

Title: Method and apparatus for accurately applying structures to a substrate

The invention relates to a method and an apparatus for accurately applying lacquer structures to a substrate.

To date, use is often made of masks to locally screen a lacquer, which is used for forming the structures, from lighting. The use of such masks is laborious and expensive. Moreover, for each new structure, a new mask
5 needs to be manufactured. Another problem in applying structures to a substrate is formed by the large amount of lacquer and solvents used therein. Another problem one is faced with is providing structures with sharp outlines. The relative positioning of the structures in the various
10 layers is also an important problem for accurately applying structures to a substrate.

Applications of the method may, for instance, be a method for manufacturing electronic components, such as for instance an OLED, a solar cell, a TFT structure on a display or the like. With these components,
15 it is very important that, in a large number of layers of material which are applied successively, the structures therein are very accurately positioned with respect to one another. Here, a so-called overlay accuracy of at least 2 microns and preferably at least 1 micron is desired.

The invention contemplates a method for applying lacquer structures
20 to a substrate with which at least a number of the above-described problems are solved.

For this purpose, the invention provides a method where, in a scanning step, structures already applied to the substrate are detected by at least one scanning provision of a processing head, while the processing head
25 is provided with at least one lighting provision, which lighting provision

locally lights the applied lacquer structure in a lighting step by using the information obtained with the scanning step.

Using the scanning provision of the processing head, positions of already applied structures can be determined very accurately, so that the applied lacquer structure can very accurately be lighted locally. Preferably,
5 the processing head forms a direct mechanical coupling between the scanning and the lighting provision, which is strongly favorable to the positioning accuracy.

In this context, the term "lighting" is to be understood in a broad
10 sense. "Lighting" is not only understood to mean treatment with visible light, but also with UV radiation, IR radiation, ion beam and E beam. The lighting results in a change of the structure of the lacquer, for instance in that the lacquer cross-links or in that the solvent is removed from the lacquer. The term "lacquer" is also to be understood in a broad sense.
15 Possibilities are photoresist, UV-curing lacquer, PPV and PDOT for the purpose of manufacturing OLEDs, and the like.

Through the lighting step, carried out by the lighting provision, structures with fine, sharp boundaries can be obtained. A local lighting step is not understood to mean a lighting step using a mask, but locally lighting
20 the lacquer with the aid of one narrow beam or with an array of narrow beams, which are each individually controllable. With such a narrow beam or array of individually controllable narrow beams – which may for instance be laser beams, infrared beams, visible-light beams, UV beams, ion beams or E beams – the desired structure can be written in the lacquer, as it were.
25 The lighting can take place in those areas where the lacquer needs to be removed or, conversely, in those areas where the lacquer needs to remain present, depending on the lacquer used.

According to an aspect of the invention, the information obtained with the scanning step is also used for depositing the lacquer structure at a

desired position. In this manner, the new lacquer structure can accurately be positioned with respect to the existing structure.

According to a further elaboration of the method, the processing head may also be provided with an inkjet printing provision, where a complete
5 lacquer layer or a lacquer structure is applied to the substrate in an inkjet printing step using the inkjet printing provision of the processing head. Preferably, in the inkjet printing step, the lacquer is applied locally for forming a lacquer structure.

In this manner, the depositing of the lacquer is effected by means of
10 an advantageous printing technique. Because the inkjet printing is used, instead of completely covering the substrate with lacquer, the lacquer can be used in a much less wasteful manner. This is because the lacquer only needs to be applied where the forming of structures is desired. Incidentally, the invention does not preclude the possibility that, with the inkjet printing
15 provision, a complete lacquer layer is applied to the substrate instead of a lacquer structure.

Further, in this manner, the processing head is provided with both the inkjet printing provision and with the lighting provision. In that case, in one movement of the processing head with respect to the substrate, both the
20 delivery of lacquer and the lighting of the lacquer just applied can be realized. In this manner, the position of the lighting provision is, moreover, directly mechanically coupled to the position of the processing head. As a result, after the application of the lacquer, it can be determined with great accuracy where this lacquer is then lighted using the lighting provision. The
25 direct coupling of the position of the processing head with the lighting provision practically excludes the possibility of the lighting provision carrying out a lighting operation at wrong positions on the substrate. With the local lighting step, the relatively inaccurate outlines of the lacquer applied with the inkjet technique can be "cut off", so that lighted structures
30 with fine, sharp boundaries are obtained.

