

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
29 August 2002 (29.08.2002)

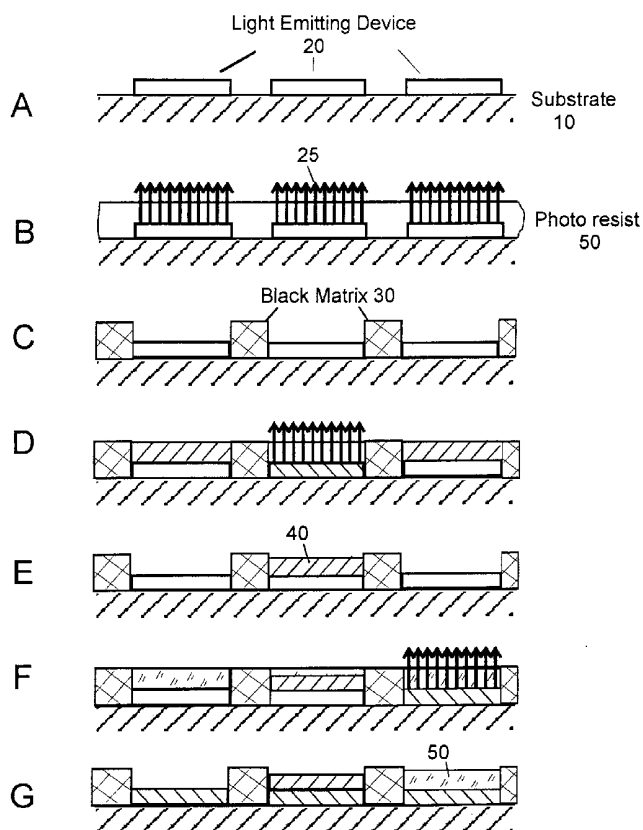
PCT

(10) International Publication Number
WO 02/067054 A2

- (51) International Patent Classification⁷: **G03F 7/00**
- (21) International Application Number: PCT/EP02/01140
- (22) International Filing Date: 5 February 2002 (05.02.2002)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
01104098.7 21 February 2001 (21.02.2001) EP
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- (81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

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(54) Title: HIGH-RESOLUTION PHOTORESIST STRUCTURING OF MULTI-LAYER STRUCTURES DEPOSITED ONTO SUBSTRATES



(57) Abstract: For fabricating a multi-layer structure of m 2 layers deposited on a substrate, a radiation irradiated by structure elements themselves is used for the lithographic exposure of a covering layer thus to achieve spatial self-alignment between the different layers. In a first step, a first layer is deposited onto the substrate. In a next step, the first layer is structured into structure elements. In a further step, a second layer of a material, which is sensitive to a physical and/or chemical interaction appropriate for an image transfer from the structure elements into the second layer, is deposited onto the substrate. The second layer is exposed with a pre-mentioned interaction originated or modulated by the structure elements. Finally, the exposed or non-exposed material of the second layer is removed from the substrate thus revealing the second layer structured in accordance with said image transfer.



(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

- 1 -

D E S C R I P T I O N

**High-Resolution Photoresist Structuring of Multi-Layer
Structures Deposited onto Substrates**

BACKGROUND OF THE INVENTION

The invention generally relates to the field of lithography for making multi-layer structures of at least two layers deposited on a substrate and more particularly to mask alignment of different structural elements building-up the multi-layer structures.

Color filters and color converters for color display applications are currently fabricated using standard photolithographic processes which consist of the following necessary steps:

- a) coating the substrate with a layer of a photoresist material;
- b) designing a mask;
- c) aligning the mask with the substrate or a structure already present on the substrate;
- d) exposing the photoresist material with a photoactive radiation while masking the radiation with the aligned mask;
- e) developing the exposed photoresist material; and
- f) removing the developed photoresist material from the

- 2 -

substrate.

In step f) the removal of developed photoresist (so-called positive photolithographic process) alternatively the non-developed photoresist material can be removed (so-called negative photolithographic process).

