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(54) **IMPRINTED MICRO-LOUVER STRUCTURE**

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(52) **U.S. Cl.**

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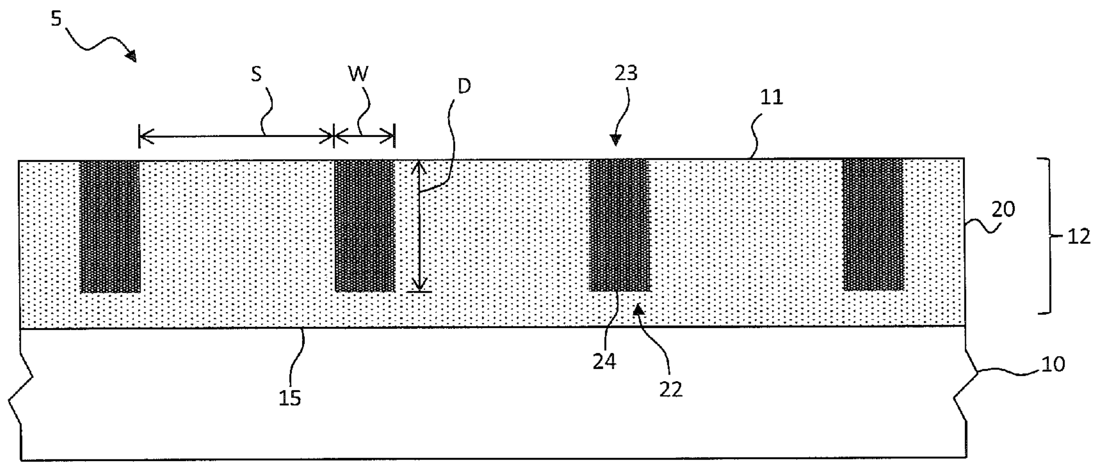
(57) **ABSTRACT**

A micro-louver structure includes a cured layer on a surface. A plurality of micro-channels forms a pattern in the cured layer. The micro-channels have a greater depth than width and are spaced apart by a separation distance greater than the width. A cured light-absorbing material is located in the micro-channels.