According to a further elaboration of the invention, a scanning step can be carried out immediately prior to the inkjet printing step in that a first scanning provision is provided on the processing head, and that on the upstream side of the inkjet printing provision, viewed in the relative direction of movement of the processing head with respect to the substrate. With such a scanning step, it is known where the already applied structures are located on the substrate, so that, directly after the scanning step – in the printing step – new structures can accurately be positioned with respect to these structures already present on the substrate.

However, it would further be advantageous to immediately check the structure just applied and lighted, for instance to determine whether the lacquer has been applied everywhere in the right manner. For this purpose, according to a further elaboration of the invention, a scanning step can be carried out immediately after the inkjet printing step in that a second scanning provision is provided on the processing head, and that on the downstream side of the inkjet printing provision, viewed in the relative direction of movement of the processing head with respect to the substrate.

Here, using the information obtained with the second scanning provision, it can be determined whether printing has taken place where it should have and, if this is not the case, the lacquer can still be printed at the desired positions in a second printing step. For this purpose, the head can go through a forward and backward movement over the same area of the substrate. If it is detected with the second scanning provision that to some areas the lacquer has not yet been applied, lacquer can still be deposited and lighted in those areas in the backward movement.

According to an aspect of the invention, a scanning step is carried out immediately prior to the lighting step in that a first scanning provision is provided on the processing head, and that on the upstream side of the lighting provision, viewed in the relative direction of movement of the processing head with respect to the substrate.

In this manner, in one movement of the processing head with respect to the substrate, it can be determined where the applied lacquer structure is to be lighted locally, while the lighting of the lacquer can be carried out in the same movement of the processing head. It is then advantageous according to the invention if a scanning step is carried out immediately after the lighting step in that a second scanning provision is provided on the processing head, and that on the downstream side of the lighting provision, viewed in the relative direction of movement of the processing head with respect to the substrate. Thus, using the information obtained with the second scanning provision, it can be determined whether lighting has taken place where it should have and, if this is not the case, the lacquer is still lighted at the desired positions in a second lighting step. Also in this case, for this purpose, the head can go through a forward and a backward movement over the same area of the substrate. If it is detected with the second scanning provision that the lacquer has not yet been lighted in some areas, lacquer can still be lighted in those areas in the backward movement. Detecting a desired lighting may, for instance, take place on the basis of an expected change of the lacquer, which change is realized under the influence of the lighting. Such a change may, for instance, be a change in color, structure and/or shape of the lacquer.

Detecting in a second scanning step whether lacquer has been lighted at a desired position can of course be combined with detecting whether lacquer has been deposited at a desired position, at least if a lacquer deposition step has also been carried out before this second scanning step. In this manner, the lacquer can relatively rapidly and accurately be deposited as well as lighted, preferably during the forward and backward movements of the processing head.

Further, information obtained with the second scanning provision can also be fed back to a measuring system with the aid of which the position of the processing head is controlled. When new structures in a next layer are

far removed from a previously applied structure, such a feedback to a measuring system is important because no direct reference can be made to the previously applied structures during the movement of the head over the substrate.

5 According to a further embodiment of the invention, the lacquer structure can be applied for the purpose of creating a structure in a material layer applied or to be applied to the substrate.

Such processes are known per se and may, for instance, comprise etching away a material layer which is partly covered with the lacquer
10 structure. Applying material layers to and/or between the lacquer structures as for instance described in US 3,832,176 (a fill-in process) and US 4,674,174 (a lift-off process) is also one of the possibilities.

Here, the material layer may, for instance, be a metal, such as for instance molybdenum, chromium, etc., a semiconductor, a dielectric layer,
15 such as for instance SiO_x , SiN_x , or ITO. However, a plurality of different substances are also possible.

The steps of the method according to the invention may be part of a method for manufacturing an electronic component, such as for instance a TFT structure, an OLED, a solar cell or the like.