There already exist some approaches to make a mask alignment unnecessary. As a first approach, a method for manufacturing semiconductor light emitting devices allegedly making the alignment of a high accuracy mask unnecessary is disclosed in Japanese Abstract JP4162689A2. Hereby the photoresist is flatly applied to a cap layer surface and the photoresist is removed so that only the top part and vicinity of the protrusion of the cap layer are exposed. Further a part of the remaining photoresist is removed so that the cap layer surface is flattened approximately while the remaining photoresist is used as a mask.

Further, U.S. Patent No. 5,688,551 discloses a method of forming a multicolor organic electro-luminiscent (EL) display panel using a close-spaced deposition technique to form a separately colored organic EL medium on a substrate by transferring, patternwise, the organic EL medium from a donor sheet to the substrate. More specifically, a transparent conductive layer is formed and patterned to provide a plurality of spaced electrodes on a transparent substrate. Further, on the spaced electrodes, color organic EL media are provided by close-spaced deposition from the donor sheet forming adjacent colored subpixels which emit the primary colors, respectively. In addition, a conductive layer is formed and patterned on the colored subpixels to provide a plurality of spaced electrodes. The close-spaced deposition is

- 3 -

provided by transferring to the transparent substrate each of the colored organic EL media by illuminating the respective donor sheet which is pre-patterned with a light absorbing layer. That method allegedly does not require conventional photolithography and thus shall avoid the incompatibility issues of the organic EL medium with photolithography processes.

Thereupon, U.S. Patent No. 4,743,099 discloses a method of making a thin film transistor (TFT) liquid crystal (LC) color display device which provides alignment between red-green-blue color filters and pixel electrodes by using the electrodes to create the color filters in a polychromatic glass. The method uses an assembly having spaced front and rear glass panels, one of which is an unexposed polychromatic glass material. A transparent common electrode layer is formed on the inside surface of one of the glass panels. An array of individually addressable pixel electrodes is formed on the inside surface of the other of the glass panels. The cavity defined by the glass panels is temporarily filled with a liquid crystal material doped with an opaque substance. Ultraviolet light is directed at the non-polychromatic glass panel. The pixel electrodes associated with one color are then addressed to selectively switch the liquid crystal to a transparent state and thus locally exposing certain regions of the polychromatic glass panel by the external ultraviolet light. Thereby certain hue in those areas are created and the procedure is repeated with different electrodes to establish different hues in different regions of the polychromatic glass panel. The assembly is then heat treated to fix the established hues. The assembly finally is completed by removing the temporary liquid crystal material from the cavity and replacing it with a suitable, permanent liquid crystal material.

- 4 -

The aforescribed known masking techniques suffer from several deficiencies. First the number of individual steps is relatively high and most of the above described known techniques involve the critical step of mask alignment. Secondly, for achieving sufficiently high resolution, contact masks are required what involves complicated process steps and mask devices.

As a result, the known techniques have common the drawback that they require the number of deposited layers actively to be aligned to each other thus requiring at least a corresponding number of deposition and alignment steps.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a method and device for fabricating an aforementioned multi-layer structure which avoid the pre-mentioned drawbacks of an underlying multi-layer structuring process with respect to the necessary spatial alignment between the different layers.

It is another object to provide such a method and device which make a mask alignment unnecessary.

It is still another object to provide very high spatial alignment and resolution of at least two layers deposited on a substrate using a lithographic technique with minimum technical efforts.

It is yet another object to enhance throughput of a fabrication process for the above mentioned patterned

- 5 -

structures.

It is yet another object to avoid time- and cost-extensive alignment steps and thus reduce the fabrication costs.

The above objects are solved by the steps and means according to the independent claims. Advantageous embodiments are subject matter of the subclaims.

The idea underlying the invention is to use a radiation of the structure elements themselves, i.e. light or radiation self-irradiated by the structure elements, for the lithographic exposure of e.g. a covering layer and thus to achieve spatial self-alignment between the different layers.

More particularly, the invention makes use of the fact that structured monochromatic devices, e.g. symbols or pixels, can already be used as irradiation or light sources in the photolithographic process for the fabrication of structured full-color devices like color filters, color converters, black masks, studs etc. Exemplary structure elements can be light emitting diodes or vertical cavity lasers.

