AXIC APPLICATION REPORT

PRINCIPAL CHARACTERISTICS OF DRY ETCHING 13

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FROM THE POINT OF VIEW OF SURFACE PATTERNING we can distinquish the following characteristics of the etching process:

- **anisotropy**
- **underetching**
- **load-effect**
- **surface texture**
- **resolution**
- **uniformity**
- **reproducibility**

ETCH PROFILE BY ISOTROPIC ETCHING

Each point on the exposed surface is moved spherically into a material (see Fig. 1). Line width increases proportionally to the etching time. One can always see that $l_V \geq l_m + 2d$. Isotropic profiles are typical for plasmochemical etching and chemical etching. For example, isotropic etching of Si with fluor radicals ($F^{\bullet}$) in gases as are: CF_4-O_2, NF_3 or SF_6-O_2. However, plasmochemical etching must not be always isotropic, for instance, etching of GaAs substrates in Br plasma exhibits different etching rates for different crystallographic orientations.

It is not possible to etch structures with lateral dimensions smaller than value twice larger than film thickness (Fig. 2). On the other side, the isotropic process has advantages in so called **"lift-off"** technique or in smoothing of surfaces.

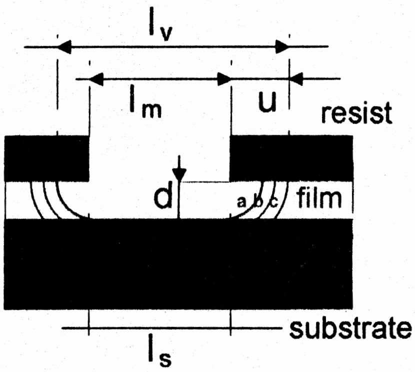

FIG. 1
Isotropic profile at 0 % overetching (a), 50% overetching (b) and 100% overetching.

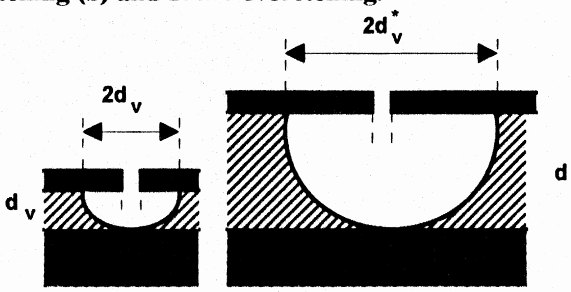

FIG. 2
Influence of film thickness on line width.

ETCH PROFILE BY ANISOTROPIC ETCHING

Anisotropic etching is characterized by vertical walls and smooth profile (Fig. 3). It usually is produced by physical methods or by reactive ion etching. Anisotropy (A) is defined by relation

$$A = 1 - \frac{R_h}{R_v}$$

R_h and R_v are lateral and vertical components of etching rate, respectively. Full anisotropic profile has A=1, for pure isotropic profile A=0 ($0 \le A \le 1$).

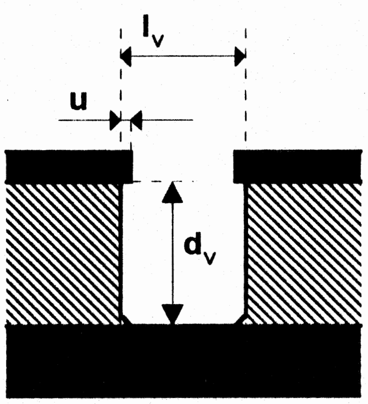

FIG. 3
Anisotropic profile.

Degree of anisotropy depends on chemical activity, energy and sort of active particles, mask thickness, type of crystallographic structure, geometry of etched structure and process conditions. In principle, several processes can take place in creation of anisotropic profiles:

- ion bombardment of surface (sputtering of adsorbed reaction products - for instance. etching of InP in Cl_2) - Fig. 4-a.
- increased removal of polymer layers from horizontal areas followed by chemical etching - Fig. 4-b.
- polymer film deposition from hydrocarbon components on vertical walls of profile.

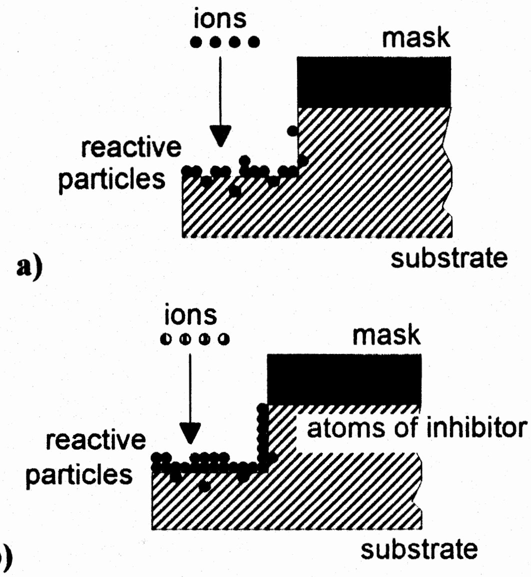

FIG. 4
Mechanism of anisotropy in plasma etching.