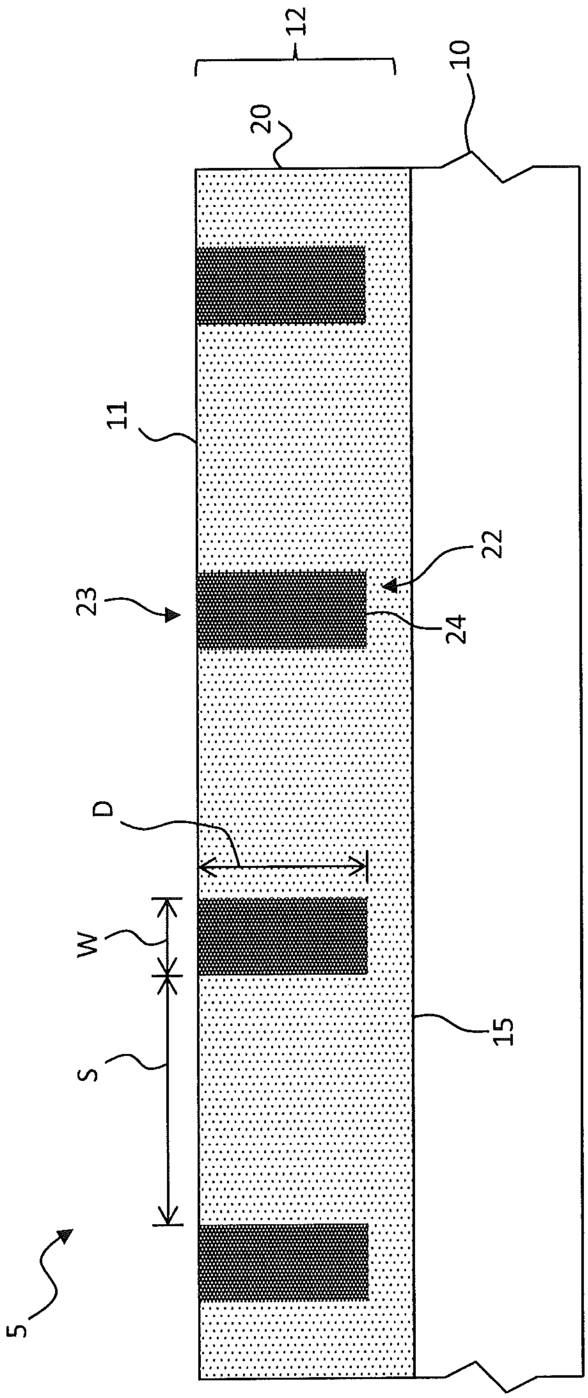


FIG. 1

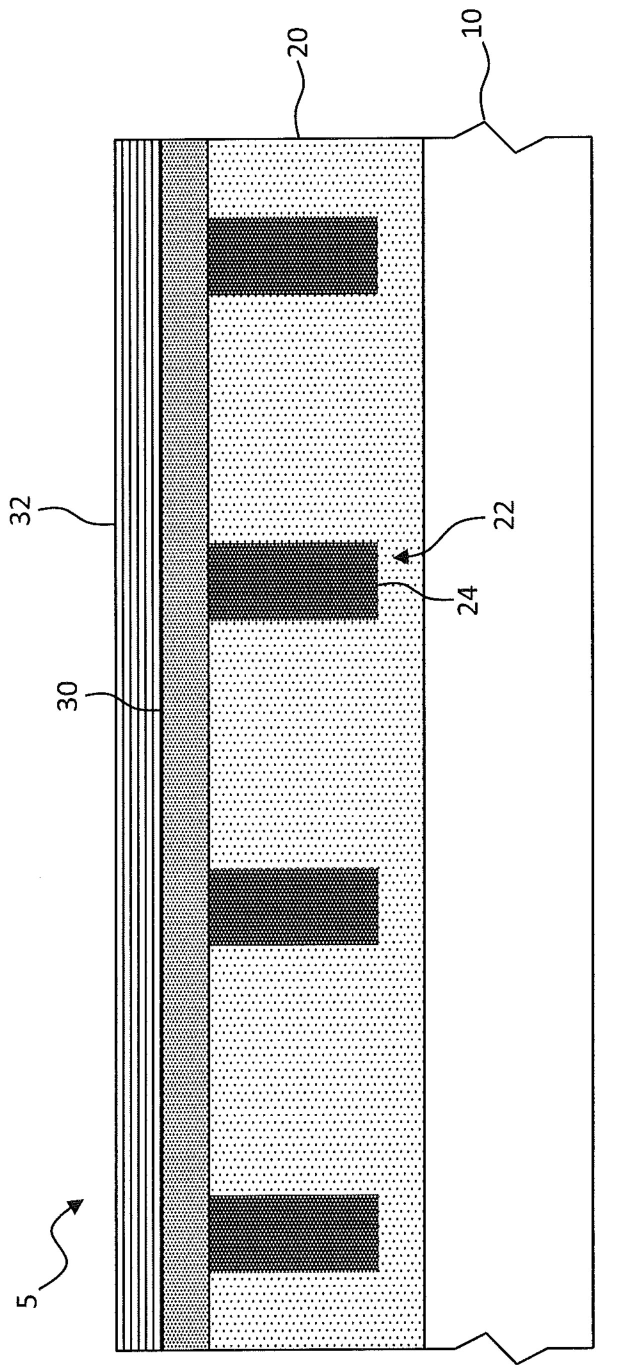


FIG. 2A

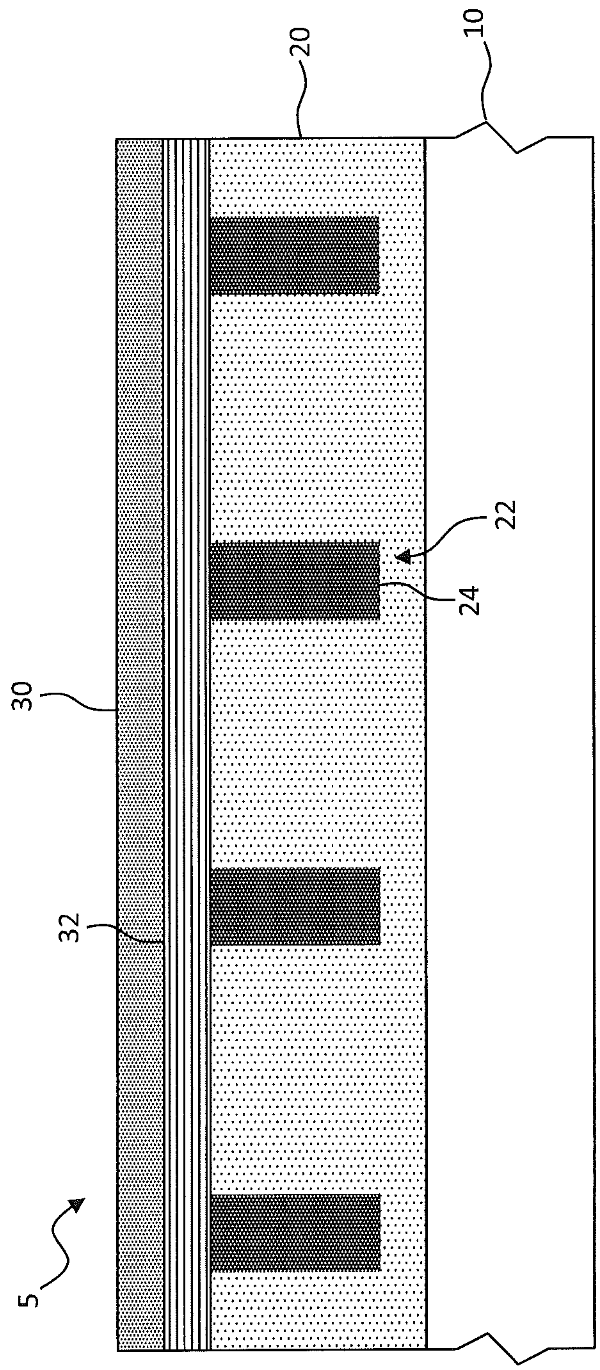


FIG. 2B

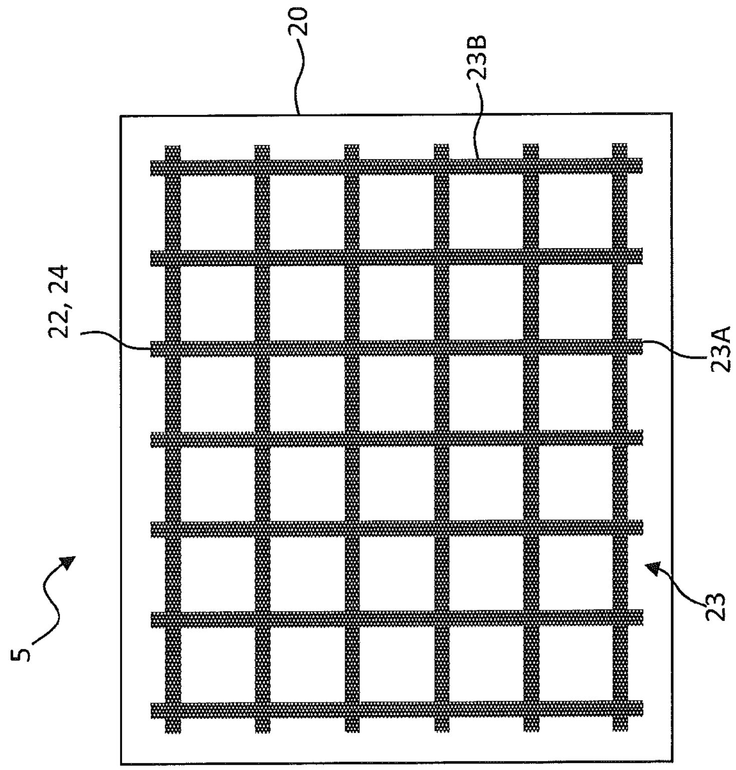


FIG. 4

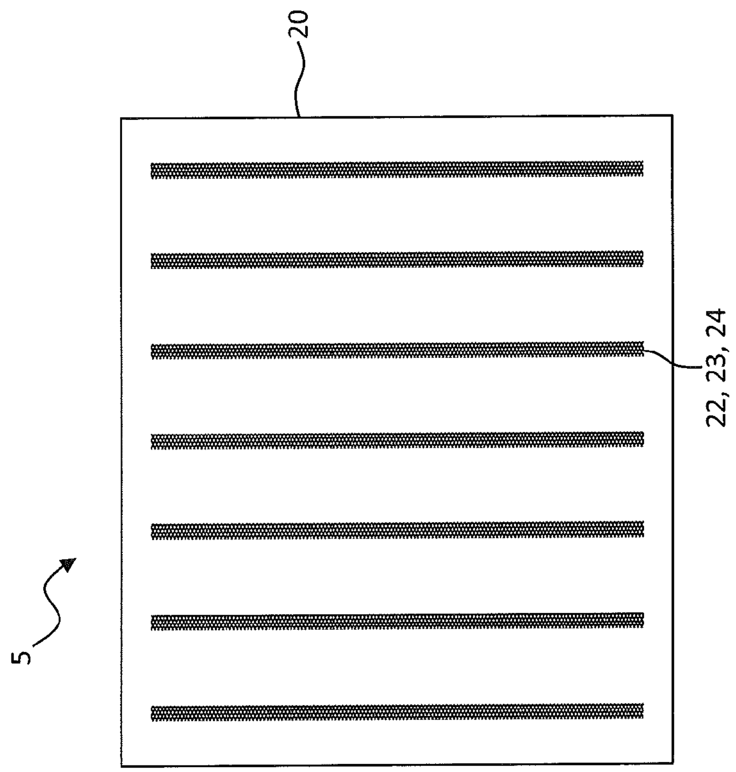


FIG. 3

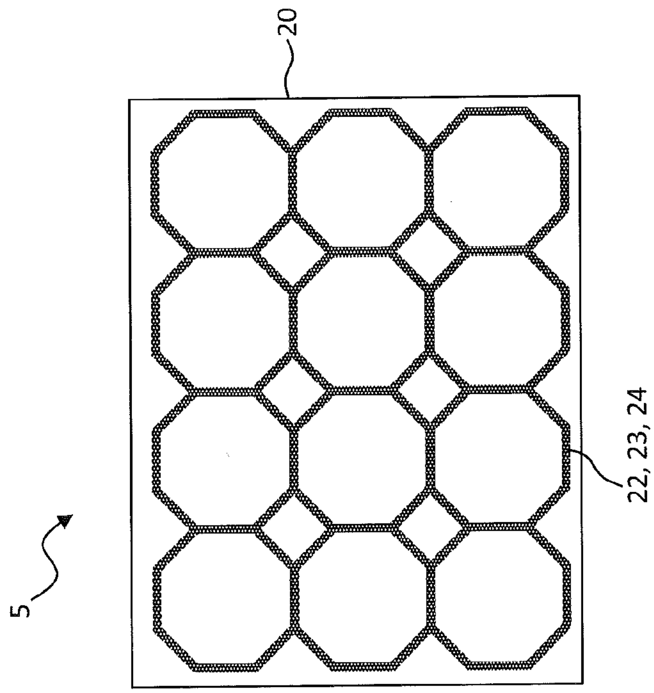


FIG. 6

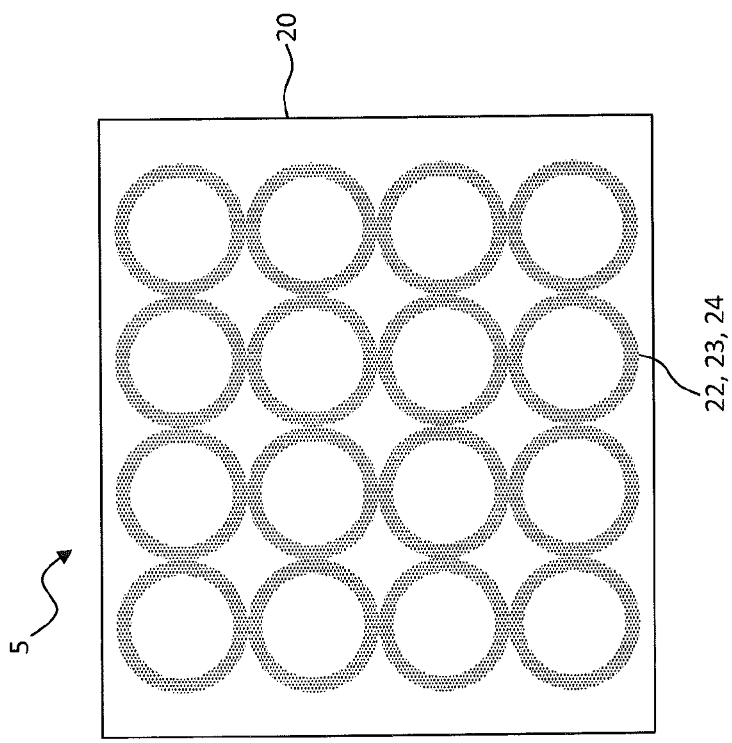


FIG. 5

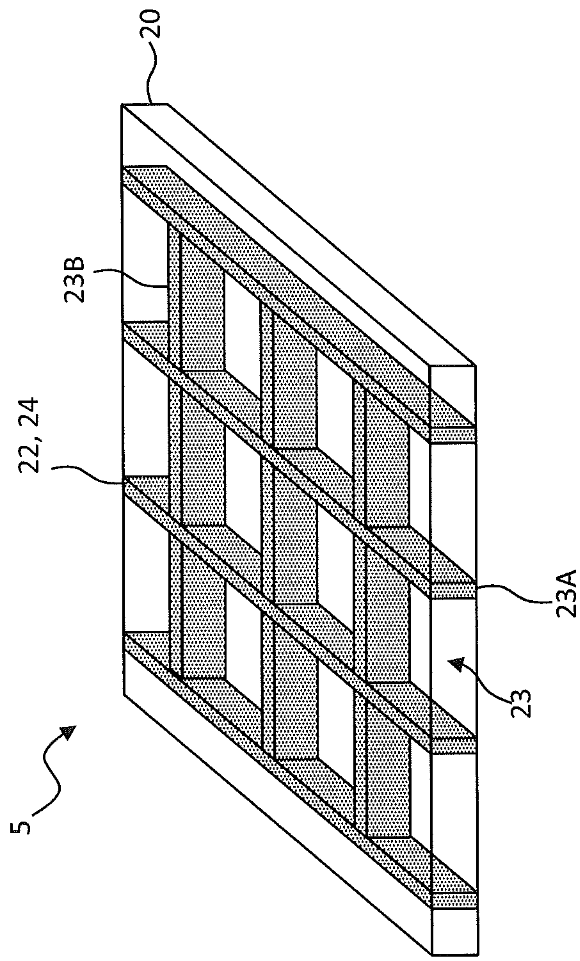


FIG. 7

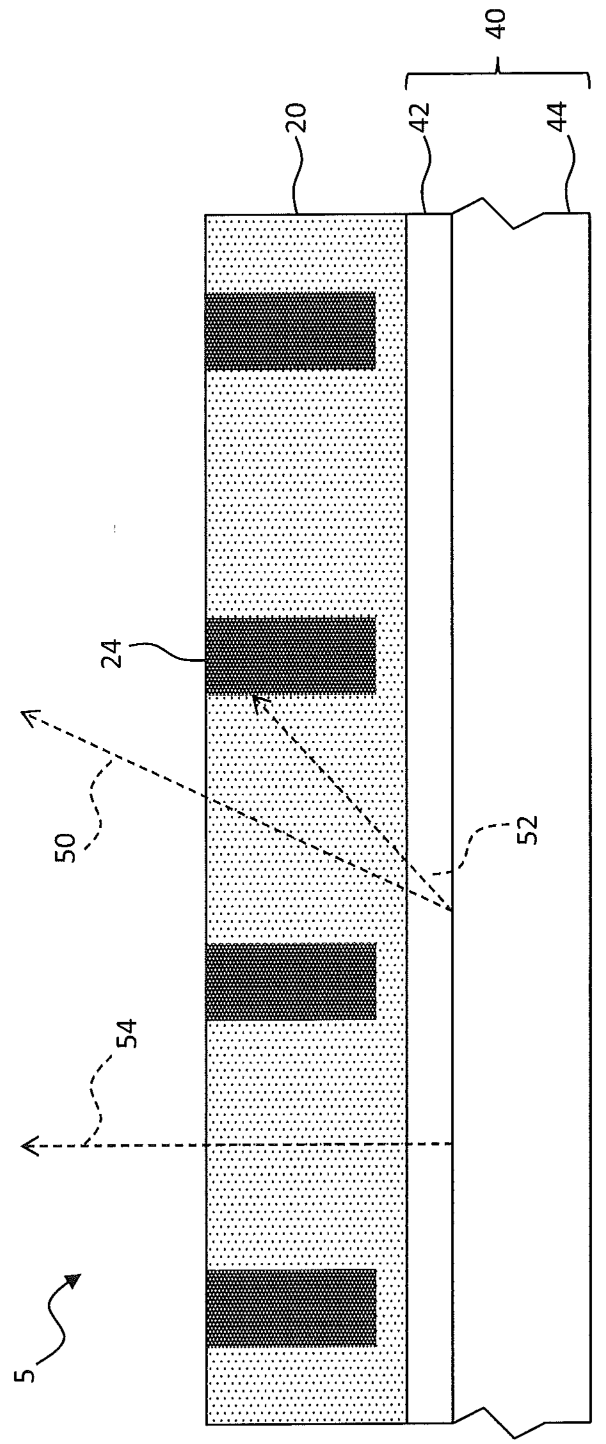


FIG. 8

