The disclosure relates to a mask for use in X-ray lithography wherein a window is provided for X-rays, a pattern being placed over the window which absorbs the X-rays along the pattern, thereby providing a mask to the X-rays in accordance with the pattern and causing the X-rays to strike a mask on a device at all points except where the X-rays have been masked. Photoresist systems which are responsive to X-rays are well known, these including polymethylmethacrylate. The mask is formed from a thin layer of silicon carbide with a ring of material supporting the silicon carbide, preferably silicon. The desired pattern is then formed on the silicon carbide, using a material which absorbs X-rays, such as gold.

The mask is formed by utilizing a starting substrate such as silicon and depositing a thin layer of silicon carbide thereon. The silicon is then etched down to the silicon carbide at all points except for the perimeter of the silicon carbide or in segments such as quadrants to provide a support for the silicon carbide. The silicon carbide is thin and acts as a window to X-rays. An X-ray absorbing mask is then formed on the silicon carbide window to provide the final X-ray lithograph mask.
Fig. 1a

Fig. 1b

Fig. 1c

Fig. 1d

Fig. 1e

Fig. 2
This invention relates to an X-ray lithography mask and method of making same, and, more specifically, to an X-ray absorbing mask on a silicon carbide window and method of making same.

In the semiconductor art, it is often desirable and necessary to define very narrow lines in the semiconductor device on the order of 0.1 to 1 microns in width. It has been a problem to provide such narrow lines in the prior art. One attempt to solve this problem has been by the use of masks. This method has proved to be very expensive, slow and not particularly reliable. It is therefore desirable and necessary to find other techniques whereby etching lines which are as narrow as 0.1 to 1 microns in width can be provided.

In accordance with the present invention, the above problem is substantially overcome and there is provided a relatively inexpensive and useful technique for providing etching of lines in the 0.1 to 1 micron width range. Briefly, in accordance with the present invention, there is provided an X-ray lithography mask which includes a thin layer of silicon carbide on a support, the silicon carbide acting as a window to X-rays. A mask in the shape of a desired pattern is then formed on the silicon carbide thin layer by depositing thereon a material which absorbs X-rays such as gold. The result is a mask which can be used in conjunction with X-rays for exposing selected portions of a material responsive to X-rays in the same manner as photo-resists are responsive to light in the well known prior art etching techniques. Polymethylmethacrylate or other such material can be removed along lines as thin as 0.1 microns to permit etching of lines of this thickness.

The mask in accordance with the present invention is formed by providing a silicon substrate or other substrate material which is compatible with silicon carbide and on which silicon carbide can be deposited as well as having a similar coefficient of thermal expansion. Silicon meets these conditions and is therefore a preferable substrate material. Silicon carbide is then deposited in a thin layer over one upper surface of the substrate by any of many well known techniques in the art. One such technique is set forth in the Journal of the Electrochemical Society, Volume 114, No. 11, Nov. 19, 1967, at pages 1158-1161 in an article entitled “Some Properties of Vapor Deposited Silicon Carbide” by Kenneth E. Bean and Paul S. Gleim. The silicon is then etched back to the silicon carbide layer except for small support regions, for example, at the periphery of the silicon carbide layer. An X-ray absorbing mask, such as gold, is then formed in desired shape on the silicon carbide layer to provide the final X-ray lithography mask for use with X-rays to permit etching of lines as narrow as 0.1 microns.

It is therefore an object of this invention to provide a method of forming an X-ray lithography mask.

It is a further object of this invention to provide a mask wherein a pattern absorbs X-rays and the remainder of the mask acts as a window to X-rays.

It is a yet further object of this invention to provide a silicon carbide window on a silicon support with an X-ray absorbing pattern thereon for use as an X-ray lithography mask.

It is a yet further object of this invention to provide a silicon carbide window on a silicon support with an X-ray absorbing pattern on the silicon carbide to provide an X-ray lithography mask.

It is the yet further object of this invention to provide a method of forming an X-ray lithography mask which includes the steps of depositing silicon carbide on a silicon substrate, etching the silicon substrate to provide a support, for example, around the perimeter of the silicon carbide, and depositing an X-ray absorbing pattern on the silicon carbide window.

