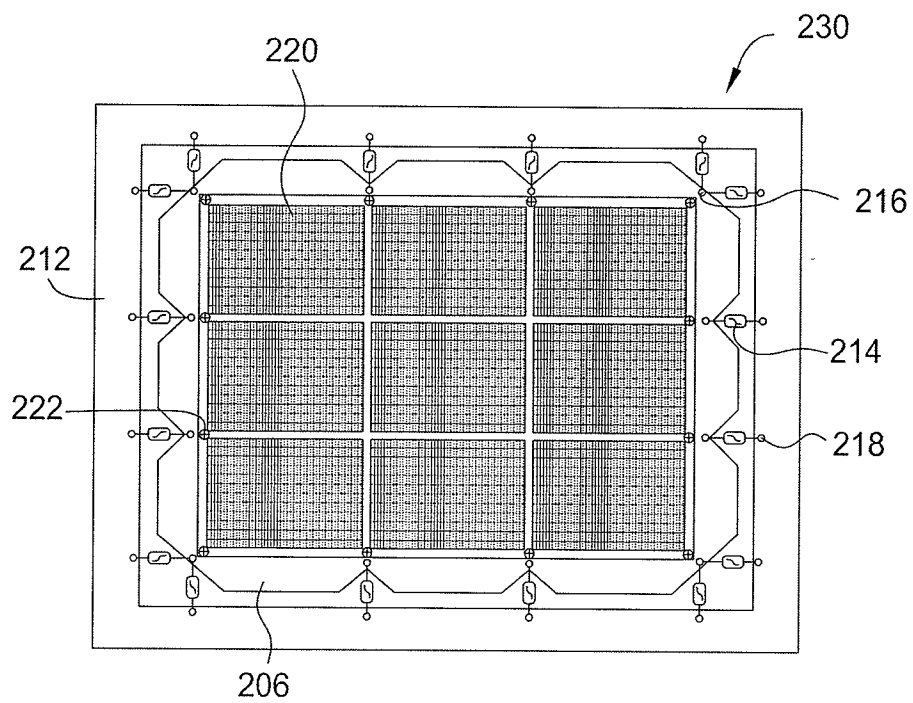


FIG. 2

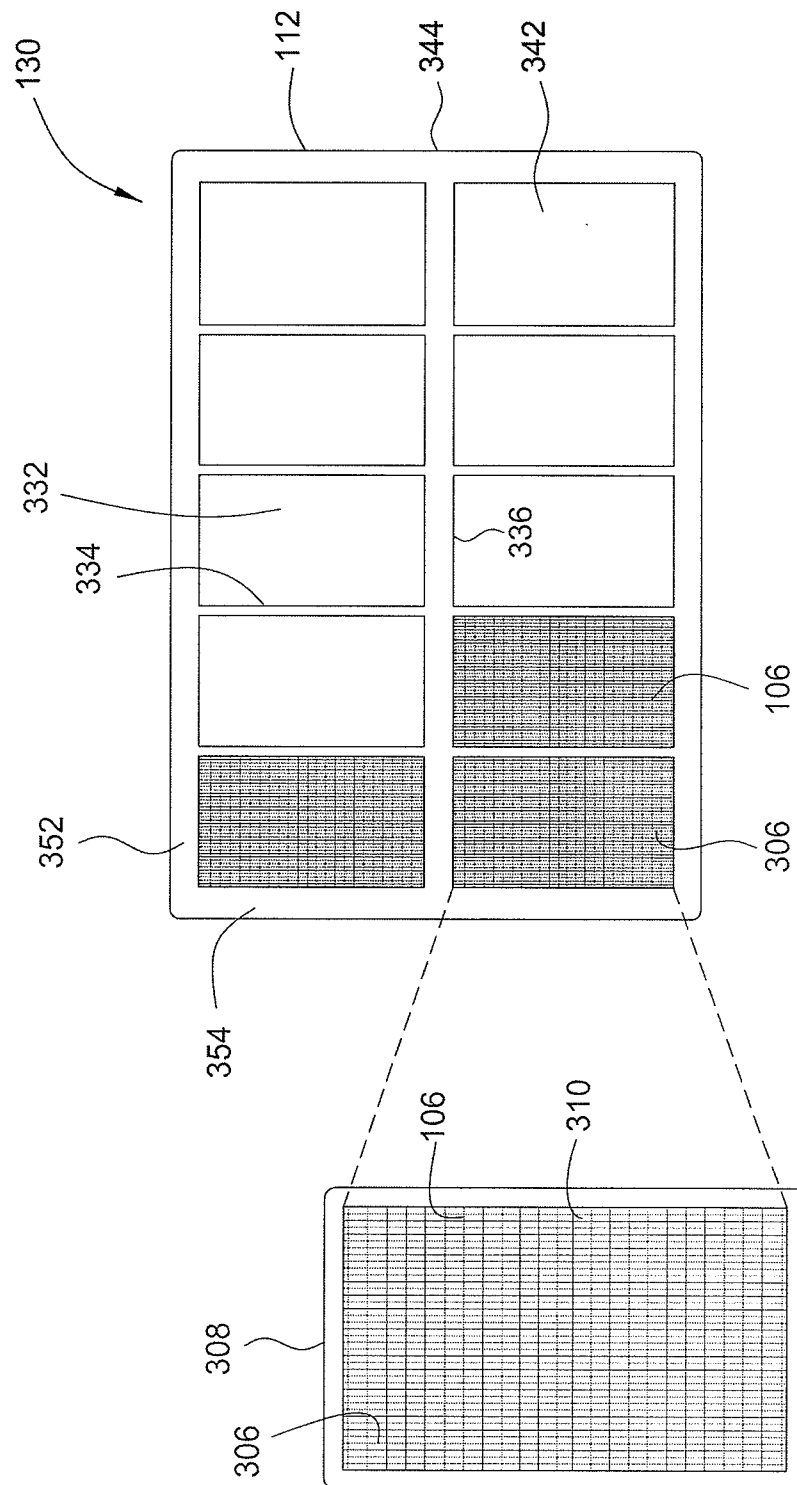


FIG. 3

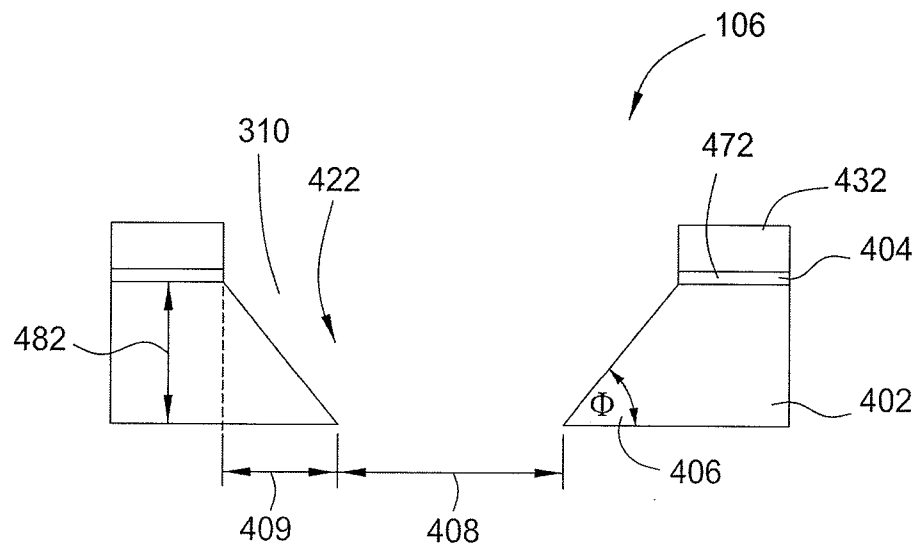


FIG. 4A

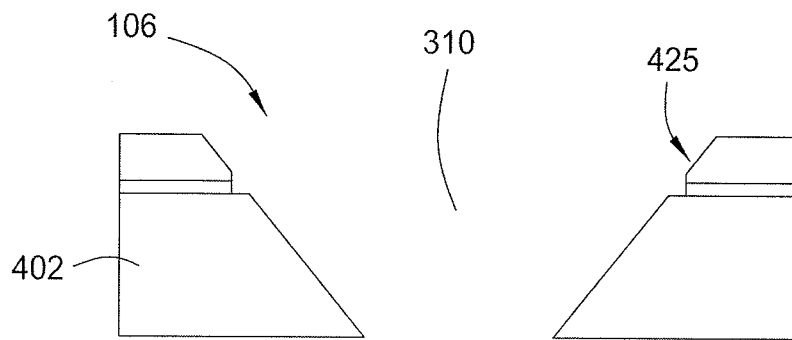


FIG. 4B

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2016/080756**A. CLASSIFICATION OF SUBJECT MATTER**

H01L 51/56(2006.01)i; H01L 51/52(2006.01)i

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)

H01L

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)

CNABS,CNTEXT,DWPI: aperture, fine metal mask, FMM, tension, opening

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 104404446 A (UNIV SHANGHAI ENG SCIENCE) 11 March 2015 (2015-03-11) the whole document	1-15
A	CN 105144421 A (APPLIED MATERIALS INC) 09 December 2015 (2015-12-09) the whole document	1-15
A	US 2014290574 A1 (KIM) 02 October 2014 (2014-10-02) the whole document	1-15

☐ 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

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“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

17 January 2017

Date of mailing of the international search report

07 February 2017

Name and mailing address of the ISA/CN

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2016/080756

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	104404446	A	11 March 2015	None			
CN	105144421	A	09 December 2015	US	2016043319	A1	11 February 2016
				KR	20160015214	A	12 February 2016
				WO	2014176163	A1	30 October 2014
				TW	201510637	A	16 March 2015
				JP	2016521316	W	21 July 2016
US	2014290574	A1	02 October 2014	KR	20140118507	A	08 October 2014