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(54) Title: AN ETCH TECHNIQUE FOR METAL MASK DEFINITION

(57) Abstract

A technique (figure 3), for high resolution feature mask definition, in which a selectively non-erodable masking layer (1) is defined using electron resist (7) and electron lithography, and used in the selective etching of a metal coating (3). Another selective etchant is used subsequently to remove the masking material (1). The metal coating (3) is typically of chrome and may be selectively etched using a chlorine/oxygen plasma. The masking material (1) may be silicon dioxide and etched using a hydrogen containing fluorocarbon (eg. CF_4/H_2; CHF_3). Alternatively, it may be of aluminium and etched using a chlorine, boron trichloride or carbon tetrachloride plasma. Other masking materials may be used eg. titanium, silicon, germanium or nickel. The masking layer may be formed using electron resist above the layer material (figures 1 to 3). Alternatively, the masking material and electron resist may be applied in reverse order and a float-off process used (figure 6).

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AN ETCH TECHNIQUE FOR METAL MASK DEFINITION

Technical Field

The present invention concerns improvements in or relating to etch techniques for metal mask definition.

Chrome metal coated mask plates are widely used in the manufacture of microelectronic devices. Images on the mask plate are replicated in photoresists on wafers of different kinds. Replication is usually by means of exposure of the resist to U.V. light with the mask plate in contact with the resist, or by imaging the mask plate with a lens, again using U.V. light.

To obtain images with very small critical dimension (say 0.5 micron or less) contact photolithography is frequently used with short wavelength U.V. (200-300nm). This requires chrome mask plates with features of half micron dimension controlled to tight tolerances. Typically the tolerance allowed the mask maker on a half micron line would be ± 10%, ie. ± 0:05 micron. Since this tolerance "budget" has to embrace inaccuracies in resist exposure, resist development and chrome etching, the allowable error in any one of these individual processes is probably no greater than ± 0.01 to 0.02 micron.

Background Art

If a wet isotroptic etchant is used to delineate features in the chrome coating of the mask, through a layer of patterned resist, there will be undercutting

of the resist image by an amount comparable with the thickness of the chrome coating (typically 800 Å). Thus a slot developed in the resist will be broadened by about 0.2 micron when transferred to the chrome coating. With
5 conventional electron beam lithography machines (such as the Cambridge Instruments EBMF-2) chrome features (eg. holes) smaller than 0.5 micron therefore become very difficult to achieve or control since they require resist images smaller than 0.3 micron.

10 A dry etching technique such as reactive ion etching (RIE) might appear to offer a simple solution, since undercutting can be largely eliminated. Though there can be gains in edge smoothness and hence in dimensional control by using RIE techniques, resist erosion frequently
15 does not permit dimensions significantly smaller than those achievable by wet etching to be obtained. This is particularly true if high contrast, high resolution positive resists such as PMMA are used. Clearly an unfavourable etch rate ratio between chrome and resist
20 leading to significant resist erosion would also imply reduced dimensional control if etch rates were to vary from place to place on a mask, or from time to time.

It seems likely that for the chlorine/oxygen plasmas normally used to etch chrome, many, if not all,
25 conventional polymeric electron resists will have etch rates too fast to permit either very small features or

adequate dimensional control to be achieved.

Disclosure of the Invention

The present invention is intended as an improved dry etch technique wherein chrome or like metal mask features
5 may be defined to a high degree of accuracy.

The solution provided here is to use a masking layer in place of the electron resist alone, in particular a masking layer of a material which will not erode significantly during plasma or reactive ion etching of the
10 chrome or like metal coating, but which can be patterned readily by electron-lithography.

In accordance with the invention thus there is provided an etch technique for metal mask definition, this technique comprising:-
15 providing a mask blank of metal-coated material;
forming, in contact with the metal coating on the surface of the mask blank, a layer of selectively non-erodable masking material patterned using electron resist and electron-lithography;
20 dry etching the metal coating using a first etchant, an etchant that is selective with respect to the metal coating; and,
removing the layer of masking material using a second etchant, an etchant that is selective with respect to the
25 masking material.