The above objects and still further objects of the invention will immediately become apparent to those skilled in the art after consideration of the following preferred embodiment thereof, which is provided by way of example and not by way of limitation, wherein:

FIGS. 1a–1e illustrate a series of steps required to form an X-ray lithography mask in accordance with the present invention; and

FIG. 2 is a schematic diagram of a system of X-ray lithography utilizing the mask in accordance with the present invention.

Referring first to FIGS. 1a–1e, there is shown a series of steps which provide a method for forming an X-ray lithography mask in accordance with the present invention. As shown in FIG. 1a, there is initially provided a silicon substrate 1. It should be understood that though silicon is the preferred substrate material, any material upon which silicon carbide can be deposited, which has a coefficient thermal expansion similar to that of silicon carbide and which is etchable by materials with which silicon carbide is not reactive can be used. A thin layer of silicon carbide 3 is then deposited on one surface of the silicon substrate 1 as shown in FIG. 1b by any of many well known techniques. The silicon carbide layer 3 is made as thin as possible but must be sufficiently strong to hold a mask and be capable of being handled.

A preferred method of depositing silicon carbide is set forth in the above enumerated article of Bean and Gleim, though other well known methods could also be used. With reference to FIG. 1c, a mask is then placed around the outer periphery of the silicon. This can be wax 5 as shown in FIG. 1c or any other material which will mask the silicon during etching as is well known. The silicon is then etched back to the silicon carbide layer as shown in FIG. 1d, the silicon remaining only where masked, this being around the periphery of the silicon carbide to provide a silicon support therefor. It should be understood that the silicon support need not be at the periphery of the silicon carbide and could be in any operable pattern, such as a matrix of lines on the silicon carbide. The silicon carbide acts as an etch stop.

The silicon carbide layer 3 is preferably at the order of 1–2 microns. The silicon layer 1 can be of any thickness, the sole requirement being that it be thick enough to act as a proper support for the silicon carbide layer but not to thick so that a great deal of etching is necessary to provide the etching set forth in FIG. 1d, this being merely an economic consideration. The silicon carbide is essentially transparent to X-rays and acts as a window for X-rays. A pattern 7, which can be of gold or any other material which absorbs X-rays is then formed over the silicon carbide layer as shown in FIG. 1e to provide the final mask. The gold mask 7 can be deposited onto the silicon carbide layer 3 through a mask or gold can be deposited directly onto the silicon carbide layer 3 without a mask, the gold then being etched to the desired pattern by means of an electron beam or by any other acceptable procedure. The final mask is shown as mask 9 of FIG. 2 with silicon support
11 around the perimeter, the silicon carbide layer 3 and the gold pattern 7 thereon.

Referring now to FIG. 2, there is shown an X-ray gun 13 which provides a beam 15 of X-rays which travel through the silicon carbide layer 3 of the X-ray lithography mask 9 but are absorbed by the pattern 7. The X-rays pass through to a substrate 15 which can be of semiconductor material having a layer 17 of a material which is responsive to X-rays such as polyethylene glycol. The X-rays impinge upon the entire layer 17 of polyethylene glycol within the region of the pattern 19 which is the same pattern as the mask pattern 7. In this way, due to the very narrow dispersions of X-rays, pattern lines can be provided on the substrate 15 which are on the order of 0.1 to 1 microns wide. The semiconductor device is then formed in accordance with standard practices to etch or diffuse the areas in accordance with the thicknesses of the pattern. It should also be noted that the mask 7 can be used for diffusion processes, selective oxidation and other processes as is apparent to those skilled in the art.

It can be seen that there has been provided a method of forming an X-ray lithography mask and a mask which is relatively inexpensive and which provides dependable and accurate results.

By way of silicon carbide, there is provided an etch stop for the substrate material whereas, if silicon per se were used, there would be no easy way of providing an etch stop. Furthermore, silicon per se is less transparent to X-rays than is silicon carbide. Also, the use of silicon carbide provides a window which is hard and inert to chemical etching. For this reason, the mask 7 can be removed by etching and a new mask can be placed on the same silicon carbide window. Such reuse of the window is not readily available with other materials.

Though the invention has been described with respect to a specific preferred embodiment thereof, many variations and modifications will immediately become apparent to those skilled in the art. It is therefore the intention that the appended claims be interpreted as broadly as possible in view of the prior art to include all such variations and modifications.

