Method of Preparation AZP4330 PR Pattern with Edge Slope 40°

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Abstract. When the edge which is under the multi-film is more steep or angular, the stress in the multilayer film near the edge is concentrated, this situation will greatly reduce the reliability of electronic components. And sometimes, we need some special structure such as a slope with a specific angle in the MEMS, so that the metal line can take the signal to the output pad through the slope instead of deep step. To cover these problems, the lithography method of preparing the structure with edge slope is studied. In this paper, based on the Kirchhoff scalar diffraction theory we try to change the contact exposure gap and the post-baking time at the specific temperature to find out the effect about the edge angle of the photoresist. After test by SEM, the results were presented by using AZP4330 photoresist, we can get the PR Pattern with edge slope 40° of the process and the specific process parameters.

1. Introduction
In the IC process, there always be some structure under the multi-film, but the stress of the film much higher near the step of the structure rather than other smooth place. This situation will greatly reduce the reliability of electronic components. This phenomenon is from the lithography and etch process, we usually make the process like figure 1. The conventional process (left), after normal lithography from process (a) to (b), the edge of the PR pattern is steep, and then, after etch process, the pattern is almost copy onto the substrate, the edge can’t be changed.

![Figure 1. The conventional process (left) and the special process(right)](image)

And at the same time, in the MEMS, we also need some special structure such as a slope with a specific angle[1,2], so that the metal line can take the signal to the output pad through the slope instead of deep...
step or we need some specific structure to make the light refraction and this requirement is more extreme because the structure always more than tens or even hundreds microns deep. Conventional processes are far from meeting this need. New processes in this area are rarely published. we need to try to develop a new method to solve this problem by lithography such as the process in figure 1. The special process(right).

2. Theories and Methods
In the lithography process, the first step is coating photoresist, we usually adopt Spin coating at a high rotating speed to throw the photoresist from the center of the wafer to outside so that the centrifugal force and viscous force make the photoresist forming a layer of thin film on the flat silicon substrate. The second step is soft bake, it can make the organic solvent of the photoresist volatile, and then the photoresist thin film become hard enough so that it can contact reticle with not deformed. The third step is exposure, in the ultraviolet radiation, the solubility of the photoresist which is exposed in the developer is changed, after developing, we can get the graphics the same with the reticle. The last step is hard bake, it can make the rest of the organic solvent of the photoresist volatile, and then the photoresist graphic thin film is cured.

In the above process steps, the most important factors affecting the edge morphology of the photoresist are exposure mode, contact exposure gap, exposure dose, hard-bake film temperature and time[3-5].

When we use the proximity exposure mode, the principle model as shown in figure 2. Based on the Kirchhoff scalar diffraction theory, the light dose of the pattern edge is progressively increased, so that we can get the slope by developing.

![Figure 2. Proximity exposure mode](image)

In the MEMS dry etching process, we usually use thick photoresist as the etching masking layer, the AZ4330 PR is widely used in this process, in the main sizing speed of 3000 r / min, the AZ4330 PR film thickness can be controlled at 4um or so, and its critical dimension can reach to a few microns, by using of the SUSS MA6 contact lithography exposure, set the exposure dose at 400mJ / cm2, in the proximity mode, by setting the exposure gap between the wafer and the mask, to make the parallel ultraviolet light diffraction, the edge of the photoresist pattern is irradiated by partially diffracted ultraviolet light, while the other regions are normally exposed or masked, so that the edges of the photoresist pattern are subject to gradient changes in the light, in the subsequent development, a slope-like edge will be formed, but at this time the edge of the slope is still far from our needs, because the surface roughness is very large. By adjusting the temperature and time of the bake film, the edges of the photoresist are softened and self-leveling to form a smooth slope.

Based on the above principles, we designed an experiment, only change the exposure gap, to test the result of different and then, change the hard bake temperature and time, to test the effect of temperature. First, we set the exposure gap at 10 microns, 30 microns, 50 microns, and keep the other
steps the same, to get 2 sets of samples, and then, take 1 set of the samples to process with hard bake at 120 °C.

After the multi-round test, we obtained a set of photomask mask pattern samples, since the photoresist was relatively thin on the silicon substrate and was easily damaged in the physical cutting, so it is hard to get a clear photo of the profile in the intuitive test, we try to manually split the samples with external force, to make sure that the split direction is the same to the silicon wafer crystal direction, in the early lithography we must make sure that the observed photolithography profile parallel to the silicon crystal direction, so that we can get a neat profile, after observed by Hitachi 8230 scanning electron microscopy, we can get a clear profile photo, and by the test of the photoresist profile slope, we can get a certain angle.

3. Results and Discussion
After the multi-round test, we get the test photo by SEM, after software measurement, we found that when the exposure gap at 10 microns, 30 microns, 50 microns, the slope edge angle is about 44°, 42°, 40°, as figure 3, figure 4, figure5 respectively.

![Figure 3. The PR slope at Contact exposure gap 10um](image)

When the baking temperature is set to 120 °C, and the baking time is set to 4 minutes, 8 minutes, 12 minutes, The slope angle will gradually decrease, the surface will gradually become smooth, but the overall angle change is not very obvious, as figure 6. From the above test, we can draw a set of empirical values, by changing the exposure gap, post-bake time and other parameters, you can get different slope of the photoresist graphics, so as to provide more options for future process.
Figure 4. The PR slope at Contact exposure gap 30μm

Figure 5. The PR slope at Contact exposure gap 50μm
Figure 6. The PR slope at Contact exposure gap 50um and hard-bake

Through the above SEM test picture data, We can draw out the table 1, it can show us directly that the effect of the contact exposure gap and the hard bake. When the exposure gap is 0, we can get a steep steps which is conventional process requirements, when we set the exposure gap to 10 microns, the steps become to a slope with an angle 44°, when the exposure gap is set to 30 microns and 50 microns, the slope angle become sharper and sharper correspondingly.

Table 1. Test results about the gap changing.

| Exposure gap | Slope angle | After hard bake |
|--------------|-------------|-----------------|
| 10 microns   | 44.05°      | 43.98°          |
| 30 microns   | 42.23°      | 42.18°          |
| 50 microns   | 40.68°      | 40.60°          |

4. Conclusions

In this paper, by changing the exposure gap and the post-bake time under the contact lithography condition, the edge of the photoresist pattern is ramped at a certain angle, and the slope PR is provided for the subsequent dry etching process, which is more favorable for obtaining the edge Structure, to ease the multi-layer film cover when the edge of the stress concentration, to improve the reliability of the device.

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