The step of exposing the at least second layer with a physical and/or chemical interaction further uses the fact that, on the one hand, any interaction that is originated by the structure elements can be used to structure the at least second layer by a lithographic process based on said interaction. On the other hand, any interaction or physical and/or chemical property of the second layer that can at least be modulated by the structure elements, is sufficient for the proposed mechanism. Said physical and/or chemical interaction can also be any electric or magnetic or thermal interaction between the first

- 6 -

layer and the at least second layer appropriate for said image transfer, e.g. a magnetic field or an electric current.

The proposed mechanism avoids the aforementioned time- and cost-extensive alignment steps. Additionally it guarantees that the different layers of a structure fabricated using that mechanism are self-aligned to each other without need of a particular alignment step or technique. Due to the inherent near-field character of the proposed technique, a very high spatial resolution of the fabricated devices or structures and a precise alignment between the respective different layers can easily be obtained.

It is emphasized that using conventional techniques, such a high resolution and alignment can only be obtained using special contact mask techniques which are disadvantageous insofar as they might cause damage to the monochromatic devices due to the mechanical contact (so-called alignment defects) and thereupon require an additional high-precision alignment step.

The proposed mechanism is technically non-complex vis-à-vis the known approaches insofar as some of the prementioned necessary alignment steps become obsolete thus reducing the time and cost efforts for its implementation. Thereupon the mechanism can be implemented using known technology or even existing structures. It only requires that the material used for the first layer is emitting a radiation adequate to enable radiation-induced development and structuring of the mask layer(s) i.e. the radiation used must be able to influence or change a mechanical, physical or chemical property of the mask material so that mask material can be removed in a well-defined manner during a lithographic step.

- 7 -

In addition, due to the prementioned self-emitting feature, the mechanism advantageously allows that the substrate to be structured must not be planar, but can also be flexible or even bent during the structuring process.

It is further emphasized that the proposed technique is applicable to all kinds of self-emitting devices like light emitting diodes (LEDs), organic electro-luminescent image display devices (OLEDs) or polymer LEDs (pLEDs), but also to illuminated devices like back-lighted LCDs.

Furthermore, all kinds of photolithographic methods, e.g. positive or negative photolithographic processes or lift-off techniques, can be used for the implementation of the proposed method and device.

In addition, it is understood that the invention can either be implemented by using the pre-mentioned self-emitting devices or by using passively emitting structures comprised of a radiation-absorptive material, e.g. a thermal absorptive, fluorescent or phosphorescent material. Hereby the structures can be initiated to reemit a radiation adequate for the photoresist development process step by irradiating the structures with another radiation of a basically different wavelength. Only exemplarily, this could be achieved by irradiating the structures with a non-thermal radiation like ultraviolet rays and using a thermally sensitive resist as lithographic material.

BRIEF DESCRIPTION OF THE DRAWINGS

- 8 -

The invention will be understood more readily from the following detailed description when taken in conjunction with the accompanying drawings, wherein similar or functionally identical features are referred to by identical reference signs.

In the drawings:

Fig. 1a, b show procedural steps of a first embodiment of the method according to the invention, wherein a. is an example for manufacturing a black matrix color display and b. an example for manufacturing a color display without a black matrix;

Fig. 2 shows procedural steps of a second embodiment of the invention;

Fig. 3 depicts an enlarged sectional side view of a masking substrate according to the invention; and

Fig. 4 shows procedural steps of a third embodiment of the invention.

DETAILED DESCRIPTION OF THE DRAWINGS

Fig. 1a shows a first embodiment of a lithographic process in accordance with the invention for manufacturing a full-color black-matrix display on a plain substrate 10. It is noteworthy that instead of using a plain or flat substrate, the process described in the following can also be performed on a non-flat or even bent substrate.

- 9 -

Starting from blue pixels 20 emitting a radiation 25, the black mask 30 and color converters 30, 40 for green and red emission are added. In this example, the blue emitting devices 20 (step A) are coated with photoresist 50, which is then exposed by the light 25 of the blue emitter (step B). The black matrix 30 principally can be produced by a positive or negative lithographic process (C). For the color converters 30, 40, photoresists doped with suitable dyes can be used. Therefore, only an exposure (D) and development (E) cycle, but no mask fabrication and alignment, as in the prior art, is needed to produce a structured full-color device where the pixel combination produced in steps D & E is used for generating green color light (not shown) and the combination of steps F & G for generating red color (not shown).