20 The lacquer structure may be formed by a photoresist structure or by a lacquer curing rapidly under the influence of a lighting operation, such as for instance a UV-curing lacquer. It is also possible that the structure of the lacquer is changed by removing a solvent from the lacquer using the lighting, for instance using IR lighting.

25 Preferably, in the application of the successive structures, an overlay accuracy is achieved of at least 0.7 micron, more particularly at least 0.4 micron.

For this purpose, the measurements in the scanning step may, for instance, be based on an interferometric measurement, a triangulation
30 measurement or image recognition.

A very accurate local lighting can be carried out using an array of individually controllable lasers, LEDs or similar lighting means which can quickly be switched on and off or modulated with the aid whereof a respective lacquer can be lighted.

5 The invention further relates to an apparatus for carrying out a method according to any one of claims 1-18, wherein the apparatus according to the invention is provided with a processing head which is movable relative to a substrate carrier, wherein the processing head comprises at least one scanning provision and at least one lighting
10 provision.

Using the processing head, a desired structure may, for instance, be written in a lacquer applied immediately before that. In order to accurately position the processing head with the lighting provision with respect to already applied structures, the processing head comprises at least one
15 scanning provision. Using this at least one scanning provision, already applied structures can be detected, so that an accurate lacquer lighting can be carried out by the lighting provision.

The lighting provision needs to generate at least one, but preferably an array of individually controllable narrow beams, such as for instance
20 laser beams, infrared beams, visible-light beams, UV beams, E beams or ion beams, so that very fine structures can be positioned and formed in the lacquer with great accuracy.

According to a further elaboration of the apparatus, the processing head is further provided with an inkjet printing provision. With such an
25 inkjet printing provision, instead of a complete lacquer layer, lacquer structures can be formed, which results in a saving on the lacquer use.

Here, it is more particularly preferred if the processing head is provided with two lighting provisions, while a first lighting provision is arranged upstream and a second lighting provision is arranged downstream
30 of the inkjet printing provision, viewed in the relative direction of movement

of the substrate with respect to the processing head. With such a head, in two directions of movement, lacquer can be applied and be lighted immediately afterwards.

Further, the processing head is preferably provided with two
5 scanning provisions, while a first scanning provision is arranged upstream and a second scanning provision is arranged downstream of the inkjet printing provision, viewed in the relative direction of movement of the substrate with respect to the processing head. With such a head, both prior to applying the lacquer and immediately afterwards, scanning can take
10 place during the relative movement of the head with respect to the substrate. The measurements carried out during scanning can be used for regulating the delivery of lacquer with the aid of the processing head in a backward movement of the processing head. In addition, the measurements can be used for positioning the structures in the lacquer with the aid of the
15 lighting provision.

According to an aspect of the invention, for this purpose, the processing head is provided with two scanning provisions, while a first scanning provision is arranged upstream and a second scanning provision is arranged downstream of the at least one lighting provision, viewed in the
20 relative direction of movement of the substrate with respect to the processing head.

As a result, both prior to lighting the lacquer and immediately afterwards, scanning can take place during the relative movement of the head with respect to the substrate. In this case, the measurements carried
25 out during scanning can be used for regulating the lacquer lighting with the aid of the processing head in a backward movement of the processing head. In this manner, it can be determined whether lighting has taken place where it should have and, if this is not the case, the lacquer can still be lighted at the desired positions in a second lighting step.

Because the head is provided with two scanning provisions, lacquer can moreover be lighted accurately in two directions of movement of the head.

In order to expose the substrate to vibrations and similar conditions
5 causing inaccuracy as little as possible, it is preferred to arrange the processing head so as to be movable relative to the fixed world, while the substrate carrier is stationary, at least during the carrying out of the inkjet printing step and the lighting step of the method.

It will be clear that the apparatus is provided with a control arranged
10 for processing information obtained with the at least one scanning provision, which control is further arranged for controlling the movement of the processing head, and controlling the at least one lighting provision. Further, the control may also be arranged for controlling the various nozzles of the inkjet printing provision.

15 The scanning provision may be arranged for carrying out, for instance, an interferometric measurement, a triangulation measurement or image recognition. Such measurements provide a very high accuracy.

