

"A PROCESS FOR MAKING A LIGHT-SHIELDING THIN FILM"

The present invention relates to a process for making a light-shielding thin film.

5 Heretofore, the making of a light-shielding thin film has been accomplished by the steps of forming a photo-resist on a light-shielding thin film, exposing the photo-resist in a desired pattern, developing the exposed photo-resist to form a desired photo-resist pattern, and etching the light-shielding thin film by
10 using the photo-resist pattern as a mask.

The above-mentioned process, however, has the disadvantage that, after etching, the light-shielding thin film has a sharp step. Therefore, when forming a thin film to cover the step at the edge of the light-shielding thin film, the step is not completely covered,
15 and the thin film applied to it is liable to be broken away. Accordingly, it is an object of the present invention to provide a process for etching a light-shielding thin film which permits the step to be
20 covered completely.

According to the present invention, there is provided a process for making a light-shielding thin film comprising forming a light-shielding thin film directly or indirectly on a light-transmitting
25 substrate; forming a photo-resist pattern on the light-shielding thin film; etching the light-shielding thin film by using the photo-resist pattern as a mask,

thereby forming a light shielding thin film pattern;
exposing the photo-resist pattern through the reverse
side of the light-transmitting substrate by using the
light-shielding thin film pattern as a mask; developing
5 the exposed photo-resist pattern so as to form a
reduced size photo-resist pattern; and etching the
light-shielding thin film pattern by using the reduced
size photo-resist pattern as a mask.

10 The photo-resist pattern may be formed by applying
a photo-resist layer to the light-shielding thin film,
selectively exposing the photo-resist layer, and
developing the exposed photo-resist layer so as to form
the photo-resist pattern.

15 The light-shielding thin film may be a metal thin
film and the latter may be formed into a gate electrode.

Alternatively, the light-shielding thin film may
be a semiconductor thin film e.g. of silicon. The latter
may comprise an intrinsic amorphous silicon layer and an
extrinsic silicon layer. In this case, a patterned
20 conductive thin film is preferably formed on the
extrinsic silicon layer; and, using the patterned
conductive thin film as a mask, the extrinsic silicon
layer is etched to form source and drain electrodes.

If desired, prior to the formation of the patterned conductive thin film, a photo-resist pattern is formed on the light-shielding thin film and the latter is used as a mask in the exposure of the photo-resist pattern through the reverse side of the light-transmitting substrate.

The invention also comprises a product, e.g. a thin film transistor or a photo-sensor, having a light-shielding thin film produced by the process set forth above.

The invention is illustrated, merely by way of example, in the accompanying drawings in which Figures 1, 2 and 3 respectively illustrate steps in first, second and third embodiments of the present invention.

Figure 1 shows a first embodiment of the present invention in which a process for making a light-shielding thin film is applied to a metal thin film forming gate electrodes or gate wiring of a thin-film transistor.

In Figure 1, there are shown, in the form of successively superposed layers, an insulating light-transmitting substrate 11 which may be made of glass, a light-shielding thin film 12 which may be made of a metal thin film, and a photo-resist layer 13.

Each step of the process will be described in the order of (A) to (F) shown in Figure 1.

(A) On the light-transmitting substrate 11 there is evaporated a light-shielding thin film 12 (Cr in this case) to form a gate electrode. To this light-shielding

thin film 12 there is applied a positive photo-resist layer 13, which is subsequently pre-baked.

(B) The pre-baked photo-resist layer 13 is selectively exposed, followed by development, to form a photoresist pattern 13a of desired shape. No post-baking is performed.

(C) Using the photo-resist pattern 13a as a mask, the light-shielding thin film 12 is etched by an aqueous solution of cerium ammonium nitrate $(\text{NH}_4)_2\text{Ce}(\text{NO}_3)_6$ to form a light shielding thin film pattern 12a which matches the photo-resist pattern 13a. Then, the reverse side of the light-transmitting substrate 11 is irradiated with ultra-violet rays 14 so as to expose the photo-resist pattern 13a by using the light-shielding thin film pattern 12a as a mask. (This step is referred to as back exposure). Since the ultra-violet rays 14 are absorbed by the light-shielding thin film pattern 12a, the photo-resist pattern 13a is hardly exposed. However, the edge of the photo-resist pattern 13a is partly exposed by the ultra-violet rays 14 which are diffracted or reflected (by the light shielding thin film pattern 12a).