It is noted hereby that the above procedure can also use a photoresist in combination with a negative lithographic process, wherein coating of the converter materials and lift-off.

The second example illustrated in Fig. 1b is for a full-color display not comprising a black matrix. Therefore this example does not require steps B and C in Fig. 1a. For the other steps D' to G' it is referred to the corresponding steps D to G in Fig. 1a.

In the embodiment shown in Fig. 2, procedural steps A'' and B'' are identical with the pre-described embodiments. Again, structure elements 20 deposited on a substrate 10 are over-coated by a photoresist layer 50. But in contrast to the other embodiments, the structure elements 20 consist of a material which is re-emitting a radiation after being irradiated with a radiation like a thermal radiation. Accordingly, the

- 10 -

photoresist material 50 has to be development-sensitive with respect of that radiation, i.e. in the case of thermal radiation able to be developed by means of the re-emitted radiation.

Further procedural step deviating from the previously described embodiments therefore is step 60 where the over-coated substrate is irradiated with a radiation 60 thus initiating the structure elements 20 to re-emit radiation 25. Following procedural steps E'' - G'' are similar or identical with the corresponding steps in the other embodiments.

Fig. 3 depicts an enlarged sectional side view of a masking substrate according to the invention which can be fabricated as a pre-configured masking device. As described beforehand, the device consists of a substrate 10 and pre-deposited and pre-structured elements 20, in this example comprising a black matrix 30 between the elements 20. The masking device can be pre-coated with a photoresist 50 appropriate for being developed by the radiation 25 emitted by the elements 20. Emission of the elements 20 can be controlled by voltage supply lines 80 so that the mechanism proposed by the invention and described above allows fabrication of even complex structure patterns like those being used in semiconductor manufacturing.

In addition, the method proposed by the invention can also be used for the build-up of electrical circuits consisting of several layers of conducting paths. To illustrate this, Fig. 4 shows a rigid or flexible substrate 100 bearing a first layer of conducting paths 105 (step A). The first layer 105 is coated with an isolating resist 110 sensitive to thermal interaction (step B). In individual conducting paths 115 an

- 11 -

electric current is switched on (step C). Due to the internal resistance these paths heat up 120 and thus locally expose the resist 110, i.e. change a physical and/or chemical property of the resist 110 like its hardness or chemical resistance against a solvent. In the next step the resist is removed, leaving the conducting paths 115 that were switched on with an isolating coating 125 of the resist (step D). As these paths are now protected, subsequent layers 130 of conducting paths can be deposited on top of the first layer, e. g. creating interconnects between different conducting paths 135, 140 (step E).

The advantage of the pre-described method is that complicated and expensive processes involving mask technology to protect certain conductive paths and to deposit insulating protection layers on other paths is not necessary. Simple coating techniques for the thermally sensitive resist and the self-generation of the thermal energy necessary for exposing the resist due to the internal resistance of the conductive paths are used instead.

Beyond the above described particular application scenarios, the method and device according to the invention can be used in micro-fabrication of any micro-technique using mask lithography. Only exemplarily it is hereby referred to thin film optical devices like liquid crystal displays (LCDs), thin film transistor (TFT) displays, organic light emitting diode (OLED) displays, or color filters or color converters. Thereupon it can be used for the fabrication of semiconductor devices (processors, storages, etc.) or opto-electronic devices.

- 12 -

CLAIMS

1. A method of making a multi-layer structure of at least two layers deposited on a substrate using lithography, comprising the steps of:
 - a) providing a first layer of addressable structure elements onto said substrate, said first layer being capable of selectively generating a physical and/or chemical interaction;
 - b) depositing at least a second layer of a material, which is sensitive to said physical and/or chemical interaction appropriate for an image transfer from said structure elements into said at least second layer, onto said substrate on top of said structure elements; and
 - c) exposing said at least second layer with said physical and/or chemical interaction originating from said structure elements.
2. Method according to claim 1, comprising the further step of removing the exposed or non-exposed material of said at least second layer from the substrate thus having said at least second layer structured in accordance with said image transfer.
3. Method according to claim 1 or 2, wherein said physical and/or chemical interaction is any radiation interaction for which the material of the at least second layer is sensitive for said image transfer.