The at least one lighting provision for creating the at least one narrow beam may comprise an array of individually controllable lasers,
20 LEDs or similar lighting means which can quickly be switched on and off or modulated, with the aid of which a respective lacquer can be lighted locally.

The invention will now be explained in more detail on the basis of an exemplary embodiment, with reference to the drawing, in which:

Fig. 1 shows a diagrammatic perspective view of a combined inkjet
25 printhead with double lighting provision and double scanning provision;

Figs. 2-14 each show, in a left part, a cross-sectional view and, in a right part, a corresponding perspective view of a substrate undergoing a number of method steps; and finally

Fig. 15 diagrammatically shows the various process steps gone through for applying a structure in a layer of material applied to a substrate.

Fig. 1 shows a substrate S and an inkjet printhead 1 comprising a rod-shaped array of nozzles. On both sides of the inkjet printhead 1, a rod-shaped lighting provision 2, 3 and a rod-shaped scanning provision 4, 5 are fixedly connected with the inkjet printhead 1. Each rod-shaped lighting provision 2, 3 comprises an array of LEDs, lasers or the like which can be modulated individually for intensity, for instance in that they can be switched on and off individually. Each rod-shaped scanning provision 4, 5 comprises an array of sensors. The head as a whole is bearing-mounted with guides 6, 7 and provided with a drive 8 with the aid of which the head can be moved over the substrate S. In a movement of the head over the substrate S, using a scanning rod 4, 5, structures already applied to the substrate S can be detected and, depending thereon, using the inkjet printhead 1, the lacquer can be deposited on the substrate at the desired moment, such that the position of the lacquer is adjusted to the positions of the previously applied structures. Further, in the same movement, the lacquer can be lighted directly using the lighting rods 2, 3, while use can also be made of the positions of the already applied structures detected with the scanning rods 4, 5. Because lighting rods 2, 3 and scanning rods 4, 5 are provided on both sides of the inkjet printhead 1, the steps of scanning, printing and lighting can be carried out both in a forward and a backward movement. In addition, as a result of the double scanning rod 4, 5, the printed and lighted structure can be measured directly and, optionally, on the basis of the measurements, a second printing, lighting and a second scanning step can be gone through for correcting possibly incomplete structures applied in the first printing and lighting step.

Figs. 2-14 show an example of a process of which the method according to the invention is part. The process shown is exclusively an

example and is particularly suitable for manufacturing, for instance, a TFT structure on a substrate. The method for applying lacquer structures may also be used in different processes, for instance in processes as described in US 3,832,176 and US 4,674,174. Further, the method may also be used for
5 accurately applying PDOT and PPV or similar organic lacquers to a substrate for manufacturing an OLED or for manufacturing electronic components, such as for instance solar cells.

Fig. 2 shows a substrate S. Fig. 3 shows the same substrate after the deposition of a layer of material 9 on the substrate S over the whole surface
10 of the substrate S (step (a)). Fig. 4 then shows the substrate S after the inkjet printing step (step (b)) of the method has been gone through. With some overmeasure, using inkjet printing, the desired structure has been applied to the substrate S in the form of a lacquer 10, such as for instance photoresist or a different lacquer changing its structure under the influence
15 of electromagnetic radiation (UV, visible, IR), E beam or ion beam. Instead of local application of the lacquer, full-surface printing of the lacquer could also be used. Fig. 5 shows the substrate S after it has gone through the lighting step (step (c)). Clearly visible are the sharp boundaries 11a of the structures 11 which have been applied using the lighting. Fig. 6 then shows
20 the substrate S after a developing step (step (d)) has been gone through, i.e. after the lacquer has been developed and the lighted lacquer has been preserved and the non-lighted lacquer parts have been removed or vice versa. Fig. 6 clearly shows that the layer of material 9 in which the structure is to be provided is still completely present. Then, an etching step
25 (step (e)) is gone through of which the result is shown in Fig. 7. It is clearly visible that the material layer 9 has now substantially been removed with the exception of the structure areas where the lacquer structure 11 is still present. Then, using an incineration step, the cured lacquer 11 which is still present is removed (step (f)). The result thereof is shown in Fig. 8. Removing

the cured lacquer which is still present can also be carried out using solvents.

