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A-1-2 MICROFABRICATION TECHNIQUE BY GAS PLASMA ETCHING METHOD

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In modern microelectronics, complicated patterns with submicron dimensions must be fabricated for the realization of ultimate performance potential of various devices. Practical techniques for the microfabrication, therefore, have become the center of wide interest now.

As is generally known, good knowledges of the following subjects are, at least, required for the microfabrication;

i) suitable exposing and developing method for making resist relief image,

ii) suitable process for etching substrates using the resist relief image as a mask, and

iii) inspecting system to check thus fabricated patterns.

As for the etching process, sputtering or ion-beam-etching techniques might cause disconnections of electrodes because the edges cut by those methods are too sharp. Moreover in the application of these processes ion-or molecular-beam bombardment might cause serious damages on device itself.

Wet chemical-etching process without hardbaking has a disadvantage of undercutting because of the poor adhesiveness between photoresist and insulating films. But hardbaking also results in "resist-flow" because of thermal deformation or degradation of polymers and changing the effective area of the window.

At present, this phase is most serious and many engineers have been involved to find a better way of etching.

Considering those aspects, the gas-plasma-etching method was examined for a better way of microfabrication. Poor adhesiveness of photoresist can be ignored in this case and an annealing process eliminates damages caused by the gas-plasma injection. It has also been clarified in the application of the gas-plasma-etching for patterns greater than one micron that undercutting can be controlled easily. It is apparent, therefore, the gas-plasma-etching is more advantageous than any other techniques mentioned above.

We have studied a process in which gas-plasma-etching method is used for films of silicon nitride (Si_3N_4), poly-crystalline silicon (poly-Si) and silicon dioxide (SiO_2). These films were obtained on n-type silicon wafers by Vacuum system CVD and thermal oxidation (dry O_2). Film thickness varies from 500 Å to 8000 Å.

Submicron to 60 μm patterns, were obtained with the conventional photolithographic process.

The pattern widths obtained were measured with metallurgical microscope (x600) for those exceeding one micron and with SEM (x10,000~x30,000) for those less than one micron.

Etching was performed with a conventional gas plasma etching machine utilizing CF_4 or CF_4-O_2 mixed gas. Etching rate was controlled by the applied power and the degree of vacuum.

The relation between the resist pattern width (W_R) and etched pattern width (W_E) was investigated and the results were obtained as shown in Fig. 1 with the following conditions: applied power, 200W; vacuum degree, 0.7torr. Under these conditions, W_E is smaller than W_R, that is, undercutting occurred. However, it is possible to control the undercutting if the pattern width exceeds one micron, and "just etching (W_R=W_E)" or "negative undercutting ($W_E > W_R$)" are even obtained. Fig. 2 shows an example of the situation, where the undercutting (ΔW=W_R-W_E) is ploted against the etched depth (W_t) of Si_3N_4 with the pattern width as a parameter. If the pattern width is longer than one micron, ΔW is positive and negative in the cases of W_t=3000Å and 1500Å, respectively. That means certain region where ΔW becomes zero or "just etched region" exists between those etched depths. If the pattern width is in the submicron dimensions, ΔW is positive even in the case of W_t=1500Å with above-mentioned etching condition. The relation between ΔW and W_t, however, has the same tendency. Therefore, "just-etching" will be possible also in this case. Controlling the etching rate will enlarge the region of "just-etching".

Photographs 1 and 2 show the SE images of the submicron pattern before and after etching by the gas-plasma method. A suitable taper can be observed clearly after etching.

The results obtained are as follows:

a) Gas-plasma-etching offers the best process for the purpose of etching various insulating films and fabricating microelectronic device with submicron dimensions.

b) Sides of patterns even with submicron dimensions have suitable taper after being etched by gas-plasma-method.

c) Accurate patterns can be obtained without any hardbaking.

d) Both negative-or positive-acting photoresist can be used for the gas-plasma-etching. The resolution is less dependent on the coated film thickness in case of positive-acting photoresist.

Photo. 1 SEM micrograph of exposed resist lines on Si_3N_4. $W_R \fallingdotseq 0.8$ μm

Photo. 2 SEM micrograph of gas plasma etched Si_3N_4 lines on Si wafer. $W_E \fallingdotseq 0.5$ μm

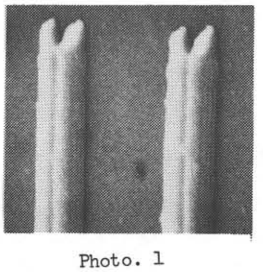


Photo. 1

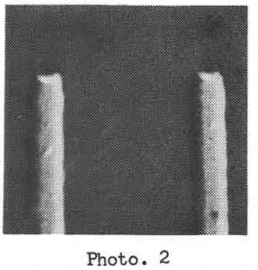
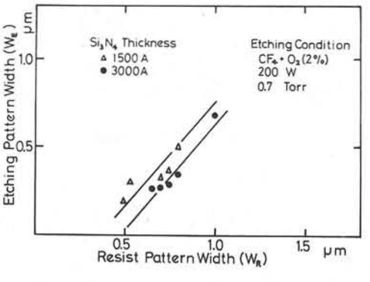


Photo. 2



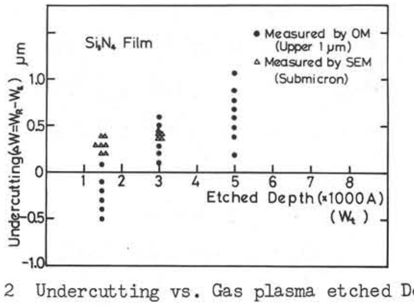


Fig. 1 Resist pattern width vs. etched pattern width. Fig. 2 Undercutting vs. Gas plasma etched Depth.