It is an advantage of the technique aforesaid that the selectively non-erodable material can be patterned to a high resolution to serve thereafter as a more satisfactory masking material during subsequent dry etching.

Suitable selectively non-erodable materials include oxides and metals, particularly, but not exclusively: silicon dioxide; silicon; titanium; germanium; nickel; and, aluminium.

Various methods may be employed as a means of patterning the layers of masking material.

In one such method (a positive image method) a full planar layer of the masking material may be provided on the surface of the metal coating and covered by electron resist. The latter then is patterned electron-lithographically and the image, thus formed, transferred to the underlying masking material by subsequent etching.

In an alternative method a reversed (negative) image method , a full planar layer of electron resist may be provided on the surface of the metal coating and patterned by electron-lithography. This layer, now patterned, is then covered by deposited masking material and then removed to float-off surplus masking material leaving a patterned layer of the remaining masking material in relief.

In both methods aforesaid, it is preferable to use

a positive electron-resist since such resist materials do in general offer better resolution capability than do their negative resist counterparts. Where positive resists are adopted, therefore, the one method aforesaid is preferred for defining a metal coated mask having a "dark-field" pattern. The alternative method aforesaid is preferred for "light-field" pattern definition.

BRIEF INTRODUCTION OF THE DRAWINGS

In the accompanying drawings:-

Figures 1 to 5 are cross-section illustrations showing a metal-coated mask blank at successive stages of a first technique performed in accord with this invention; and,

Figures 6 to 9 are cross-section illustrations showing a metal-coated mask blank at successive steps of a second and alternative technique performed likewise in accord with this invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

So that this invention may be better understood, reference will now be made to the drawings, and embodiments of the technique aforesaid, will be described. The description that follows is given by way of example only.

The steps of this technique may be performed as set forth below:-

i) A thin layer of silicon dioxide SiO_2 1 (approximately 1000Å thick) is first deposited on top of a chromium film (approximately 600Å thick) coated mask blank 3, 5 by R.F. sputtering or chemical vapour
5 deposition;

ii) A layer 7 (approximately 4000Å thick), of PMMA or of another suitable high resolution positive electron resist is then spun down on top of the silicon dioxide SiO_2 coated mask blank 1, 3, 5;

10 iii) The PMMA resist is then exposed and developed to define the desired feature pattern (figure 1);

iv) The resist image is then transferred to the silicon dioxide SiO_2 layer 1 by reactive ion etching using hydrogen and carbon tetrafluoride CF_4/H_2, or other
15 hydrogen-containing fluorocarbon plasma eg. methyl-trifluoride (figure 2);

v) The silicon dioxide SiO_2 image thus formed is then transferred to the chromium Cr film 3 by reactive ion etching using a chlorine/oxygen Cl/O_2 or other suitable
20 chlorine-containing oxidising plasma; and (figure 3),

vi) Finally, the remaining resist is removed by ashing using an oxygen plasma (figure 4), and then the remaining silicon dioxide SiO_2 1 is removed by further reactive ion etching using a fluorocarbon plasma or by wet chemical
25 methods (figure 5).

The etching conditions and rates given below are representative and have been taken from published data describing the PMMA resist/silicon dioxide SiO_2 system, namely "Reactive ion etching for submicron structures" by
5 J.D.Chinn et al, J.Vac.Sci. Technol., 19, 1418 (1981):-

TABLE 1

COMPARATIVE ETCH RATES OF SiO_2 AND PMMA

	CHF_3-Plasma	CF_4/35% H_2 Plasma
Frequency (MHz)	13.56	13.56
10 Power (W/cm^2)	0.15	0.1
Pressure (M Torr)	30	15
Flow Rate(A/min)	30	30
PMMA etch rate (A/min)	75	50
SiO_2 etch rate (A/min)	200	200

15 The comparative data given is for an RIE configuration in which the plate to be etched is placed on the driven electrode.