- 13 -

4. Method according to claim 1 or 2, wherein said physical and/or chemical interaction is thermal conduction between the first layer and the at least second layer.
5. Method according to claim 1 or 2, wherein said physical and/or chemical interaction is any electric or magnetic interaction between the first layer and the at least second layer appropriate for said image transfer.
6. Method according to claim 1 or 2, wherein said physical and/or chemical interaction is a mechanical piezo-effect and wherein said at least second layer is sensitive to mechanical strain and/or mechanical stress.
7. Method according to any of the preceding claims, wherein said at least second layer is comprised of a mask material and wherein the method comprises the further step d) of depositing an at least third layer onto said substrate on side of the structured mask material.
8. Method according to any of the preceding claims, wherein said structure elements are comprised of addressable light emitting devices, in particular light emitting diodes composed of inorganic III-V and/or II-VI compounds, or organic OLEDs or field emission devices or vertical cavity lasers.
9. Method according to any of claims 1 to 7, wherein said structure elements are comprised of a material re-emitting an irradiation-induced radiation appropriate for radiation-induced structuring of the at least second layer.

- 14 -

10. Method according to claim 9, wherein said structure elements are irradiated by thermal radiation and wherein said at least second layer is comprised of a material appropriate for thermal-induced structuring.
11. Method according to claim 9 or 10, wherein using a radiation-transparent substrate and irradiating the structure elements from the backside of the substrate.
12. A masking device for fabricating a multi-layer structure of at least two layers deposited on a substrate using lithography, comprising a layer of addressable structure elements being capable of selectively generating a physical and/or chemical interaction with at least a second layer of a material, which is sensitive to said physical and/or chemical interaction appropriate for an image transfer from said structure elements into said at least second layer.
13. Masking device according to claim 12, wherein said structure elements are self-emitting an electrically generated radiation.
14. Masking device according to claim 12 or 13, wherein said structure elements are made from a piezo-effective material and wherein said at least second layer is sensitive to mechanical strain and/or mechanical stress.
15. Masking device according to claim 12 or 13, wherein said structure elements are light emitting devices.

- 15 -

16. Masking device according to claim 12 or 13, wherein said structure elements are re-emitting an irradiation induced radiation, in particular thermal radiation.
17. Masking device according to claim 16, wherein the material of said at least second layer is appropriate for radiation induced, in particular thermal induced, structuring.
18. A multi-layer structure of at least two layers deposited on a substrate fabricated using the method according to any of claims 1 to 11 and/or using a masking substrate according to any of claims 12 to 17.
19. Multi-layer structure according to claim 18, comprising a first layer of addressable structure elements onto said substrate, said first layer being capable of selectively generating a physical and/or chemical interaction and at least a second layer of a material, which is sensitive to said physical and/or chemical interaction appropriate for an image transfer from said structure elements into said at least second layer, onto said substrate on top of said structure elements.
20. Multi-layer structure according to claim 18 or 19, wherein said addressable structure elements are self-emitting an electrically generated radiation.
21. Multi-layer structure according to claim 18 or 19, wherein said structure elements are made from a piezo-effective material and wherein said at least second layer is sensitive to mechanical strain and/or mechanical stress.

- 16 -

22. Multi-layer structure according to claim 18 or 19, wherein said structure elements are light emitting devices.
23. Multi-layer structure according to claim 18 or 19, wherein said structure elements are re-emitting an irradiation induced radiation, in particular thermal radiation.
24. Multi-layer structure according to claim 23, wherein the material of said at least second layer is appropriate for radiation induced, in particular thermal induced, structuring.