In Figs. 9-14, the respective steps (a)-(f) are again repeated for applying a structure in a second material layer 12 which has been deposited on the previous material layer 9 and the substrate S. It goes without saying that the process can be repeated a further number of times for applying an accumulation of different structures applied in successive material layers.

Finally, Fig. 15 diagrammatically shows a number of blocks which each represent a processing station in which the various steps carried out per processing station are shown.

In block a1, deposition of the material 9 on the substrate S takes place;

in block a2, the deposited material is cleaned (this step is not necessary for all materials);

in block bc, the printing, lighting and scanning takes place;

in block d, the lacquer is developed, whereby the lighted lacquer structure is preserved and the non-lighted lacquer parts are removed or vice versa;

in block d2, the remaining lacquer structure is baked to cure it further;

in block e, the excess material is etched away. Only under the lacquer structures which are still present, the material remains present during the etching treatment, which is intended;

in block f, the remaining cured lacquer structure is then removed using, for instance, an incineration step or using solvents.

It will be clear that the invention is not limited to the exemplary embodiment described.

The description of the figures each time refers to an inkjet printhead because, in the exemplary embodiment, the head is provided with an inkjet printing provision 1. It already appears from the claims that one main

provision on the head is the at least one lighting provision, while another main provision is the scanning provision; this is why the term processing head is used in the claims. Therefore, the invention also comprises an embodiment in which the head is not provided with an inkjet printing provision but only with at least one lighting provision, supplemented with
5 at least one scanning provision. In the latter case, the head may, for instance, be referred to as a lighting head.

Further, for instance, processing steps may be added between the processing steps described. Here, possibilities are cleaning steps for, for
10 instance, removing waste created after the incineration step. Also, instead of horizontal, the orientation of the substrate could, for instance, be vertical. Further, instead of the inkjet printhead, the substrate could move and the inkjet printhead could be stationary. As already indicated hereinabove, the method may also be used in completely different processes, namely
15 processes in which the accurate application of a lacquer locally undergoing a structure change due to lighting with electromagnetic radiation (IR, visible and/or UV), E beam or ion beam plays a role.

In order to calibrate the apparatus, use may be made of a calibration grid placed in the apparatus instead of a substrate.

20 Further, a substrate may already have been provided with a lacquer layer in different manners, for instance by spin coating, spraying or immersion.

CLAIMS

1. A method including:
 - providing a substrate (S);
 - providing a processing head having:
 - at least one lighting provision (2, 3);
 - a first scanning provision (4) on an upstream side of the lighting provision (2, 3) viewed in the relative direction of movement of the substrate with respect to the processing head;
 - a second scanning provision (5) on a downstream side of the lighting provision (2, 3) viewed in the relative direction of movement of the substrate (S) with respect to the processing head;
 - a lighting step for locally lighting an applied lacquer structure;
 - a first scanning step in which structures already applied to the substrate (S) are detected by the first scanning provision (4) carried out immediately prior to the lighting step;
 - a second scanning step carried out immediately after the lighting step by the second scanning provision (5);
 - using information obtained with the first scanning step during the lighting step for locally lighting the applied lacquer structure.
2. A method according to claim 1, wherein the information obtained with the first scanning step is also used for depositing the lacquer structure at a desired position.
3. A method according to claim 1 or 2, wherein the processing head is further provided with an inkjet printing provision (1), wherein, in an inkjet printing step, a lacquer layer is applied to the substrate using the inkjet printing provision of the processing head,

wherein, in the inkjet printing step, the lacquer layer is preferably applied locally for forming said applied lacquer structure.

4. A method according to claim 3, wherein a said scanning step is carried out immediately prior to the inkjet printing step in that the first scanning provision (4) is provided on the processing head, and that on the upstream side of the inkjet printing provision (1), viewed in the relative direction of movement of the processing head with respect to the substrate (S).

5. A method according to claim 3 or 4, wherein a said scanning step is carried out immediately after the inkjet printing step in that a second scanning provision (5) is provided on the processing head, and that on the downstream side of the inkjet printing provision (1), viewed in the relative direction of movement of the processing head with respect to the substrate (S).