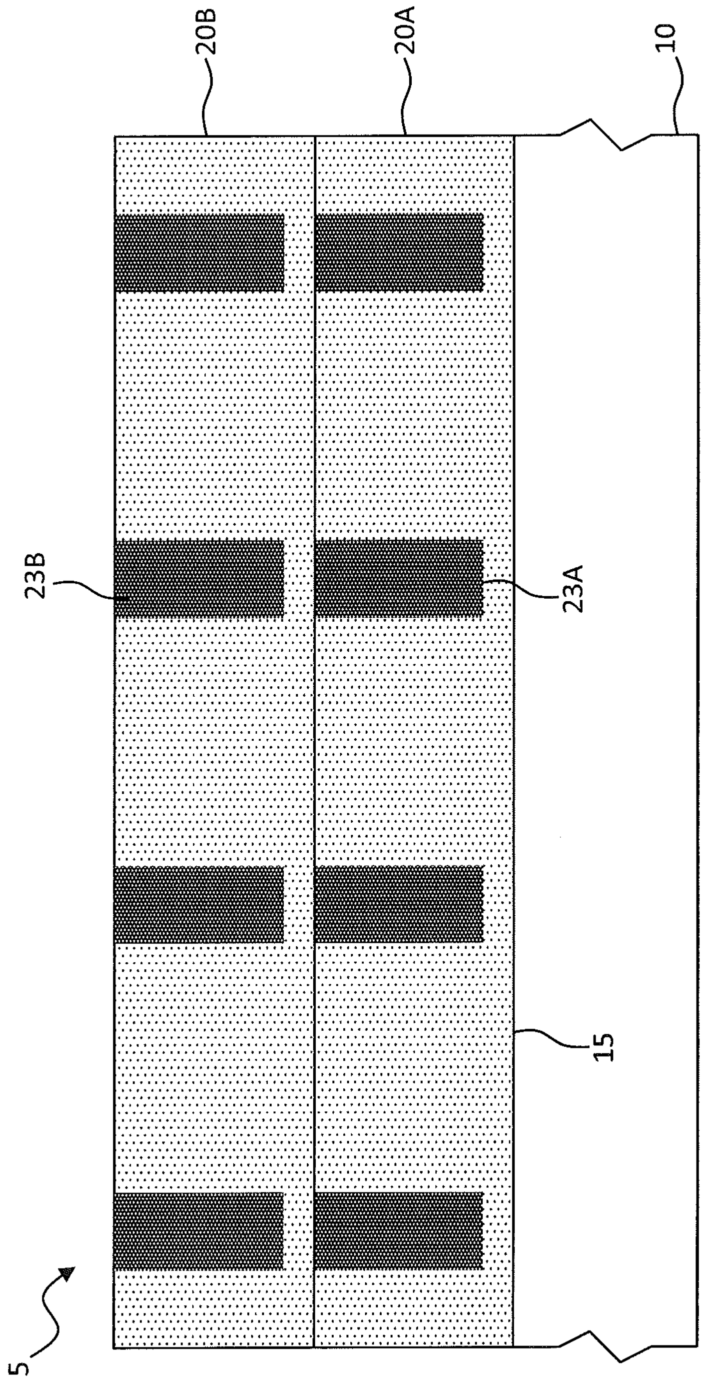


FIG. 9

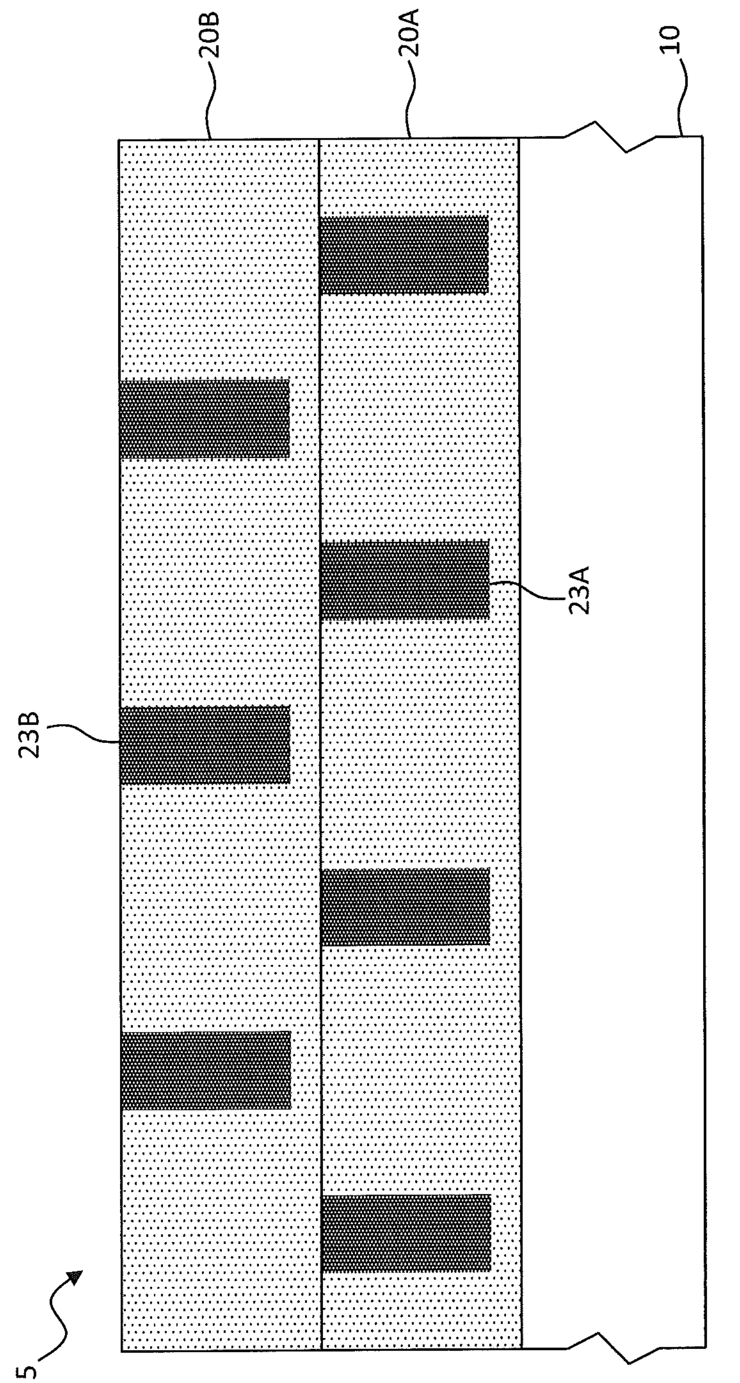


FIG. 10

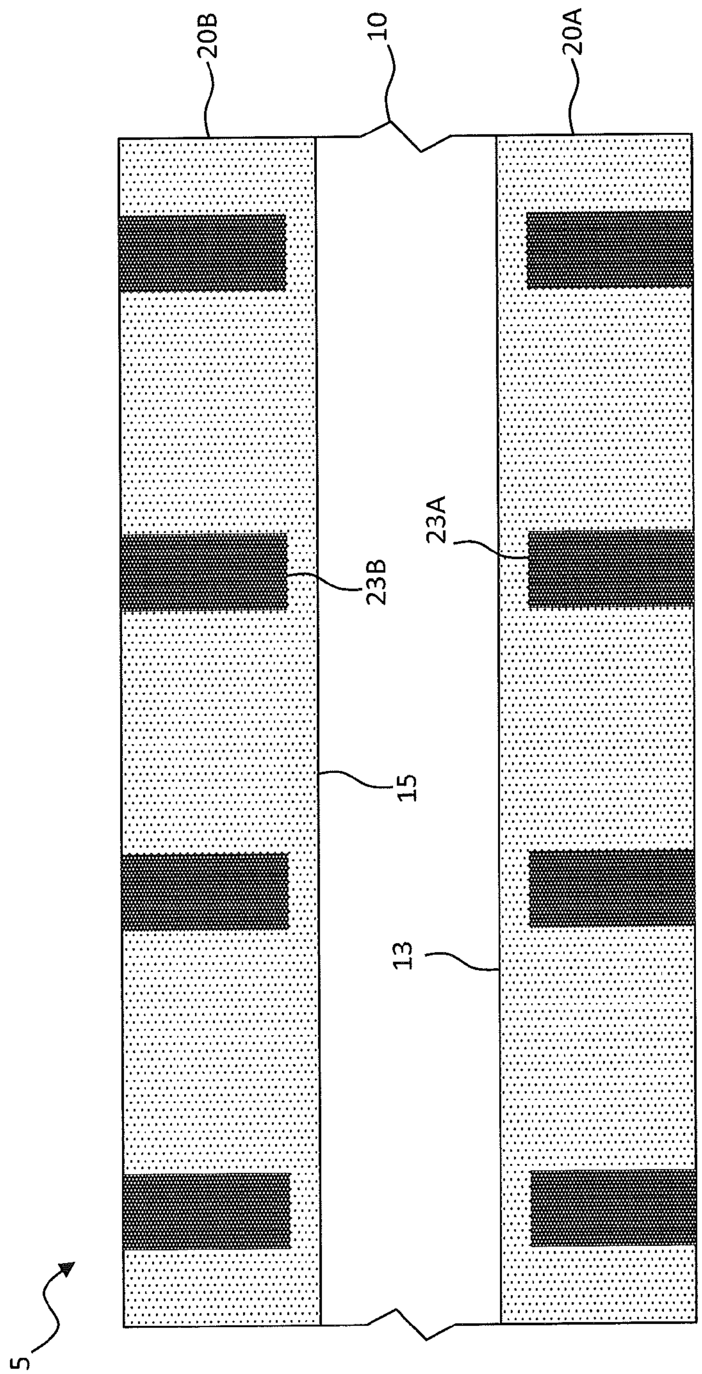


FIG. 11

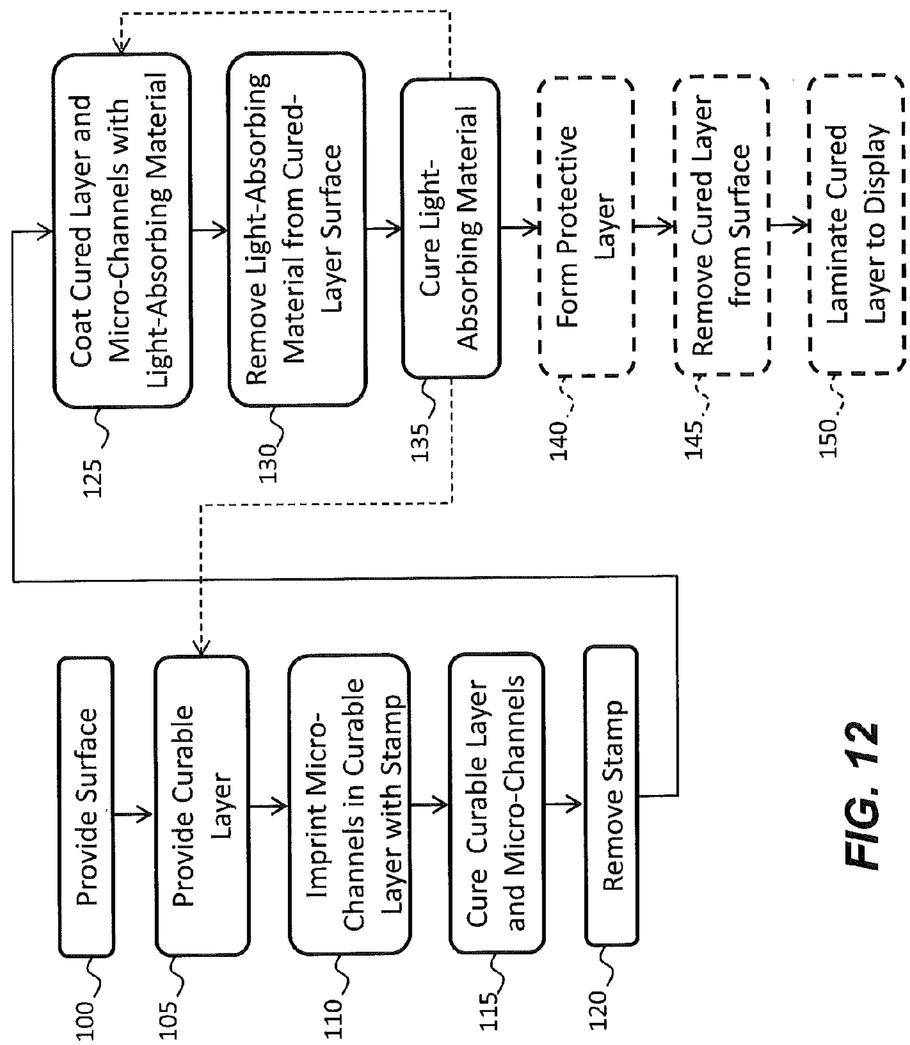

Provide Surface
Provide Curable Layer
Imprint Micro-Channels in Curable Layer with Stamp
Cure Curable Layer and Micro-Channels
Remove Stamp
Coat Cured Layer and Micro-Channels with Light-Absorbing Material
Remove Light-Absorbing Material from Cured-Layer Surface
Cure Light-Absorbing Material