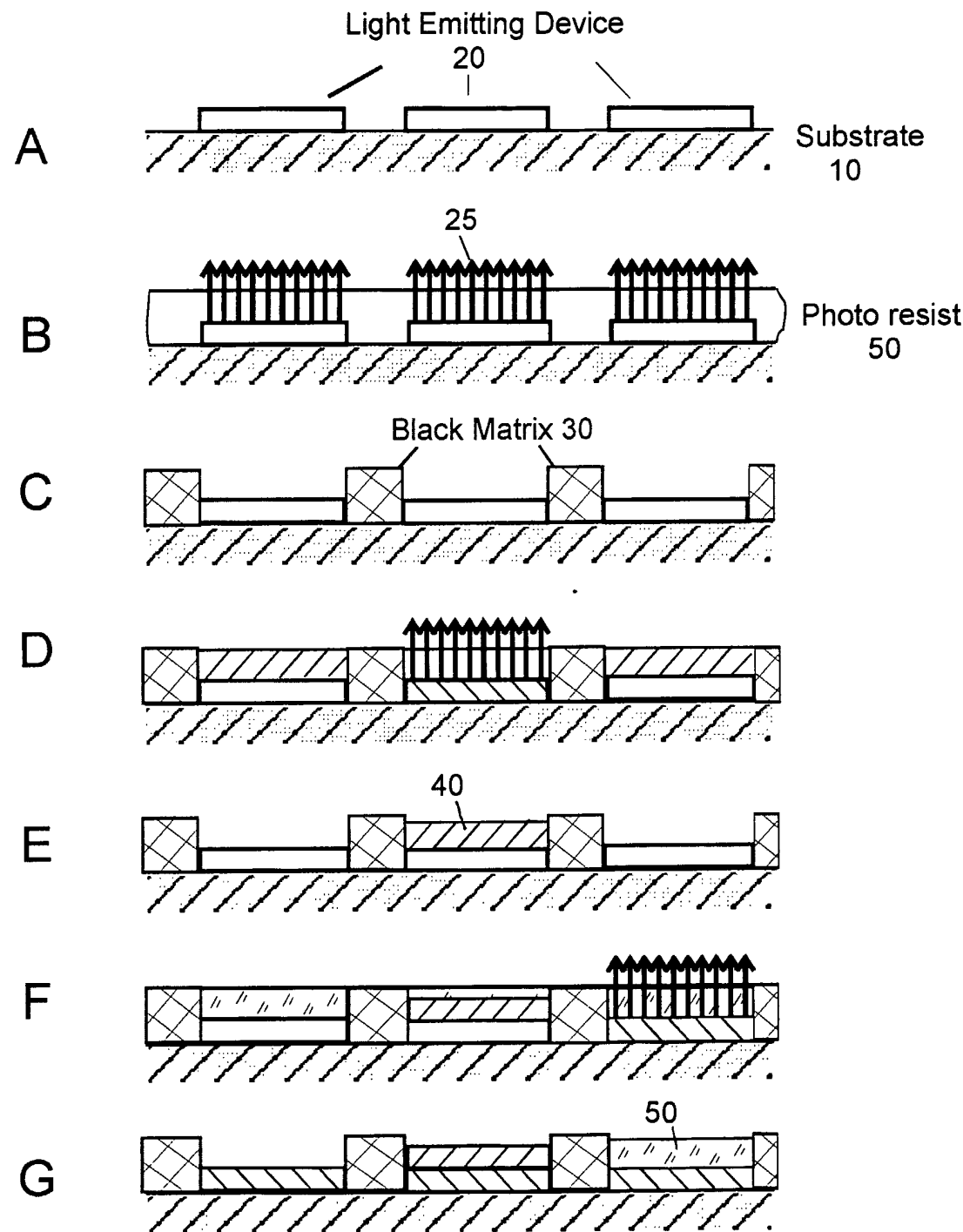


FIG. 1A

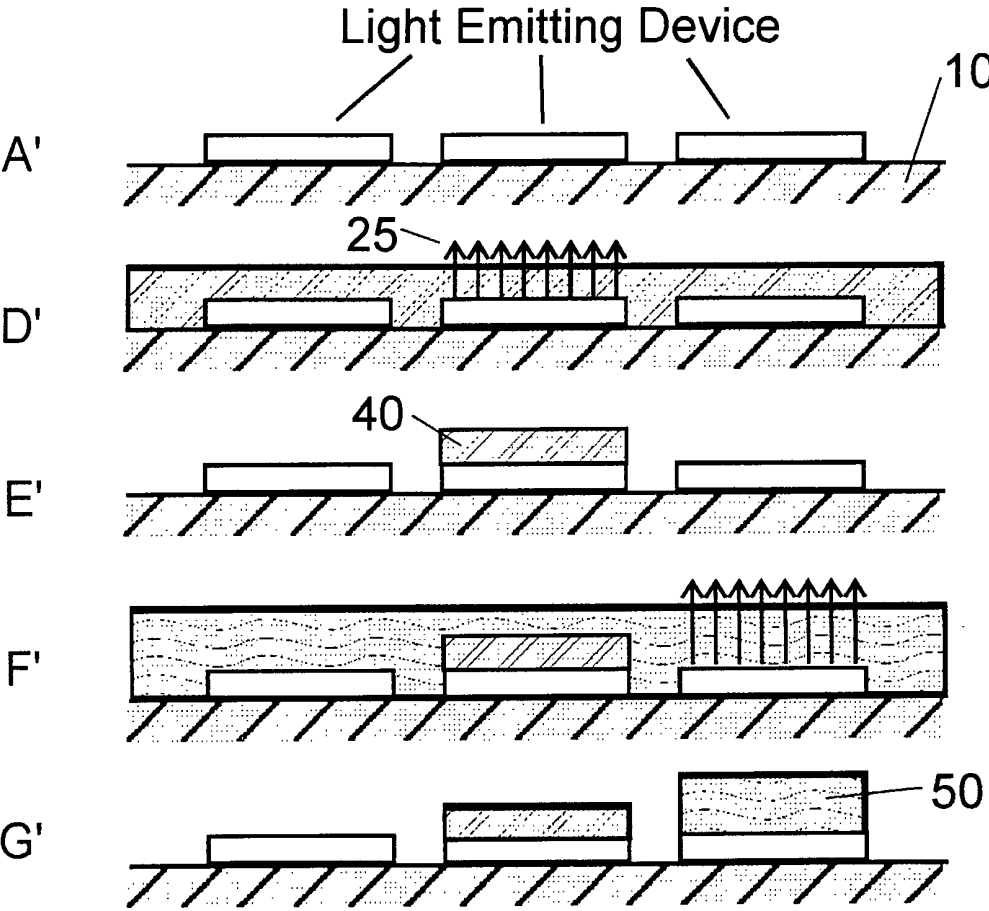