What is claimed is:

1. A method of forming a mask for X-ray lithography, which comprises:
   a. providing a substrate of a material capable of being etched by materials to which silicon carbide is inert and having a coefficient of thermal expansion similar to that of silicon carbide;
   b. forming a layer of silicon carbide on said substrate which is sufficiently thin to be transparent to X-rays;
   c. etching away predetermined portions of said substrate up to said layer of silicon carbide whereby the unetched portions provide a support for said silicon carbide layer; and,
   d. forming an X-ray absorbing mask on said layer of silicon carbide.

2. A method as set forth in claim 1 wherein said substrate is silicon.

3. A method as set forth in claim 1 wherein said X-ray absorbing mask is gold.

4. A method as set forth in claim 2 wherein said X-ray absorbing mask is gold.

5. A method as set forth in claim 1 wherein step (c) includes the steps of forming an etch resistant mask around the outer periphery of said substrate and then etching the exposed areas of said substrate.

6. A method as set forth in claim 2 wherein step (c) includes the steps of forming an etch resistant mask around the outer periphery of said substrate and then etching the exposed areas of said substrate.

7. A method as set forth in claim 3 wherein step (c) includes the steps of forming an etch resistant mask around the outer periphery of said substrate and then etching the exposed areas of said substrate.

8. A method as set forth in claim 4 wherein step (c) includes the steps of forming an etch resistant mask around the outer periphery of said substrate and then etching the exposed areas of said substrate.

9. A method as set forth in claim 1 wherein step (d) includes the steps of depositing an X-ray absorbing material over said silicon carbide layer and then removing selected portions of said X-ray absorbing material with an electron beam.

10. A method as set forth in claim 2 wherein step (d) includes the steps of depositing an X-ray absorbing material over said silicon carbide layer and then removing selected portions of said X-ray absorbing material with an electron beam.

11. A method as set forth in claim 3 wherein step (d) includes the steps of depositing an X-ray absorbing material over said silicon carbide layer and then removing selected portions of said X-ray absorbing material with an electron beam.

12. A method as set forth in claim 4 wherein step (d) includes the steps of depositing an X-ray absorbing material over said silicon carbide layer and then removing selected portions of said X-ray absorbing material with an electron beam.

13. A method as set forth in claim 5 wherein step (d) includes the steps of depositing an X-ray absorbing material over said silicon carbide layer and then removing selected portions of said X-ray absorbing material with an electron beam.

14. A method as set forth in claim 6 wherein step (d) includes the steps of depositing an X-ray absorbing material over said silicon carbide layer and then removing selected portions of said X-ray absorbing material with an electron beam.

15. A method as set forth in claim 7 wherein step (d) includes the steps of depositing an X-ray absorbing material over said silicon carbide layer and then removing selected portions of said X-ray absorbing material with an electron beam.

16. A method as set forth in claim 8 wherein step (d) includes the steps of depositing an X-ray absorbing material over said silicon carbide layer and then removing selected portions of said X-ray absorbing material with an electron beam.

17. An X-ray lithography mask, which comprises:
   a. a layer of silicon carbide, said layer being sufficiently thin to permit passage of X-rays therethrough;
   b. a support on predetermined areas of said layer, said support having a coefficient of thermal expansion similar to that of silicon carbide; and,
   c. an X-ray absorbing mask on said layer of silicon carbide.

18. An X-ray lithography mask as set forth in claim 17 wherein said support is formed from silicon.
19. An X-ray lithography mask as set forth in claim 17 wherein said support is a continuous member at the periphery of said silicon carbide layer.

20. An X-ray lithography mask as set forth in claim 18 wherein said support is a continuous member at the periphery of said silicon carbide layer.

21. An X-ray lithography mask as set forth in claim 17 wherein said X-ray absorbing mask is formed from gold.

22. An X-ray lithography mask as set forth in claim 18 wherein said X-ray absorbing mask is formed from gold.

23. An X-ray lithography mask as set forth in claim 19 wherein said X-ray absorbing mask is formed from gold.

24. An X-ray lithography mask as set forth in claim 20 wherein said X-ray absorbing mask is formed from gold.

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