Other methods may may be adopted for defining the silicon dioxide SiO_2 pattern. For example, instead of
20 depositing the silicon dioxide SiO_2 layer 1 directly onto the entire surface of the chrome metal coating 3, the layer of electron resist 7 may be applied first. This layer 7 thus may be spun onto the surface of the chrome Cr coating 3, exposed and developed in normal manner, and the
25 silicon dioxide SiO_2 layer pattern 1 formed by a process of deposition and float-off.

The technique described is not limited to the use of silicon dioxide SiO_2 as masking material. Indeed there can be advantages in using aluminium Al in place of silicon dioxide SiO_2, especially where a float-off
5 process is used. This is illustrated in figures 6 to 9:-
(i) As shown in the first of these figures, figure 6, a layer 7 of PMMA positive electron resist, typically 0.5 microns thick, has been spun onto the surface of the chrome Cr metal film coating 3. This resist layer 7 has
10 been patterned electron-lithographically and a 0.1 to 0.2 micron thick layer 9 of aluminium evaporated onto the surface of the resist layer 7. The exposed parts of the chrome metal Cr coating 3 are also covered by aluminium Al 11. The advantage here of using aluminium Al is that it
15 can be easily evaporated at a relatively low temperature and this will be deposited without causing any undue thermal distortion of the resist pattern 7.
ii) In the next step of this alternative technique, the resist is removed and the surplus aluminium Al 9 floated-
20 off, leaving only the pattern aluminium Al 11 on the surface of the chrome metal Cr coating 3 (figure 7).
iii) Surplus chrome Cr material 3, that part exposed, is now removed using a selective dry etchant - for example, chlorine/oxygen Cl/O_2 plasma. The latter chosen etchant
25 is particularly well suited as it is most selective and

will not etch the aluminium Al to any appreciable extent (figure 8).

iv) A chlorine based dry etchant, (for example chlorine Cl, boron trichloride BCl_3, or carbon tetrachloride
5 CCl_4 plasma) may then be used to remove the masking aluminium material 11. The chosen plasma etchants show good selectivity for aluminium Al and therefore etch the same without appreciable effect upon the chrome metal Cr pattern 3. The chrome metal Cr pattern 3 is thus left
10 on the surface of the mask 5 (figure 9).

Alternatively, the aluminium Al can be removed by a selective wet etching procedure.

For this "float-off" procedure to work satisfactorily, the evaporation process must take place at
15 a sufficiently low temperature to prevent thermal distortion of the resist pattern. Otherwise a deposition technique other than thermal evaporation should be adopted. As in the case of aluminium, discussed above, it must be possible to etch the chrome film on the mask with
20 a plasma or other dry etch process which etches the masking material only very slowly. Titanium, silicon, germanium and nickel are other materials that can be chosen for the masking layer.

This "float-off" process allows one to effectively
25 "reverse" the polarity of the image. Thus one will obtain

the inverse of the pattern that would have resulted if the resist pattern had been used as the etch mask. This can be beneficial if, for example, a high resolution light-field pattern is required. Ordinarily, to obtain a light-field pattern a negative resist would be used. These generally have a resolution inferior to positive resists however. The advantage of a "float-off" process, such as that described above, in this context, is that a positive resist can be used to achieve high resolution, and image reversal performed to obtain an image in the correct polarity.

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CLAIMS

What we claim is:-

1. An etch technique for metal mask definition, this technique comprising:-

5 providing a mask blank of metal-coated material;

forming, in contact with the metal coating on the surface of the mask blank, a layer of selectively non-erodable masking material patterned using electron resist and electron-lithography;

10 dry etching the metal coating using a first etchant, an etchant that is selective with respect to the metal coating; and,

removing the layer of masking material using a second etchant, an etchant that is selective with respect to the

15 masking material.