FIG. 1B

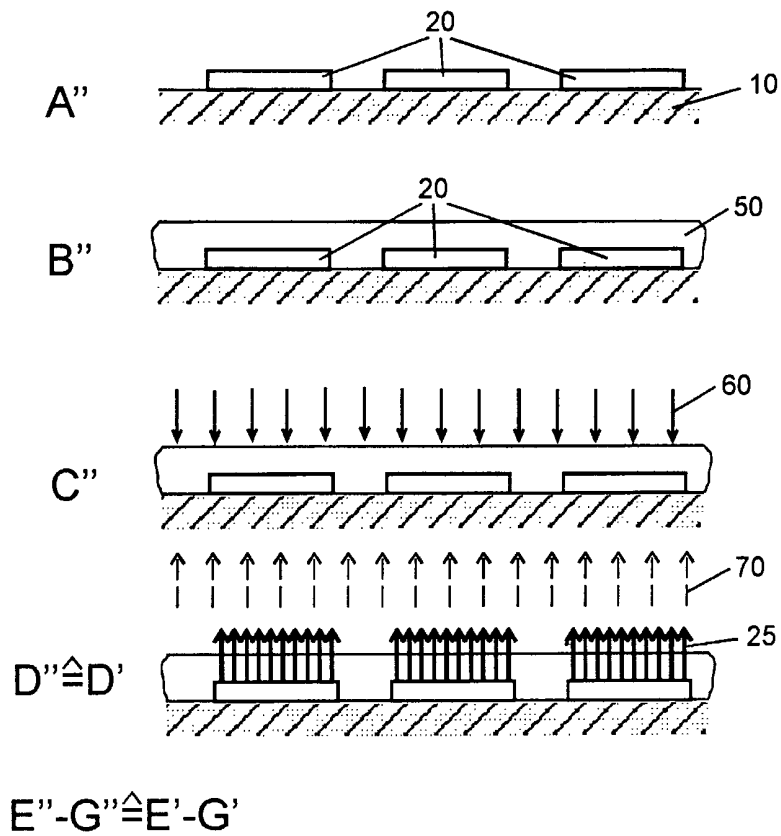


FIG. 2