Form Protective Layer
Remove Cured Layer from Surface
Laminate Cured Layer to Display
100
105
110
115
120
125
130
135
140
145
150

FIG. 12

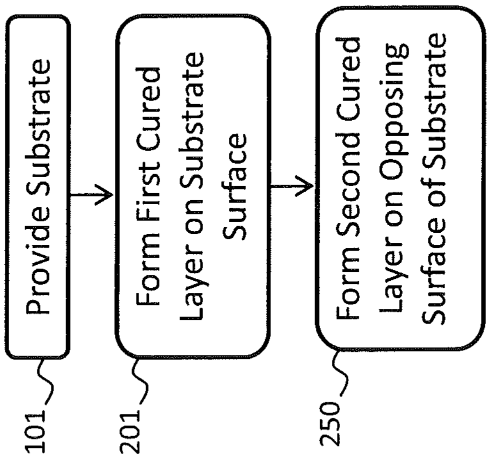

Provide Substrate
Form First Cured Layer on Substrate Surface
Form Second Cured Layer on Opposing Surface of Substrate
101
201
250

FIG. 14

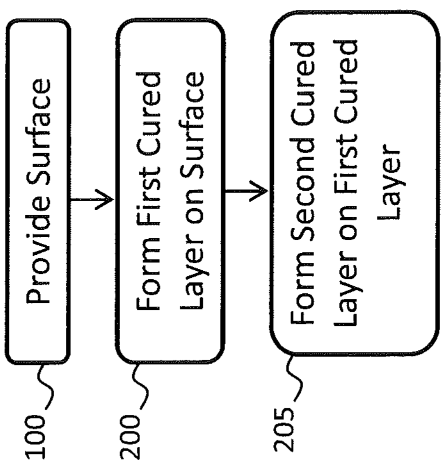

Provide Surface
Form First Cured Layer on Surface
Form Second Cured Layer on First Cured Layer
100
200
205

