SHADOW MASK

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Field

The present invention relates to a shadow mask, a method of fabricating a shadow mask and a method of shadow masking.

Background

A number of methods are known for fabricating the individual components on semiconductor devices. Patterning/deposition for example, is used for many applications such as patterning of features on a substrate for circuits, transistors, interconnects, circuitries for RF components and MEMS technology.

One well known method of patterning/deposition is photolithography. A pattern of photo mask is provided on top of a layer of photo resist. The unmasked portion is then exposed to ultraviolet light. This affects the stability of the unmasked portion such that the underlying substrate can then be etched according to the pattern of the photo mask. However, photolithography is relatively expensive.

Other patterning techniques have been proposed that are less expensive than photolithography. For example a shadow mask may be mechanically placed on a wafer to mask the portions for patterning of the device.

A silicon (Si) wafer shadow mask is one option used for patterning of features on various substrates. However, the use of a Si wafer shadow mask to provide sub-micron features is expensive and the process to fabricate the mask is not suitable for non circular shaped Si substrate. A Si wafer shadow mask

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cannot be too thin as the material is brittle and prone to cleave along crystal planes. Also, a Si wafer shadow mask may achieve a high aspect ratio, but the required thickness of the Si substrate may produce trench features that are too deep. In some cases, the sputtered/evaporated material may only reach the side wall and may not reach the surface of the substrate.

Also, for a pattern with long features, eg: a long trench line, a support beam may be required to prevent breakage. With the implementation of beam on the Si wafer shadow mask, careful steps must be taken so as to prevent non-uniform patterning/deposition of materials.

Shadow masks may also be made using metals and alloys, eg: stainless steel. However, metal shadow masks are more deformable and may not achieve patterns of high precision. They can also result in sharp edges which may damage the previously patterned layers, when the shadow mask is placed on the substrate. Also, most conventional technologies for fabricating metal shadow masks (such as: wire & laser cutting and chemical etching) have limitation on the dimension of the features they can offer (preferably for features more than 50um).

Summary

In general terms the invention relates to a polymer shadow mask with a rigid backing layer. The shadow mask may be used for thin film patterning/deposition of micro-features on substrate for circuits, transistors, interconnects, circuitries for RF components and MEMS technology.

The polymer may be liquid crystalline polymer (LCP) thin film. The LCP thin film may be bonded on a silicon (Si) wafer. The Si wafer may provide the rigidity required for a shadow mask and the LCP thin film may provide elasticity of

the structure as a shadow mask. LCP may have the flexibility to be placed on an uneven substrate to minimize the gap between them. LCP may also allow fine micro-features for the thin film patterning/deposition on a substrate. Micro-machined features may be created on the LCP with precise dimension of several tenth micrometers (um) down to 5 um. The aspect (height : width) ratio of more than 5 may be achieved on the micro-features.

A ferromagnetic material may be deposited on the surface of the mask. The ferromagnetic material may secure the substrate between the LCP mask and a magnetic plate installed behind the substrate. This may also minimize the gap of the mask and substrate for the precise patterning/deposition of the fine features.

This may enable a low cost shadow mask to be created and/or may provide an easy technique for the patterning/deposition of micro-features on substrate for circuits and MEMS technology.

LCP material may be micro-machined to provide desired features/designs with deep RIE process using oxygen (O_2).

A shadow mask using LCP and Si wafer bonded together may provide the rigidity to support the mask membrane flatly and may provide a small thickness to avoid shading effect during patterning/deposition. It may also provide the ability to create fine micro-features for the thin film patterning/deposition.

The LCP mask can be used repeatedly and can be cleaned by using commercially available etchants.

Brief Description of the Drawings

Exemplary embodiments will now be described for the sake of example only with reference to the drawings, in which:

Figure 1 illustrates a shadow mask according to an exemplary embodiment,

Figure 2 illustrates a method of fabrication of the shadow mask in Figure 1,

Figure 3 illustrates the process flow for the method in Figure 2,

Figure 4 illustrates a method of shadow masking using the shadow mask in Figure 5, and

Figure 5 illustrates the process flow for the method in Figure 4.