(D) The photo-resist pattern 13a is developed so that the edge of the photo-resist pattern 13a which has been exposed in the step (C) above is removed. Thus a photo-resist pattern 13b is obtained which is a reduced size version of the photo-resist pattern 13a.

(E) The light-shielding thin film pattern 12a is

etched by plasma dry etching which uses a mixed gas of tetrachloromethane (CCl_4) and oxygen as an etchant. During the plasma dry etching, the photo-resist pattern 13b is drawn back. A mixture of chlorine-containing gas and oxygen is used in this example because a metal thin film of chromium is used as the light-shielding thin film. This mixed gas may be replaced by another one composed of fluorine-containing gas and oxygen in the case where some other metal thin film is used.

10 (F) The photoresist pattern 13b is removed. Thus there is formed a gate electrode of light-shielding thin film pattern 12b.

15 The light-shielding thin film pattern 12b formed by the above-mentioned steps has a thinned edge, as shown in Figure 1(F), because the light-shielding thin film has undergone etching twice.

20 Especially in the case where the second etching is performed by plasma dry etching, the resulting light-shielding thin film pattern 12b has a very smoothly tapered edge.

Figure 2 shows a second embodiment of the present invention, in which the process of making the light-shielding thin film is applied to a semiconductor thin film of a thin film transistor.

In Figure 2, there are shown an insulating light-transmitting substrate 21 which may be made of glass, a light-shielding thin film 22 constituted by a semiconductor thin film, and a photo-resist layer 23.

5 Each step of the process will be described in the order of (A) to (H) shown in Figure 2.

 (A) The substrate 21 has a previously formed gate electrode 25 (preferably formed by the process shown in Figure 1) and a gate insulating layer 26. On this gate
10 insulating layer 26 there are formed an intrinsic amorphous silicon layer 221 (150~250 nm thick) and an extrinsic silicon layer 222 (30~50 nm thick) by the plasma CVD (chemical vapour deposition) method. (The silicon layer
15 221 contains substantially no impurities which function as donors or acceptors, and the silicon layer 222 contains an appropriate amount of impurities which function as donors or acceptors). The intrinsic amorphous silicon layer 221 and the extrinsic silicon layer 222 are
20 semiconductor thin films which collectively constitute the light-shielding thin film 22. Onto this light-shielding thin film 22 there is applied a positive photo-resist layer 23, followed by prebaking.

 (B) The pre-baked photo-resist layer 23 is exposed, followed by development, to form a photo-resist pattern 23a
25 of desired shape. No post-baking is performed.

(C) Using the photo-resist pattern 23a as a mask, the light-shielding thin film 22 is etched in the usual way to form a light-shielding thin film pattern 22a. (In the case where the light-shielding thin film is made of silicon as in this embodiment, the light-shielding thin film 22 is etched, while the photo-resist pattern 23a is drawn back, with plasma dry etching in which a mixture of fluorine-containing gas (e.g., CF_4) and oxygen is used as an etchant). Then, the light-transmitting substrate 21 is irradiated through its reverse side with ultra-violet rays 24 so as to expose the photo-resist pattern 23a, using the light-shielding thin film pattern 22a as a mask. (Back exposure). Since the ultra-violet rays 24 are absorbed by the light-shielding thin film pattern 22a, the photo-resist pattern 23a is hardly exposed. (A thickness of about 200 nm is enough for the ultra-violet rays 24 to be mostly absorbed by the light-shielding thin film of amorphous silicon). However, the edge of the photo-resist pattern 23a is partly exposed by the ultra-violet rays 24 which are diffracted or reflected by the light-shielding thin film pattern 22a.

(D) The photo-resist pattern 23a is developed so that the edge of the photo-resist pattern 23a which has been exposed in the step (C) above is removed. Thus there is obtained a photo-resist pattern 23b which is a reduced size version of the photo-resist pattern 23a.

(E) The light-shielding thin film pattern 22a is etched, using the reduced size photo-resist pattern 23b as a mask, by plasma dry etching which uses a mixture of fluorine-containing gas such as CF_4 and oxygen as an etchant. During the plasma dry etching, the photo-resist pattern 23b is drawn back. (A mixture of fluorine-containing gas and oxygen is used in this embodiment because a semiconductor thin film of silicon is used as the light-shielding thin film. This gas mixture may be replaced by another gas mixture according to the type of semiconductor thin film used).