6. A method according to claim 5, wherein, using the information obtained with the second scanning provision, it is determined whether printing has taken place where it should have and wherein, if this is not the case, the lacquer is still printed at the desired positions in a second printing step.

7. A method according to claim 1, wherein, using the information obtained with the second scanning provision, it is determined whether lighting has taken place where it should have and wherein, if this is not the case, the lacquer is still lighted at the desired positions in a second lighting step.

8. A method according to claim 1, wherein the information obtained with the second scanning provision is also fed back to a measuring system with the aid of which the position of the processing head is controlled.
9. A method according to any one of the preceding claims, wherein the lacquer structure is applied for the purpose of creating a structure in a material layer applied or to be applied to the substrate.
10. A method according to claim 9, wherein the material layer is a metal, such as for instance molybdenum, chromium, etc., a semiconductor, a dielectric layer, such as for instance SiO_x , SiN_x , or ITO.
11. A method according to any one of the preceding claims, wherein the said steps are part of a method for manufacturing an electronic component, such as for instance a TFT structure, an OLED, a solar cell or the like.
12. A method according to any one of the preceding claims, wherein the, lacquer structure is formed by a photoresist structure.
13. A method according to any one of the preceding claims, wherein the lacquer structure is formed by a lacquer changing its structure or composition under the influence of a lighting treatment.
14. A method according to any one of the preceding claims, wherein, in the application of the successive structures, an overlay accuracy is achieved of at least 0.7 micron, more particularly at least 0.4 micron.
15. A method according to any one of the preceding claims, wherein, in the a said scanning step, an interferometric measurement or a triangulation measurement or image recognition is carried out.

16. A method according to at least claim 1, wherein the local lighting is carried out using an array of individually controllable lasers, LEDs or similar lighting means which can quickly be switched on and off or modulated, with the aid of which a respective lacquer can be lighted.

17. An apparatus for carrying out the method according to any one of the preceding claims, the apparatus comprising:

- a substrate carrier;
- a processing head movable relative to the substrate carrier and having:
 - at least one lighting provision (2, 3);
 - a first scanning provision (4) on an upstream side of the lighting provision (2, 3) viewed in the relative direction of movement of the substrate (S) with respect to the processing head;
 - a second scanning provision (5) on a downstream side of the lighting provision (2, 3) viewed in the relative direction of movement of the substrate with respect to the processing head.

18. An apparatus according to claim 17, wherein the processing head is further provided with an inkjet printing provision (1).

19. An apparatus, according to claim 18, wherein the processing head is provided with two said lighting provisions (2, 3), wherein a first lighting provision (2) is provided upstream and a second lighting provision (3) is provided downstream of the inkjet printing provision (1), viewed in the relative direction of movement of the substrate (S) with respect to the processing head.

20. An apparatus according to any one of claims 18-19, wherein the first scanning provision (4) is provided upstream and the second scanning provision (5) is provided downstream of the inkjet printing provision (1), viewed in the relative direction of movement of the substrate (S) with respect to the processing head.
21. An apparatus according to any one of claims 17-20, wherein the processing head is arranged so as to be movable relative to the fixed world and wherein the substrate carrier is stationary, at least during the carrying out of the lighting step.
22. An apparatus according to any one of claims 17-21, provided with a control arranged for processing information obtained with the scanning provisions (4, 5), which control is further arranged for controlling the movement of the processing head, and controlling the at least one lighting provision (2, 3).
23. An apparatus according to the combination of claims 18 and 22, the inkjet printing provision (1) having various nozzles, the control being further arranged for controlling the various nozzles of the inkjet printing provision (1).
24. An apparatus according to any one of claims 17-23, wherein the scanning provisions (4, 5) are arranged for carrying out an interferometric measurement, a triangulation measurement or image recognition.
25. An apparatus according to any one of claims 17-24, wherein the lighting provision (2, 3) comprises an array of individually controllable lasers, LEDs or similar lighting means which can quickly be switched on and off or modulated, with the aid of which the respective lacquer can be lighted locally.