Detailed Description of Invention

Figure 1 shows a shadow mask 100 according to an exemplary embodiment. A LCP thin film layer 102 has a number of fine openings 104, through which a material may be deposited on a substrate. The LCP thin film layer 102 has a rigid Si wafer backing layer 106, which is much thicker than the LCP thin film layer 102, and has number of much larger openings 108 corresponding to the fine openings 104. For example a much larger opening 108 may span several fine openings 104.

LCP can be melt processed and machined at fast speeds with excellent replication of details. Typically, LCPs have outstanding mechanical properties at high temperature, excellent chemical resistance, inherent flame retardancy and good weatherability. LCPs come in a variety of forms from sinterable high temperature forms to injection moldable compounds.

To achieve good dimension tolerance of features on substrate during the thin film patterning/deposition, it is important to minimize the gap and maintain

good contact between the mask and the substrate. When using a shadow mask, which is either too flexible or rigid, it is difficult to minimize the gap of the features between substrate and the mask. A magnetic layer 120 is provided on the LCP thin film layer 102 and a magnet is installed behind the substrate. This magnetic attraction and/or the construction of the shadow mask 100 may help to provide good contact and also minimize the gap of the features between the mask and substrate.

Figures 2 and 3 show a method 200 of fabricating the shadow mask 100 according to an exemplary embodiment. At 202 a silicon wafer 106 is provided. At 204 a fluoropolymer 112 is coated to the wafer 106, as seen in Figure 3(a) as a bonding layer. At 206 a sheet of LCP 102 is bonded to the fluoropolymer layer 112 at 160°C for 30minutes, as seen in Figure 3(b). At 208 an aluminum layer 114 is spluttered onto the LCP layer 102, as seen in Figure 3(c). At 210 a photo resist masking 116 is spin coated to the aluminum layer 114. At 212 the aluminum layer 114 is patterned and wet etched (or alternatively, dry etching could be used), as seen in Figure 3(d). At 214 the LCP 102 and fluoropolymer 112 are deep reactive ion etched (RIE) using oxygen (O_2) to form the fine openings 104 for the features, as seen in Figure 3(e). The device is then flipped and at 216 a photo resist layer 118 is spin coated to the Si wafer 106. At 218 deep RIE is performed on the Si wafer 106, using SF_6 and C_4F_8, to form the large openings 108, as seen in Figure 3(f). At 220 the photo resist layers 116,118 are removed using acetone and the aluminum layer 114 is removed using Al etchant, as seen in Figure 3(g). At 222 a ferromagnetic layer 120 is deposited onto the LCP layer 102, as seen in Figure 3(h).

The various layers and materials may be chosen according to the desired application. For example the backing layer 106 may be a 101.6mm diameter and 300um thick silicon (Si) wafer, or other deep RIE capable material. The LCP sheet 102 used may be 25 um thick and cut to the dimension similar to

that of the Si wafer 106, such as Ultralam 3000 Series Liquid Crystalline Polymer Circuit Material from Rogers Corp, polyimide (PI), poly(methyl methacrylate) (PMMA) based film, fluoroacrylate type film or thermoset polymer film. The fluoropolymer layer 112, used for adhesion or bonding of the LCP material 102 and the Si wafer 106, may be 2um thick, such as CYTOP Series fluoropolymer from Asahi Glass Chemicals. The aluminum layer 114 may be 100 nm thick. The photo resist layer 116 on the aluminum layer 114 may be 2um thick and the photo resist layer 118 on the Si wafer 106 may be 10um. The fine openings 104 may be lines that are 5 um wide and 24 mm long. The much larger openings 108 may be 400um wide and 25mm long. The ferromagnetic layer may be a 1.0-1.5um thick layer of nickel-iron (Ni-Fe), nickel (Ni), cobalt (Co), iron (Fe) or Co-Fe. For example the ratio of the width of the smaller openings 104 to the larger openings may be 5:400 and the ratio of thickness of the LCP layer 102 to the backing layer 106 may be 25:300.