UNDERETCHING OF MASK

Underetching is defined by:

$$u = \frac{|l_m - l_v|}{2}$$

Underetching is related also to anisotropy

$$A = 1 - \frac{u}{d}\bigg|_{\Delta=0} \quad \text{or} \quad u = d \cdot (1 - A)\,\big|_{\Delta=0}$$

and depends on several factors:

- overetching time,
- area of etched material - in regions with smaller dimensions undercutting is larger ,
- resist thickness influences the size of space angle, which is allowed to touch the unmasked surface (Fig. 5),
- low resistivity of mask - its errosion (see Fig. 6),
- higher pressures (>100 Pa) → isotropic process → underetching ,
- higher frequency of electric field,
- high chemical afinity of gas to substrate ,
- low mask adhesion to substrate.

Underetching can be compensated by design of structure topography.

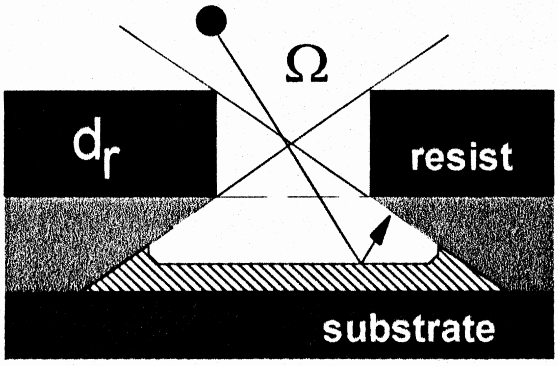

Fig. 5
Size and character of underetching in dependence on resist thickness (Ω - space angle).

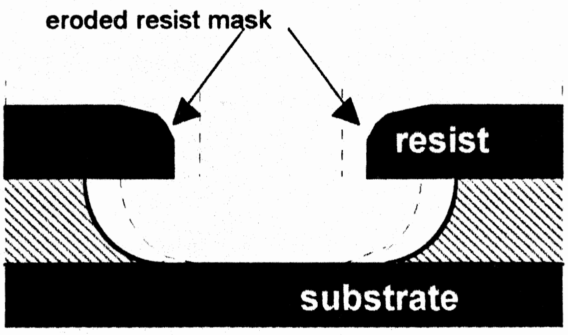

Fig. 6
Degradation of the resist mask during etching.

SELECTIVITY OF ETCHING

Selectivity is defined:

$$S = \frac{R_{THINFILM}}{R_{SUBSTRATE}}$$

In ***"dry"*** processes the selectivity is almost lower than in ***"wet"*** etching. Selectivity depends on material behaviour, gas composition, equipment behaviour and operating conditions (pressure, power, temperature, flow rate).

In the real case a mask or substrate are also touched with finite selectivity in relation to the processed film. It can be demonstrated that etching selectivity of the film to mask (S_{fm}) has an effect on change of size of the structure, and selectivity of film to substrate (S_{fs}) has influenced productivity and yield in anisotropic etching for VLSI.

UNIFORMITY AND REPRODUCIBILITY

Uniformity - process behaviour and parameters of processed structure are the same anywhere on the sample (or on all samples) during cycle, and also in other cycles - e.g. results are stable. We can consider:

- ***uniformity on the substrate,***
- ***uniformity in the reactor (on several samples) in one cycle,***
- ***uniformity in each following cycle = reproducibility.***

Main factor for standard reproducible results is stable etch rate in space and time. Plasmochemical etching is chemical processes and etch rate will depend strongly on temperature. Temperature has to be stabilized at the sample, in the reactor, and between each run, etc., for instance by:

- **replacement of samples on thermally conductive electrodes (heated or cooled) - planar system,**

[redacted]

- **using perforated cylinder ⇒ it reduces resist errosion and radiation from the plasma - barrel system,**

[redacted]

- **using lower pressure (below 10 Pa), mixing of gases with high thermal conductivity coefficient,**
- **providing stable operating conditions in separate runs,**
- **preheating of samples before processing in inert gas plasma.**

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