FIG. 13

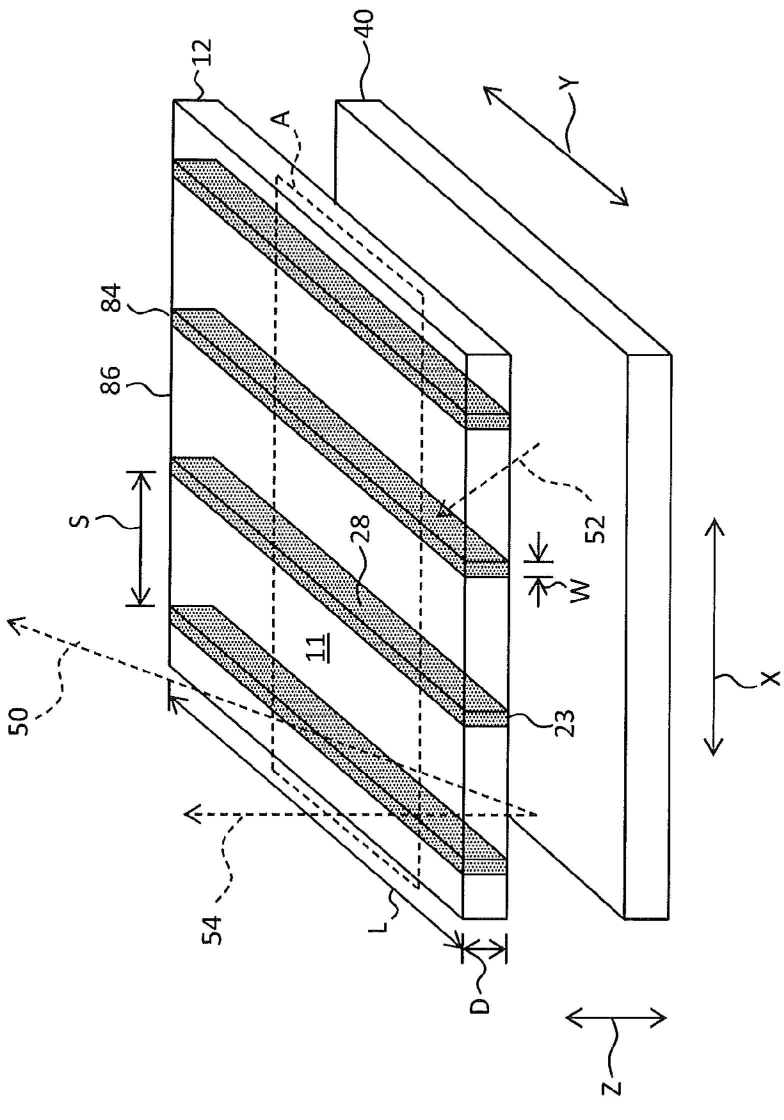


FIG. 15 – Prior Art

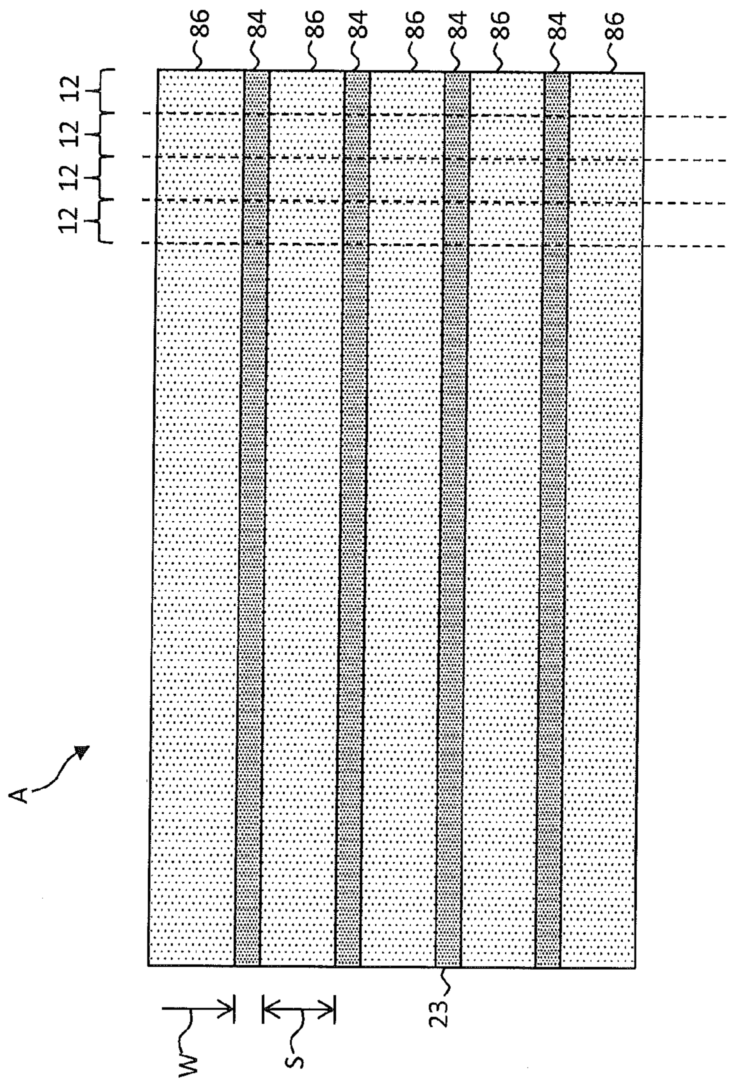


FIG. 16 – Prior Art

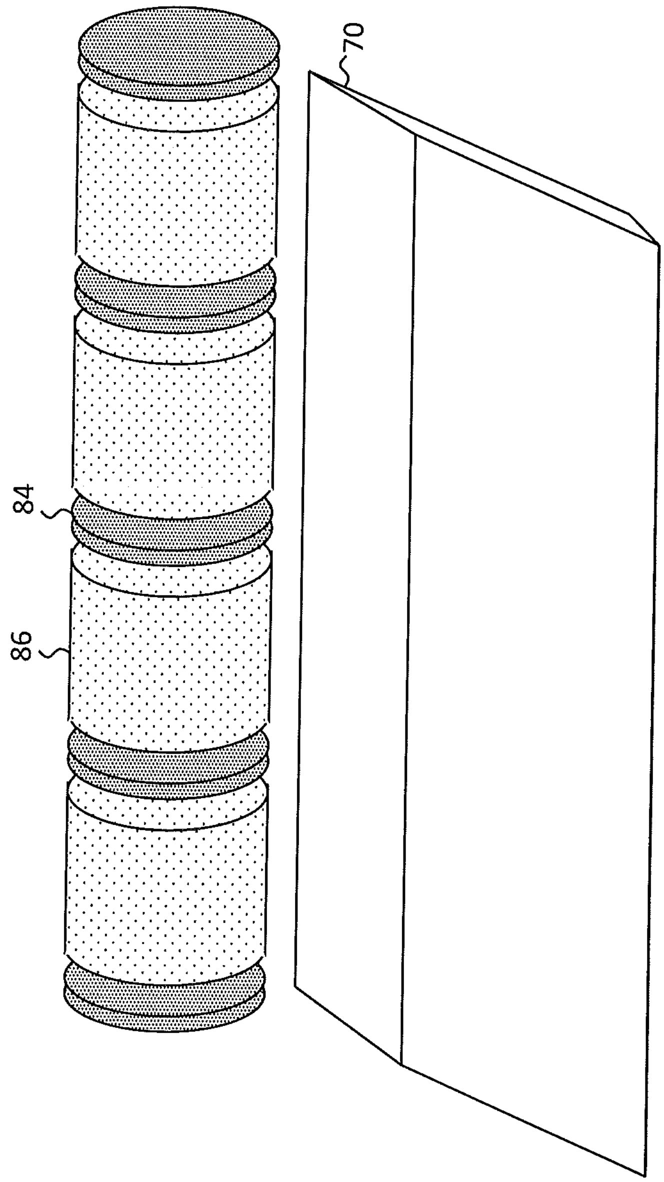


FIG. 17 – Prior Art

IMPRINTED MICRO-LOUVER STRUCTURE

CROSS REFERENCE TO RELATED APPLICATION

[0001] Reference is made to commonly-assigned U.S. patent application Ser. No. ______ filed concurrently herewith, entitled "Imprinted Micro-Louver Structure Method" by Ronald S. Cok, the disclosure of which is incorporated herein.

FIELD OF THE INVENTION

[0002] The present invention relates to micro-louver structures.

BACKGROUND OF THE INVENTION

[0003] Micro-louver structures are widely used for privacy screens to inhibit display viewing at large angles from an angle orthogonal to the display. Micro-louver structures are also useful for rejecting specular illumination of a surface at large angles from an angle orthogonal to the surface. For example, U.S. Pat. No. 5,543,870 describes a rear-projection screen with two crossed films of micro-louver light control material to provide a high degree of blocking of high-intensity light, such as sunlight that can impinge upon the front of the screen. U.S. Patent Application Publication 20090242142 describes a vertical micro-louver structure with variable angles or depths. U.S. Patent Application Publication 20080144179 describes a micro-louver sheet including a diffuser layer in a central portion of the sheet to vary the light distribution of the sheet.

[0004] Referring to the perspective of FIG. **15**, prior-art micro-louver structures are typically composed of alternating portions of a light-absorbing material **84** and a transparent material **86** arranged in a micro-louver sheet **12**. The light-absorbing material **84** extends a depth D in a z dimension Z orthogonal to a micro-louver sheet surface **11** of the micro-louver sheet **12** and in a y dimension Y a length L parallel to the micro-louver sheet surface **11** to form parallel micro-louvers **23** extending through and along the micro-louver sheet **12** leaving transparent portions of the micro-louver sheet **12** through which light **50** can pass. The width W of the micro-louvers **23** in an x dimension X parallel to the micro-louver sheet surface **11** and orthogonal to the Y dimension is relatively small compared to the length L of the micro-louvers **23** in the X dimension. It is also desirable that the width W of the micro-louvers **23** is relatively small compared to the depth D or a separation distance S between the micro-louvers **23** in the X dimension. In general, it is useful to make the width W of the micro-louvers **23** as small as possible to increase the transparency of the micro-louver sheet **12** in the Z dimension.

[0005] A cross-section A of the micro-louver sheet **12** in a plane parallel to the micro-louver sheet surface **11** has only a small proportion of the light-absorbing material **84** compared to the transparent material **86**. Hence, most of the light **54** passing through the micro-louver sheet **12** at an angle orthogonal to the surface of the micro-louver sheet **12** in dimension Z or light **50** emitted parallel to an extensive surface **28** of the light-absorbing material **84** in dimensions Y and Z will pass through the micro-louver sheet **12**. In contrast, blocked light **52** passing through the micro-louver sheet **12** at a larger angle to the orthogonal in dimension X or that is not parallel to the extensive surface **28** of the light-absorbing material **84** is absorbed by the light-absorbing material **84**. Thus, the blocked light **52** passing through the micro-louver sheet **12** at large angles from a display **40** located adjacent to the micro-louver sheet **12** cannot be seen in the X dimension, while orthogonal emitted light **54** passing through the micro-louver sheet **12** orthogonally to the micro-louver sheet **12** in the Z dimension or parallel to the extensive surface **28** of a light-absorbing material **24** in the Y or Z dimensions can be seen. The micro-louver sheet **12**, therefore, forms a privacy screen in the X dimension but not in the Y dimension.

[0006] The angle at which the blocked light **52** is absorbed in the X dimension and the transparency of micro-louver sheet **12** in the Z dimension depend upon the depth D and the separation distance S of the micro-louvers **23**. In prior-art systems, the micro-louver sheet **12** is laminated to a component of a display **40**, for example a display cover **42** through which light is emitted by the display **40**. Two privacy screens arranged with micro-louvers **23** at right angles to each other can provide privacy in two orthogonal dimensions.

[0007] In one prior-art method described in U.S. Patent Application Publication 20080144179, privacy screens are made by coating a layer of photo-sensitive resin on a first substrate. A mask is used to pattern the photo-sensitive resin. The mask has a pattern corresponding to the arrangement of light-absorbing material **84** and transparent material **86**. The pattern is etched into the exposed resin and a layer of curable material is coated over the photo-lithographically etched resin in a vacuum. The curable material is etched to expose the photo-sensitive resin layer, and cured. A transparent second substrate is then laminated to the resin layer. Alternatively, the second substrate is laminated after the resin is etched and curable material wicked into the etched areas using capillary forces, and cured. In yet another method, multiple resin layers having etched areas are laminated together forming gaps and curable material wicked into the gaps using capillary forces, and cured. These methods are limited in the depth they can achieve since photo-lithographic etching has a practical depth limitation or the patterns available are limited to those that can support etching. Furthermore, photo-lithographic processes are relatively expensive and slow.

[0008] In other prior-art methods described in U.S. Pat. No. 3,524,789, alternating layers of light-absorbing material **84** and light-transparent material **86** are laminated together, for example as shown in the cross-section A of FIG. **16**. Such layers can be formed by extrusion or by laminating pre-formed sheets together, as is also described in European Patent Application No. 466,460. The laminate is then cut into cross-sectional portions, each portion forming the micro-louver sheet **12** with micro-louvers **23** of width W separated by a separation distance S. Alternatively, as illustrated in the perspective of FIG. **17**, alternating layers of light-absorbing material **84** and light-transparent material **86** are formed in cylinders and laminated together. Thin micro-louver sheets **12** (not shown) are cut from the cylinder with a knife **70**.