Figures 4 and 5 show a method 400 of thin film patterning or shadow masking using the shadow mask 100. At 402 the LCP mask 100 is placed onto a substrate 500 (surface to be patterned) with the ferromagnetic layer 120 contacting the front side of the substrate 500, and a magnet 110 on the back side of the substrate 500, as seen in Figure 5(a). The magnet secures the LCP mask 100 on the substrate 500. It also helps to minimize the gap between the LCP mask 100 and the substrate 500 especially in the area of the patterning features. The LCP mask 100, the substrate 500 and the magnet 110 are further secured together by mechanical means for the thin film patterning/deposition process. At 404 an Al layer 502 is evaporated over the shadow mask 100, to form the features 504 in the fine openings 104, as seen in Figure 5(b). At 406 the LCP shadow mask 100, the magnet 110 and the substrate 500 are separated after the metal patterning/ deposition process, leaving the features 504 in the desired locations on the substrate 500, as seen in Figure 5(c). At 408 an appropriate

etchant is used to move the deposited material, so that the shadow mask 100 can be reused.

The substrate 500 may be silicon (Si) wafer, glass, PCB, and other polymers (such as: PMMA, PET, PEN, PC, etc). The deposition system may be sputtering, e-beam & thermal evaporation. The evaporated materials may be aluminum (Al), gold (Au), copper (Cu), silver (Ag), Ti/Al, Ti/Au, Ti/Cu, SiO, ITO, organic semiconductor materials. The layer of deposited materials may for example be 100-200nm thick.

In the foregoing specification, the disclosure has been described with reference to specific exemplary embodiments thereof. It will be evident that various modifications can be made thereto without departing from the broader spirit and scope of the invention as set forth in the following claims. The specification and drawings are, accordingly, to be regarded in an illustrative sense rather than a restrictive sense.

Claims

1. A shadow mask comprising:

a thick rigid backing layer having a plurality of large apertures, and

a polymer thin film on the thick rigid backing layer having a plurality of fine apertures corresponding to the plurality of large apertures.

2. The shadow mask as claimed in claim 1 wherein the polymer thin film is liquid crystal polymer (LCP).

3. The shadow mask as claimed in claim 1 or 2 further comprising a ferromagnetic film on the polymer thin film.

4. The shadow mask as claimed in any one of the preceding claims wherein the thickness of the polymer thin film is approximately 25um.

5. The shadow mask as claimed in any one of the preceding claims wherein the thick rigid backing layer is capable of deep reactive ion etching.

6. The shadow mask as claimed in claim 5 wherein the thick rigid backing layer is a silicon wafer.

7. The shadow mask as claimed in any one of the preceding claims wherein the thickness of the thick rigid backing layer is approximately 300um.

8. The shadow mask as claimed in any one of the preceding claims configured for depositing of features having an aspect (height : width) ratio of more than 5.

9. The shadow mask as claimed in any one of the preceding claims wherein the fine apertures are less than 20um wide.

10. The shadow mask as claimed in claim 9 wherein the fine apertures are approximately 5um wide.

11. The shadow mask as claimed in any one of the preceding claims further comprising an adhesion and/or bonding layer between the thick rigid backing layer and the polymer thin film.

12. The shadow mask as claimed in claim 11 wherein the adhesion and/or bonding layer is a fluoropolymer.

13. The shadow mask as claimed in any one of the preceding claims wherein the large apertures are approximately 400um wide.

14. The shadow mask as claimed in any one of the preceding claims wherein a single large aperture corresponds to a plurality of fine apertures.

15. The shadow mask as claimed in any one of the preceding claims wherein the ratio of the thickness of the polymer thin film to the thick rigid backing layer is approximately 25:300.

16. The shadow mask as claimed in any one of the preceding claims wherein the ratio of width of the fine apertures to the large apertures is approximately 5:400.

17. A method comprising
providing a thick rigid backing layer,
forming a polymer thin film on the thick rigid backing layer

forming a plurality of fine apertures in the polymer thin film, and

forming a plurality of large apertures in the thick rigid backing layer.

18. The method in claim 17 wherein the polymer thin film comprises liquid crystal polymer (LCP).

19. The method in claim 17 or 18 wherein the forming a plurality of fine apertures and/or the forming a plurality of large apertures comprises deep reactive ion etching.

20. A method comprising

providing a flexible shadow mask with a rigid backing,

depositing a material on selected portions of a substrate using the shadow mask, and

removing the shadow mask for reuse.

21. The method in claim 21 further comprising applying a magnetic attractive force between the substrate and the shadow mask while the material is being deposited.