(F) The reduced size photo-resist pattern 23b is removed. Thus there is formed a light-shielding thin-film pattern 22b in the shape of an island, the pattern 22b comprising intrinsic amorphous silicon layer 221b and extrinsic silicon layer 222b.

The light-shielding thin film pattern 22b formed by the above-mentioned steps has a thinned edge, as shown in Figure 2(F), because the light-shielding thin film has undergone etching twice.

(G) A conductive thin film 27 of ITO (indium tin oxide) for the source and drain electrodes is formed on the extrinsic silicon layer 222b by EB evaporation or sputter evaporation. Since the light-shielding thin film pattern 22b has a thinned edge, good step coverage of the conductive thin film 27 is obtained without the likelihood that the conductive thin film 27 can be broken at the steps.

(H) The conductive thin film 27 is patterned according to a desired shape. Using the patterned conductive thin film 27 as a mask, the extrinsic silicon layer 222b is etched to form source and drain electrodes 222c.

Thus a thin film transistor is formed by the above-mentioned steps (A) to (H).

Figure 3 shows a third embodiment of the present invention, in which the process of making the light-shielding thin film is applied to a semiconductor thin film of a photo-sensor.

In Figure 3, there are shown an insulating light-transmitting substrate 31 which may be made of glass, a light-shielding thin film 32 constituted by a semiconductor thin film, and a photo-resist layer 33.

Each step of the process will be described in the order of (A) to (H) shown in Figure 3.

(A) The substrate 31 is provided with a previously formed lower electrode 35 (preferably formed by the process shown in Figure 1). On this substrate 31 there are formed an intrinsic amorphous silicon layer 321 (about 600 nm thick) and an extrinsic silicon layer 322 by plasma CVD method. (The silicon layer 321 contains substantially no impurities which function as donors or acceptors, and the silicon layer 322 contains an appropriate amount of impurities which function as donors or acceptors). The intrinsic amorphous silicon layer 321 and the extrinsic silicon layer 322 are semiconductor thin

films which collectively constitute the light-shielding thin film 32. Onto this light-shielding thin film 32 is applied a positive photo-resist layer 33, followed by pre-baking.

5 (B) The pre-baked photoresist layer 33 is exposed, followed by development, to form a photo-resist pattern 33a of desired shape. No post-baking is performed.

 (C) Using the photo-resist pattern 33a as a mask, the light-shielding thin film 32 is etched in the usual way to form a light-shielding thin film pattern 32a. (In the case where the light-shielding thin film is made of silicon as in this embodiment, the light-shielding thin film 32 is etched, while the photo-resist pattern 33a is drawn back, with plasma dry etching in which a mixture of fluorine-containing gas (e.g. CF_4) and oxygen is used as an etchant). Then, the light-transmitting substrate 31 is irradiated through its reverse side with ultra-violet rays 34 so as to expose the photo-resist pattern 33a (back exposure). Since the ultra-violet rays 34 are absorbed by the light-shielding thin film pattern 32a, the photo-resist pattern 33a is hardly exposed. However, the edge of the photo-resist pattern 33a is partly exposed by the ultra-violet rays 34 which are diffracted or reflected by the light-shielding thin film pattern 32a.

25 (D) The exposed photo-resist pattern 33a is developed

so that the edge of the photo-resist pattern 33a which has been exposed in the step (C) above is removed. Thus there is obtained a photo-resist pattern 33b which is a reduced size version of the photo-resist pattern 33a.

5 (E) The light-shielding thin film pattern 32a is etched, using the reduced size photo resist pattern 33b as a mask by plasma dry etching which uses a mixture of fluorine-containing gas such as CF_4 and oxygen as an
10 etchant. During the plasma dry etching, the reduced size photo-resist pattern 33b is drawn back. (A mixture of fluorine-containing gas and oxygen is used in this embodiment because a semiconductor thin film of silicon is used as the light-shielding thin film. This gas mixture may be
15 replaced by another gas mixture according to the type of semiconductor thin film used).

 Then, the light-transmitting substrate 31 is irradiated through the reverse side thereof with ultra-violet rays
20 34 (back exposure) for the exposure of the edge of the photo-resist pattern 33b.