[0009] These approaches use relatively thick layers of light-absorbing material **84** and light-transparent material **86** that limit the transparency of the resulting micro-louver sheet **12**. It is also difficult to make large micro-louver sheets **12** since it is difficult to cut large, thin sheets, for example using skiving. Furthermore, such sheets typically need additional processing to remove curl and polish the edges.

[0010] Attributes such as transparency, contrast, or reflectivity are important for optical systems. Overall thickness and cost are also important device attributes.

SUMMARY OF THE INVENTION

[0011] There is a need therefore for micro-louver structures and manufacturing methods providing improved transparency and reduced viewing angle, weight, thickness, and cost.

[0012] In accordance with the present invention, a micro-louver structure comprises:

[0013] a cured layer on a surface;

[0014] a plurality of micro-channels in the cured layer, wherein the micro-channels have a greater depth than width and are spaced apart by a separation distance greater than the width; and

[0015] a cured light-absorbing material in the micro-channels.

[0016] Structures and methods of the present invention provide improved transparency and reduced viewing angle, weight, thickness, and cost for micro-louver sheets. Improved transparency is provided by enabling reduced micro-louver thickness and fewer layers. Reduced viewing angle is provided by reduced micro-louver thickness, increased micro-louver depth, and multiple micro-louver layers. Reduced weight is provided by reducing the number and thickness of the various layers; reduced cost is achieved through a roll-to-roll manufacturing process that avoids patterned photo-lithographic exposure and etching steps and avoids skiving. Micro-louver sheets of the present invention are useful as privacy screens for display systems in one or two dimensions. In such an application, reduced reflectivity or improved contrast of the micro-louver sheets is desirable, as well as inhibited or restricted display viewing angle.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The above and other features and advantages of the present invention will become more apparent when taken in conjunction with the following description and drawings wherein identical reference numerals have been used to designate identical features that are common to the figures, and wherein:

[0018] FIG. **1** is a cross-sectional view of a micro-louver structure in an embodiment of the present invention;

[0019] FIGS. **2**A and **2**B are cross-sectional views of micro-louver structures in other embodiments of the present invention;

[0020] FIGS. **3-6** are plan views of micro-louver structures in various embodiments of the present invention;

[0021] FIG. **7** is a perspective of a micro-louver structure corresponding to FIG. **4** according to an embodiment of the present invention;

[0022] FIG. **8** is a cross-sectional view of a micro-louver structure and display in another embodiment of the present invention;

[0023] FIGS. **9-11** are cross-sectional views of layered micro-louver structures with different separations and spatial phases in other embodiments of the present invention;

[0024] FIGS. **12-14** are flow diagrams illustrating various methods of the present invention;

[0025] FIG. **15** is an exploded perspective of a prior-art micro-louver sheet;

[0026] FIG. **16** is a cross-sectional view of a prior-art micro-louver structure useful in understanding the manufacture of micro-louver sheets corresponding to FIG. **15**; and

[0027] FIG. **17** is a perspective of a prior-art micro-louver structure useful in understanding the manufacture of micro-louver sheets.

[0028] The Figures are not necessarily to scale, since the range of dimensions in the drawings is too great to permit depiction to scale.

DETAILED DESCRIPTION OF THE INVENTION

[0029] The present invention is directed to micro-louvers formed in sheets. In an embodiment of the present invention illustrated in FIG. **1**, a micro-louver structure **5** includes a cured layer **20** on a surface **15**, for example the surface **15** of a substrate **10**. The cured layer **20** has a plurality of imprinted micro-channels **22** forming a pattern in the cured layer **20**. The imprinted micro-channels **22** have a greater depth D than a width W and are spaced apart by a separation distance S greater than the width W of the imprinted micro-channel **22**. A cured light-absorbing material **24** is located in the imprinted micro-channels **22**. The cured light-absorbing material **24** in the imprinted micro-channels **22** form micro-louvers **23** in the micro-louver sheet **12** including the cured layer **20**.

[0030] In an embodiment, the cured layer **20** is formed on the surface **15** of the substrate **10**. In another embodiment, the imprinted micro-channels **22** and the cured light-absorbing material **24** extend only partially through the cured layer **20** from a surface **11** of the cured layer **20**. The surface **11** of the cured layer **20** is also a micro-louver sheet surface **11**. The cured layer **20** is substantially transparent, having a transparency greater than or equal to 50%, 70, 80%, 90%, or 95%.

[0031] Referring to the cross-sectional view of FIG. **2**A, the micro-louver structure **5** includes a protective layer **30** on the cured layer **20** and in contact with the cured light-absorbing material **24** in the imprinted micro-channels **22**. In an embodiment, the protective layer **30** is itself a cured layer or includes the same material as the cured layer **20**. In alternative embodiments, the protective layer **30** is laminated as a sheet to the micro-louver sheet **12** or is coated as an uncured layer and then cured, for example with radiation. In an embodiment, anti-reflective layers **32** are located on the protective layer **30** opposite the cured layer **20**. Referring to FIG. **2**B in another embodiment, other layers, for example the anti-reflective layers **32**, are located between the protective layer **30** and the cured layer **20** in the micro-louver structure **5** so that the protective layer **30** is not in contact with the light-absorbing material **24**. The anti-reflective layers **32** serve to reduce reflections from the surface of the cured layer **20** (FIG. **2**B) or protective layer **30** (FIG. **2**A).

[0032] In an embodiment, an uncured curable layer **20** is coated over the substrate **10** and cured to form cured layer **20**. The curable layer **20** can include cross-linking materials that are cured, for example with radiation, to form the cured layer **20**. Similarly, uncured curable light-absorbing material **24** is coated over the substrate **10** and cured to form the cured light-absorbing material **24** in the imprinted micro-channels **22**. The curable light-absorbing materials **24** can include cross-linking materials that are cured, for example with radiation, to form the cured light-absorbing material **24** and the micro-louvers **23**.

[0033] As used herein, a cured layer or material is cured in situ after it has been placed in its final location. For example, the curable layer **20** is coated on substrate **10** and then cured. The curable layer **20** is not first cured and then subsequently located on substrate **10**. Similarly, the curable light-absorbing material **24** is first located in the imprinted micro-channels **22**, for example by coating, and then cured. The curable light-absorbing material **24** is not first cured and then subsequently located in the imprinted micro-channels **22**. Such a curing method enables efficient and effective construction of the elements of the present invention. An example of a suitable material for a curable layer is SU8, a well-known material in the photo-lithographic arts. In the Figures, the imprinted micro-channels **22** are indicated with an arrow while the cured light-absorbing material **24** in the imprinted micro-channels **22** is indicated with a lead line. The light-absorbing material **24** in the imprinted micro-channels **22** form the micro-louvers **23**. Furthermore, the layer **20** is referred to as both a curable layer **20** and a cured layer **20**, depending on whether the material making up the layer **20** has been cured or not. Similarly, the light-absorbing material **24** is referred to as both a curable light-absorbing material **24** and a cured light-absorbing material **24**, depending on whether the light-absorbing material **24** has been cured or not.

[0034] The substrates **10**, for example made of glass or plastic, curable layers **20**, for example including curable resins, and curable light-absorbing materials, for example including carbon black in a curable resin, are known in the art as are methods for their preparation, deposition, and curing.

[0035] In a further embodiment of the present invention, the cured light-absorbing material **24** is cross-linked to the cured layer **20**. In such an embodiment, both the curable light-absorbing material **24** and the curable layer **20** can include cross-linkable materials that cross link when cured. For example, both the curable light-absorbing material **24** and the curable layer **20** can include a common curable resin, for example cured with ultra-violet radiation or heat, that cross links when cured. Such cross-linking between the cured light-absorbing material **24** and the cured layer **20** improves the strength of the micro-louver sheet **12** and improves the scratch resistance of the micro-louvers **23**.

[0036] In an embodiment of the present invention, the depth D of the imprinted micro-channels **22** (and micro-louvers **23**) is at least two times, four times, ten times, fifteen times, twenty times, thirty times, or fifty times greater than the width W. As the depth D of the micro-louvers **23** increases and the width W decreases, the viewing angle of the micro-louver structure **5** decreases and the transparency of the micro-louver structure **5** increases. Therefore, in an embodiment of the present invention, the width W of the imprinted micro-channels **22** is less than or equal to four microns, two microns, or one micron.

[0037] In an embodiment, a cross-section of the imprinted micro-channels **22** in a plane parallel to the micro-louver sheet surface **11** of the cured layer **20** substantially forms an array of lines in one direction. Referring to FIG. **3**, the micro-louver structure **5** includes the cured layer **20** having cured light-absorbing material **24** in lines of imprinted micro-channels **22** forming micro-louvers **23**. In this embodiment, a privacy screen will limit a user's view in a direction orthogonal to the line direction.

[0038] In an alternative embodiment, a cross-section of the imprinted micro-channels **22** in a plane parallel to the micro-louver sheet surface **11** of the cured layer **20** substantially forms rows and columns of lines extending in two different directions forming a grid. Referring to FIG. **4** in a cross-sectional view and to FIG. **7** in perspective, the micro-louver structure **5** includes the cured layer **20** having cured light-absorbing material **24** in lines of imprinted micro-channels **22** forming micro-louvers **23** in two dimensions. Micro-louvers **23**A extend in one dimension and micro-louvers **23**B extend in an orthogonal dimension. In this embodiment, a privacy screen will limit a user's view in both of two orthogonal directions. Such a structure cannot be made with the prior-art methods illustrated in FIGS. **16** and **17**.

[0039] According to various embodiments of the present invention, the micro-louvers **23** need not form straight lines (when viewed in plan view) or portions of a plane (when viewed from the side). For example, referring to FIG. **5**, the micro-louver structure **5** includes the cured layer **20** having cured light-absorbing material **24** in circular imprinted micro-channels **22** forming circular micro-louvers **23**. Alternatively, referring to FIG. **6**, the micro-louver structure **5** includes the cured layer **20** having cured light-absorbing material **24** in octagonal imprinted micro-channels **22** forming octagonal micro-louvers **23**. Thus, micro-louvers **23** can form circles, polygons, or other regular or irregular shapes. In some embodiments, the shapes form simple closed curves, in others the shapes are curves, lines, line segments, are interconnected or are separate.