2. A technique, as claimed in claim 1, wherein the layer of masking material is patterned and formed by the successive steps of:-

depositing a layer of the masking material directly onto

20 the surface of the metal coating;

covering this layer with a layer of electron resist;

forming a first image pattern in the resist by exposing and developing the same; and,

transferring this first image pattern to the layer of

25 masking material by subsequent etching using a third etchant.

3. A technique, as claimed in either claims 1 or 2, wherein the metal coating is of chrome material, the first etchant is a chlorine/oxygen plasma and, the masking material is silicon dioxide.

5 4. A technique, as claimed in claim 3, wherein the second etchant or the third etchant is a hydrogen-containing fluorocarbon plasma.

5. A technique, as claimed in claim 4, wherein the second etchant or the third etchant is a hydrogen/carbon

10 tetrafluoride plasma.

6. A technique, as claimed in claim 5, wherein the second etchant or the third etchant is a methyl-trichloride plasma.

7. A technique, as claimed in claim 1, wherein the layer

15 of masking material is patterned and formed by the successive steps of:-

depositing a layer of electron resist directly onto the surface of the metal coating;

exposing and developing the resist to form a first image

20 pattern;

depositing on the patterned resist a layer of masking material, this material also covering exposed regions of the metal coating; and,

removing the resist and surplus masking material by a

25 float-off process, leaving a second image pattern defined in the masking material, a pattern that is the negative of the first image pattern.

8. A technique, as claimed in any one of the preceding claims 1, 2 or 7, wherein the metal coating is of chrome material, the first etchant is a chlorine/oxygen plasma, and, the masking material is aluminium.

5 9. A technique, as claimed in claim 8, wherein the second etchant is a chlorine, boron trichloride, or carbon tetrachloride plasma.

10. A technique, as claimed in any one of the preceeding claims, wherein the electron resist is of positive type.

10 11. An etch technique as claimed in any one of the preceeding claims 1, 2 or 7, wherein the masking material is one of the materials, titanium, silicon, germanium or nickel.

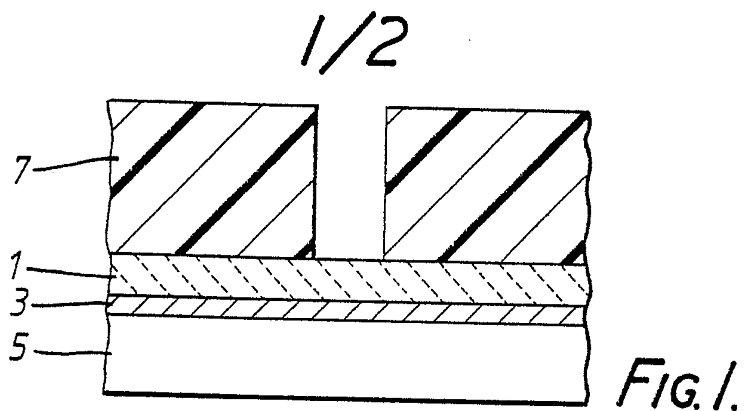

FIG. 1.

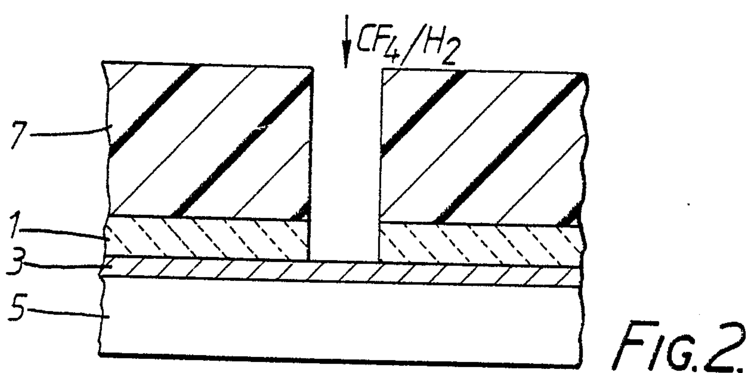

FIG. 2.