 (F) The photo-resist pattern 33b is exposed, and the edge of the photo-resist pattern 33b which has been exposed in the above-mentioned step (E) is removed. Thus there is
25 formed a photo-resist pattern 33c which is a reduced size version of the photo-resist pattern 33b.

(G) The light-shielding thin film pattern 32b is etched by plasma dry etching which uses a mixture of fluorine-containing gas such as CF_4 and oxygen as an etchant. During the plasma dry etching, the photo-resist pattern 33c is drawn back.

The light-shielding thin film pattern 32c formed by the above-mentioned steps has a stepwise thinned edge, as shown in Figure 3(G), because the light-shielding thin film has undergone etching three times.

(H) The photo-resist pattern 33c is removed. Thus there is formed a light-shielding thin-film pattern 32c shaped as an island. Then, a conductive thin film 36 of ITO (indium tin oxide) is formed by EB evaporation of sputter evaporation. The conductive thin film is patterned according to a desired shape to form an upper electrode. Since the light-shielding thin film pattern 32c has a stepwise thinned edge, good step coverage of the conductive thin film is obtained without the likelihood that the conductive thin film 36 will be broken at the steps.

Thus a photo-sensor is formed by the above-mentioned steps (A) to (H).

In the case of the first and second embodiments mentioned above, the back exposure is performed once, and in the case of the third embodiment mentioned above, the back exposure is performed twice. The back exposure may be repeated as many

times as necessary according to the thickness of the light-shielding thin film etc.

5 In the second and third embodiments, the light-shielding thin film is a silicon layer; however, it may be replaced by another semiconductor such as CdTe.

10 The process of the present invention enables the edge of the light-shielding thin film pattern to be made thinner than other parts without increasing the number of masks. Therefore, the thin film formed on the light-shielding thin-film completely covers the step of the light-shielding thin film, and it is very unlikely that the covering thin film will be broken at the stepped edges. Thus the process of the present invention permits an improvement in the manufacturing yield.



CLAIMS

1. A process for making a light-shielding thin film comprising forming a light-shielding thin film directly or indirectly on a light-transmitting substrate; forming a photo-resist pattern on the light-shielding thin film; etching the light-shielding thin film by using the photo-resist pattern as a mask, thereby forming a light-shielding thin film pattern; exposing the photo-resist pattern through the reverse side of the light-transmitting substrate by using the light-shielding thin film pattern as a mask; developing the exposed photo-resist pattern so as to form a reduced size photo-resist pattern; and etching the light-shielding thin film pattern by using the reduced size photo-resist pattern as a mask.
2. A process as claimed in claim 1 in which the photo-resist pattern is formed by applying a photo-resist layer to the light-shielding thin film, selectively exposing the photo-resist layer, and developing the exposed photo-resist layer so as to form the photo-resist pattern.
3. A process as claimed in claim 1 or 2 in which the light-shielding thin film is a metal thin film.
4. A process as claimed in claim 3 in which the metal light-shielding thin film is formed by the process into a gate electrode.
5. A process as claimed in any preceding claim in which the etching of the light-shielding thin film pattern is effected by plasma dry etching.



6. A process as claimed in claim 1 or 2 in which the light-shielding thin film is a semiconductor thin film.

7. A process as claimed in claim 6 in which the said thin film is a silicon thin film.

8. A process as claimed in claim 7 in which the light-shielding thin film comprises an intrinsic amorphous silicon layer and an extrinsic silicon layer.

9. A process as claimed in claim 8 in which a patterned conductive thin film is formed on the extrinsic silicon layer; and, using the patterned conductive thin film as a mask, the extrinsic silicon layer is etched to form source and drain electrodes.

10. A process as claimed in any of claims 6-9 in which, prior to the formation of the patterned conductive thin film, a photo-resist pattern is formed on the light-shielding thin film and the latter is used as a mask in the exposure of the photo-resist pattern through the reverse side of the light-transmitting substrate.

11. A process for making a light-shielding thin film substantially as hereinbefore described with reference to any of Figures 1-3.

12. A product having a light-shielding thin film produced by the process claimed in any preceding claim.

13. A product as claimed in claim 12 in which the product is a thin film transistor or a photo-sensor.