[0040] Referring to FIG. **8** in yet another embodiment of the present invention, the micro-louver structure **5** of the present invention is incorporated as a component into a system including the display **40** with a display substrate **44** and the display cover **42**. The cured layer **20** is formed on, or laminated to, the display cover **42**. In this embodiment, the substrate **10** of FIG. **1** is a component of the display **40** and corresponds to the display cover **42**. The display **40** can be, for example, a liquid crystal display or top-emitting organic light-emitting diode (OLED) display. In an alternative embodiment (not shown), the substrate **10** is the display substrate **44**, for example in a bottom-emitting OLED display. Other materials or structures are formed in the display **40** between the display cover **42** and the display substrate **44** but are not illustrated, for example electrode layers, backlights, liquid crystal layers, or organic material layers.

[0041] As illustrated in FIG. **8**, the orthogonal emitted light **54** emitted orthogonally from the display **40** passes through the micro-louver structure **5**. The light **50** emitted at a small angle to the display **40** orthogonal also passes through the micro-louver structure **5**. However, the blocked light **52** emitted at a large angle to the display **40** orthogonal is absorbed by the light-absorbing material **24** of the micro-louver structure **5**. Thus, the micro-louver structure **5** forms a privacy screen for the display **40**.

[0042] In another embodiment of the present invention, two cured layers **20** are located together in a spatial relationship. As illustrated in FIGS. **9** and **10**, the micro-louver structure **5** includes a first cured layer **20**A with micro-louvers **23**A. The first cured layer **20**A is formed on the surface **15** of the substrate **10**. A second cured layer **20**B with micro-louvers **23**B is formed on the substrate first cured layer **20**A. As illustrated in FIG. **9**, the micro-louvers **23**A in the first cured layer **20**A are spatially in phase with the micro-louvers **23**B in the second cured layer **20**B. As illustrated in FIG. **10**, the micro-louvers **23**A in the first cured layer **20**A are spatially out of phase with the micro-louvers **23**B in the second cured layer **20**B by 180 degrees.

[0043] Referring to FIG. **11**, the substrate **10** of the micro-louver structure **5** has the substrate surface **15** and an opposed substrate surface **13**. In this embodiment, the two cured layers **20**A, **20**B and the micro-louvers **23**A, **23**B are located on the opposing surfaces **13**, **15** of the substrate **10**. As illustrated, the micro-louvers **23**A, **23**B are spatially in phase, but in an alternative embodiment (not shown), the micro-louvers **23**A, **23**B are spatially out of phase, for example but not necessarily 180 degrees out of phase.

[0044] By locating the micro-louvers **23**A and the micro-louvers **23**B in a spatial relationship, the effective optical depth of the micro-louvers **23**A, **23**B is increased, thus reducing further the viewing angle of the micro-louver structure **5**. Whether multiple cured layers **20** or in-phase or out-of-phase micro-louvers is desired depends at least in part on the separation distance S, depth D, or width W of the micro-louvers (as shown in FIG. **1**), and the desired viewing angle characteristics.

[0045] The substrate **10** of FIGS. **9-11** can be a component of the display **40**, for example the display cover **42** or the display substrate **44**.

[0046] A micro-louver structure **5** of the present invention is used by locating the micro-louver structure **5** in an optical system in which it is desired to inhibit transmission through the optical system at large angles to the optical axis. The micro-louver structure **5** can also be used by locating the micro-louver structure **5** over the display **40** and viewing the display **40** and micro-louver structure **5** at an orthogonal to the display **40** and not viewing the display **40** and micro-louver structure **5** at angles that are large with respect to an orthogonal to the display **40**.

[0047] Referring to FIG. **12**, a method of the present invention includes making the micro-louver structure **5** that includes providing the substrate surface **15** in step **100**. The curable layer **20** is provided in step **105** on the substrate surface **15**, for example by coating. A wide variety of coating techniques are available and known in the art, for example spray coating, curtain coating, hopper coating, slot coating, or transfer coating. The curable layer **20** can include a photo-curable or heat-curable resin. Such resins are known in the art.

[0048] In step **110**, the pattern of micro-channels **22** is imprinted in the curable layer **20**. The imprinted micro-channels **22** have a greater depth D than width W and are spaced apart by a separation distance S greater than the width W. The imprinted micro-channels **22** are imprinted using a stamp located in the curable layer **20** and the curable layer **20** is at least partially cured in step **115** to form the cured layer **20**. The stamp has a relief pattern that is the inverse of the micro-channel pattern. Imprinted micro-channels **22** having a depth D more than two to six times that of width W for various widths W, for example between 1 and 5 microns, have been demonstrated. Methods for making stamps, locating them in the coated curable layer **20**, and curing the curable layer **20** to form the cured layer **20** with micro-channels **22** imprinted therein are known in the art.

[0049] In step **120**, the stamp is removed leaving the cured layer **20** with imprinted micro-channels **22**. A curable light-absorbing material **24** is coated over the cured layer **20** and in the imprinted micro-channels **22** in step **125**. At least a portion of the light-absorbing material **24** is removed in step **130** from the micro-louver sheet surface **11** of the cured layer **20** and at least a portion of the light-absorbing material **24** is left in the imprinted micro-channels **22**. In step **135**, the light-absorbing material **24** is cured to form a light-absorbing micro-louver structure **5** in each micro-channel **22**.

[0050] In a further embodiment of the present invention, the cured layer **20** is optionally polished or an optional protective layer **30** is formed in step **140**. Alternatively, the cured layer **20** is removed from the substrate surface **15** (step **145**) and laminated to another surface (step **150**). For example, the cured layer **20** is laminated to the display cover **42** or display substrate **44**.

[0051] As shown in FIG. **12**, the steps **125**, **130**, and **135** of coating the cured layer **20** and the imprinted micro-channels **22** with the curable light-absorbing material **24**, removing the excess curable light-absorbing material **24** from the cured-layer surface **11**, and curing the light-absorbing material **24** are repeated as necessary to fill the imprinted micro-channels **22** with cured light-absorbing material **24**.

[0052] In another embodiment, multiple layers **20** of cured material are iteratively coated over the cured layer **20** (step **105**), imprinted (step **110**), cured (step **115**), the imprinting stamp removed (step **120**), the cured layer **20** coated with light-absorbing material **24** (step **125**), excess light-absorbing material **24** removed (step **130**) and cured (step **135**) to create micro-louver structures **5** such as those illustrated in FIGS. **9** and **10**. As illustrated in FIG. **13**, multiple layers **20** of cured material are provided. In step **100**, the substrate surface **15** is provided. The first cured layer **20**A is formed on the substrate surface **15** in step **200** (including steps **105-135** of FIG. **12**). The second cured layer **20**B is formed in step **205** (including the same steps as for the first cured layer **20**A) on the first micro-louver sheet surface **11**.

[0053] Alternatively, a micro-louver structure **5** is formed on either side of the substrate **10**. As illustrated in FIG. **14**, a substrate **10** having two opposing substrate surfaces **13**, **15** is provided in step **101**. The first cured layer **20**A is formed on the substrate surface **13** in step **201** (including steps **105-135** of FIG. **12**). The second cured layer **20**B is formed on the opposing substrate surface **15** in step **250** (including the same steps as for the first cured layer **20**A).

[0054] In various embodiments, the curable layer **20** or the light-absorbing material **24** is provided including cross-linking materials. The curable layer **20** or the light-absorbing material **24** is cured with electromagnetic radiation or heat. In one embodiment, the step of curing the light-absorbing material **24** also at least partially cures the curable layer **20** so that the curable layer **20** is cross linked to the light-absorbing material **24**.

[0055] In other embodiments, methods of the present invention include forming the depth of the imprinted micro-channels **22** to be at least two times greater than the width of the imprinted micro-channels **22**, four times greater than the width, five times greater than the width, eight times greater than the width, or ten times greater than the width. In another embodiment, a method of the present invention includes forming the width of the imprinted micro-channels **22** to be less than or equal to four microns, two microns, or one micron.

[0056] In another embodiment of the present invention, a method includes forming imprinted micro-channels **22** so that a cross-section of the imprinted micro-channels **22** in a plane parallel to the surface of the cured layer **20** substantially forms an array of lines in one direction (as illustrated in FIG. **3**). Alternatively, a method includes forming imprinted micro-channels **22** so that a cross-section of the imprinted micro-channels **22** in a plane parallel to the surface of the cured layer **20** substantially forms a grid in one direction (as illustrated in FIG. **4**). In other embodiments, methods of the present invention include forming imprinted micro-channels **22** so that a cross-section of the imprinted micro-channels in a plane parallel to the surface of the cured layer **20** substantially forms one or more polygons (as shown in FIG. 6) or one or more circles (as shown in FIG. 5).

[0057] In another embodiment of the present invention, the imprinted micro-channels **22** are formed to extend only partially through the curable layer **20**, as illustrated in FIG. **1**.

[0058] Another method of the present invention included laminating two or more micro-louver structures **5** together or forming two micro-louver structures **5** and laminating the two micro-louver structures **5** together (as shown in FIG. **9**). The step of laminating can further include laminating the two micro-louver structures **5** together spatially in phase or spatially 180 degrees out of phase (as shown in FIGS. **9** and **10**). Alternatively, a method of the present invention can further include providing the substrate **10** and forming two micro-louver structures **5** on opposing substrate surfaces **13**, **15** of the substrate **10**. The micro-louver structures **5** can be formed spatially in phase or spatially 180 degrees out of phase.