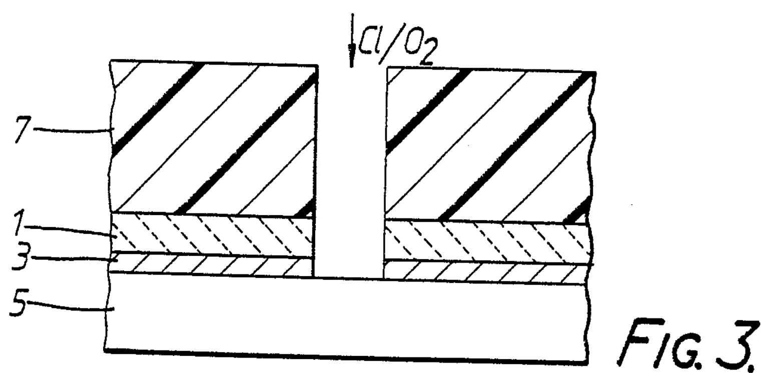

FIG. 3.

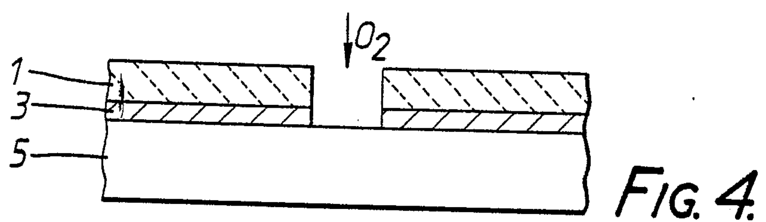

FIG. 4.

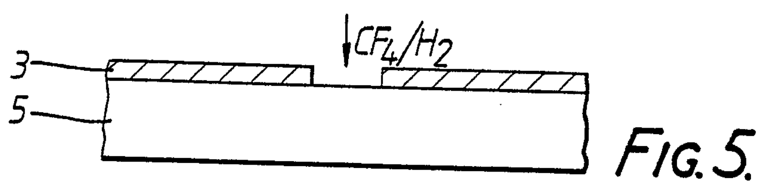

FIG. 5.

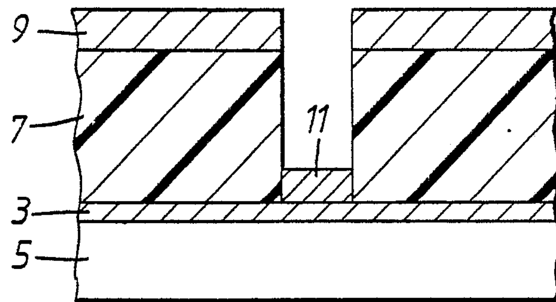

FIG. 6.

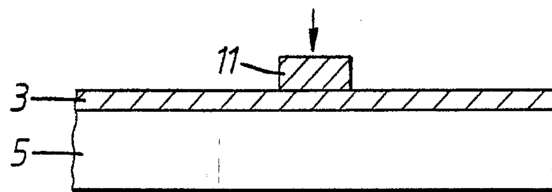

FIG. 7.

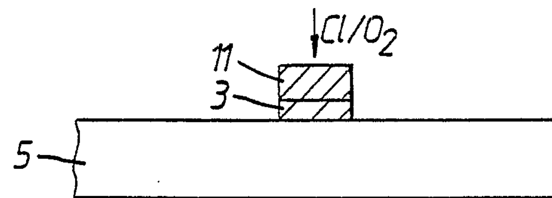

FIG. 8.

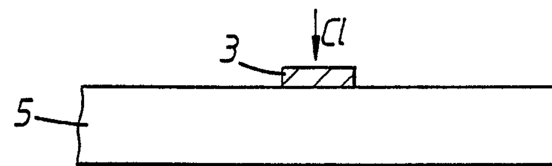

FIG. 9.