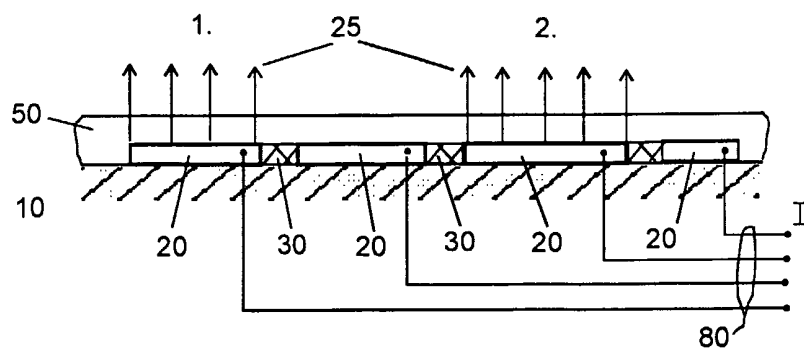


FIG. 3

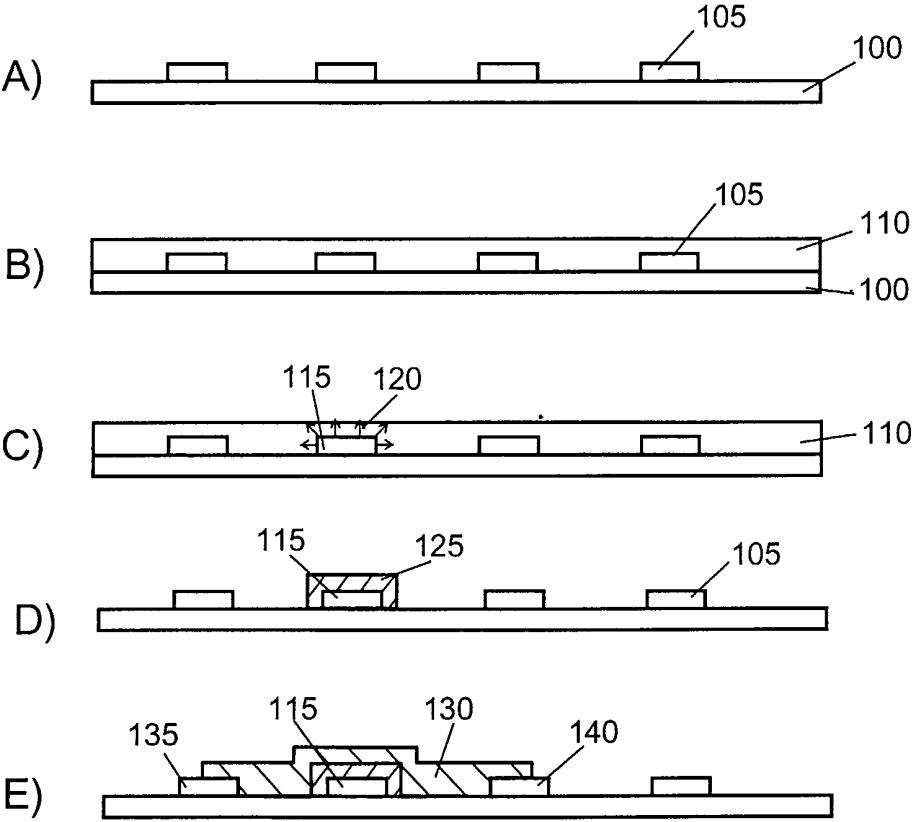


FIG. 4