[0059] A method of making a micro-louver structure **5** for use with the display **40** that permits orthogonal display viewing while inhibiting display viewing at larger angles to the orthogonal includes forming the micro-louver structure **5** by coating the curable layer **20** on a surface, for example a substrate surface **15** and imprinting a pattern of micro-channels **22** in the curable layer **20**. The imprinted micro-channels **22** have a greater depth D than width W and are spaced apart by a separation distance S greater than the width W. The curable layer **20** is at least partially cured to form a cured layer **20** that is coated with a light-absorbing material **24** in the imprinted micro-channels **22**. At least a portion of the light-absorbing material **24** is removed from the micro-louver sheet surface **11** of the cured layer **20** leaving at least a portion of the light-absorbing material **24** in the imprinted micro-channels **22**. The light-absorbing material **24** is cured to form a light-absorbing structure forming a micro-louver **23** in each imprinted micro-channel **22**. The micro-louver structure **5** is located on a viewing surface of the display **40**, whereby orthogonal display viewing is enabled while display viewing at larger angles is inhibited. Alternatively, the micro-louver structure **5** is formed on a substrate **10** that is an element of the display **40**, for example the display cover **42** or display substrate **44**.

[0060] According to various embodiments of the present invention, a substrate **10** is any material having the substrate surface **15** on which the curable layer **20** can be formed. For example, glass and plastic are suitable materials known in the art from which the substrates **10** can be made into sheets of material having substantially parallel opposed sides, one of which is the substrate surface **15**. In various embodiments, substrate **10** is rigid, flexible, or transparent.

[0061] The substrate **10** can have a wide variety of thicknesses, for example 10 microns, 50 microns, 100 microns, 1 mm, or more. In various embodiments of the present invention, the substrate **10** is provided as an element of other devices, for example the display cover **42** or display substrate **44** of the display **40** or the curable layer **20** is coated on another underlying substrate **10**, for example by coating the curable polymer layer on an underlying glass substrate **10**, such as the display cover **42**. Alternatively, the substrate **10** can be affixed to the display **40** or other device.

[0062] An imprinted micro-channel **22** is a groove, trench, or channel formed in the curable layer **20** and extending from the cured-layer surface **11** toward substrate **10** and having a cross-sectional width W, for example less than or equal to 20 microns, 10 microns, 5 microns, 4 microns, 3 microns, 2 microns, 1 micron, or 0.5 microns. In an embodiment, the cross-sectional depth D of the imprinted micro-channel **22** is greater than or equal to twice the width W, five times the width W, ten times the width W, fifteen times the width W, twenty times the width W, thirty times the width W, or fifty times the width W. The micro-channels **22** can have a rectangular cross-section, as shown. Other cross-sectional shapes, for example trapezoids, are known and are included in the present invention.

[0063] Material compositions useful in the curable layer **20** or the curable light-absorbing material **24** can be provided in one state and then processed into another state, for example converted from a liquid state into a solid state. Such conversion can be accomplished in a variety of ways, for example by drying or heating. Furthermore, useful material compositions can include a set of materials that, after deposition and processing, is reduced to a subset of the set of materials, for example by removing solvents from the material composition. For example, a material composition including a solvent is deposited and then processed to remove the solvent leaving a material composition without the solvent in place. Thus, according to embodiments of the present invention, a material composition that is deposited on the substrate **10** or in the imprinted micro-channels **22** is not necessarily the same composition as that found in the cured material composition.

[0064] In one embodiment, the light-absorbing material **24** includes carbon black, a black dye, or a black pigment. In another embodiment, the light-absorbing material **24** includes a colored dye or a colored pigment other than black. U.S. Patent Application Publication No. 2008/0257211 discloses a variety of metallic colored inks and its contents are hereby incorporated by reference. In a further embodiment, the substrate **10** and the cured layer **20** are substantially transparent.

[0065] Curing material compositions such as those in the curable layer **20** or in the curable light-absorbing material **24** can be done by drying or heating in stages. In particular, if the curable layer **20** is a polymer layer, heating the polymer layer slightly can soften the polymer so that particles, for example black pigment or carbon black particles in the light-absorbing material **24** can adhere to the polymer. Such heating can be done by convective heating (putting substrate **10** into an oven) or by infrared radiation. Heating with infrared radiation has the advantage that light-absorbing particles, for example black particles, differentially absorb the infrared radiation and heat up more than substrate **40** or curable layer **20** (that can be transparent), thus providing a more efficient adhesion or drying process for a material composition. Adhesion of the curable layer **20** to the light-absorbing material **24** is advantageous because such adhered materials are more resistant to mechanical abrasion and are thus more environmentally robust.

[0066] Methods and device for forming and providing substrates, coating substrates, patterning coated substrates, or pattern-wise depositing materials on a substrate are known in the photo-lithographic arts. Likewise, tools for laying out electrodes, conductive traces, and connectors are known in the electronics industry as are methods for manufacturing such electronic system elements. Hardware controllers for controlling touch screens and displays and software for managing display and touch screen systems are all well known. All of these tools and methods can be usefully employed to design, implement, construct, and operate the present invention. Methods, tools, and devices for operating capacitive touch screens can be used with the present invention.

[0067] The present invention is useful in a wide variety of electronic devices. Such devices can include, for example, photovoltaic devices, OLED displays and lighting, LCD displays, plasma displays, inorganic LED displays and lighting, electrophoretic displays, electrowetting displays, dimming mirrors, smart windows, transparent radio antennae, transparent heaters and other touch screen devices such as resistive touch screen devices.

[0068] The invention has been described in detail with particular reference to certain embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

PARTS LIST

[0069] A cross-section
[0070] D depth
[0071] L length
[0072] S separation distance
[0073] W width
[0074] X x dimension
[0075] Y y dimension
[0076] Z z dimension
[0077] **5** micro-louver structure
[0078] **10** substrate
[0079] **11** surface
[0080] **12** micro-louver sheet
[0081] **13** opposed substrate surface
[0082] **15** substrate surface
[0083] **20** curable/cured layer
[0084] **20**A first curable/cured layer
[0085] **20**B second curable/cured layer
[0086] **22** imprinted micro-channel
[0087] **23** micro-louver
[0088] **23**A micro-louver
[0089] **23**B micro-louver
[0090] **24** light-absorbing material
[0091] **26** transparent material
[0092] **28** extensive surface
[0093] **30** protective layer
[0094] **32** anti-reflective layer
[0095] **40** display
[0096] **42** display cover
[0097] **44** display substrate

Parts List Cont'd

[0098] **50** light
[0099] **52** blocked light
[0100] **54** orthogonal emitted light
[0101] **70** knife
[0102] **84** light-absorbing material
[0103] **86** transparent material
[0104] **100** provide surface step
[0105] **101** provide substrate step
[0106] **105** provide curable layer step
[0107] **110** imprint micro-channels in curable layer with stamp step
[0108] **115** cure curable layer and micro-channels step
[0109] **120** remove stamp step
[0110] **125** coat cured layer and micro-channels with light-absorbing material step
[0111] **130** remove light-absorbing material cured-layer surface step
[0112] **135** cure light-absorbing material step
[0113] **140** optional form protective layer step
[0114] **145** remove cured layer from surface step
[0115] **150** laminate cured surface to display step
[0116] **200** form first cured layer on surface step
[0117] **201** form first cured layer on substrate surface step
[0118] **205** form second cured layer on first cured layer step
[0119] **250** form second cured layer on opposing surface of substrate step

1. A micro-louver structure, comprising:
a cured layer on a surface;
a plurality of imprinted micro-channels in the cured layer, wherein the imprinted micro-channels have a greater depth than width and are spaced apart by a separation distance greater than the width; and
a cured light-absorbing material in the micro-channels.

2. The micro-louver structure of claim **1**, wherein the imprinted micro-channels extend only partially through the cured layer.

3. The micro-louver structure of claim **1**, further including a protective layer on the cured layer and in contact with the cured light-absorbing material.

4. The micro-louver structure of claim **1**, further including a protective layer on the cured layer but not in contact with the cured light-absorbing material.

5. The micro-louver structure of claim **1**, wherein the cured layer or the light-absorbing material includes cross-linking materials.

6. The micro-louver structure of claim **1**, wherein the light-absorbing material is cross-linked to the cured layer.

7. The micro-louver structure of claim **1**, wherein the light-absorbing material includes carbon black.

8. The micro-louver structure of claim **1**, wherein the depth of the imprinted micro-channels is at least two times greater than the width, four times greater than the width, five times greater than the width, eight times greater than the width, or ten times greater than the width.

9. The micro-louver structure of claim **1**, wherein the width of the imprinted micro-channels is less than or equal to four microns, two microns, or one micron.

10. The micro-louver structure of claim **1**, wherein a cross-section of the imprinted micro-channels in a plane parallel to the surface of the cured layer substantially forms an array of lines in one direction.

11. The micro-louver structure of claim **1**, wherein a cross-section of the imprinted micro-channels in a plane parallel to the surface of the cured layer substantially forms a grid with lines extending in two different directions.

12. The micro-louver structure of claim **1**, wherein a cross-section of the imprinted micro-channels in a plane parallel to the surface of the cured layer substantially forms one or more polygons or circles.

13. The micro-louver structure of claim **1**, further including a substrate having the surface and wherein the substrate is a component of a display.

14. The micro-louver structure of claim **13**, wherein the substrate is a display cover or display substrate.

15. The micro-louver structure of claim **1**, further including two cured layers located together in a spatial relationship.

16. The micro-louver structure of claim **15**, wherein the micro-channels of the two cured layers are spatially in phase or spatially 180 degrees out of phase.

17. The micro-louver structure of claim **15**, further including a substrate having opposed surfaces and wherein the two cured layers are located on opposing surfaces of the substrate.

18. The micro-louver structure of claim **15**, further including a substrate having a surface and wherein a first one of the cured layers is located on the surface of the substrate and a second one of the cured layers is located on the first one of the cured layers.

19. The micro-louver structure of claim **15**, further including a substrate having the surface on which at least one of the cured layers is formed and wherein the substrate is a component of a display.

20. A micro-structure for use with a display which permits orthogonal display viewing while inhibiting display viewing at larger angles, comprising:

a cured layer on a surface;

a plurality of imprinted micro-channels forming a pattern in the cured layer, wherein the imprinted micro-channels have a greater depth than width and are spaced apart by a separation distance greater than the width;

a cured light-absorbing material in the imprinted micro-channels; and

wherein the micro-structure is located on a viewing surface of the display, whereby orthogonal display viewing is enabled while display viewing at larger angles is inhibited.

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