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Self-Align-Contact Etching with Inductive Coupled Plasma

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A Self-Align-Contact (SAC) etching by inductive coupled plasma has been investigated. At the planar surface, high selectivity oxide etching over poly-Si was achieved by use of C_2F_6 at 3mTorr, however, at the corner selectivity was much lower than that at the planar surface. The ion incident angle distribution is less than 5 degree with the pressure range from 3 to 15 mTorr. The selectivity at corner increased in the case of 7.5mTorr.

1. Introduction

The drive toward higher levels of integration to achieve higher circuit density means the design and the layout of device may be limited by interconnection. For the ULSI circuits of next generation, self-align-contact (SAC) technique will become important in sub-half-micron process.

This paper describes the results of measuring the ion incident angles during the SiO_2 etching and the SAC etching profiles using poly-Si as a stopper with an inductive coupled high density plasma (HDP)[1].

2. Experimental

The experiment has been performed with an inductive coupled HDP oxide etcher as shown in Fig.1. Inductive coupled plasma is excited at helical antenna coupled with 2 MHz r.f. power which is set around quartz tube. The chamber consists of a 32cm diameter by 8cm long source region. A wafer stage which is based by r.f. power supply of 1.8MHz and it was cooled by He using mechanical clamp system. The ion density and energy can be independently controlled. The chamber is pumped at a pumping speed of 1000 litter/sec turbo molecular pump. Etching of SiO_2 with poly-Si stopper were examined using C_2F_6. The selectivity was measured by scanning electron microscopy (SEM) observation. The test sample structure[2] shown in Fig.2 was used for investigating the ion incident angle. A sample structure hemispherically etched SiO_2 by dilute HF with poly-Si mask was used for measuring the distribution of ion incident angles. After HDP etching, we evaluated the relationship between etched depth and the incident angle from the poly-Si mask edge.

3. Results and Discussion

3.1 *Selectivity dependence of taper angle*

Figure 3 shows the cross-sectional SEM photograph of SAC etching with 50% overetching, where etching by HDP was performed with at a bias power of 750W, source power of 2800W, pressure of 3.0mTorr, top electrode temperature of 260°C and the selectivity of SiO_2 to Si is about 50. In this case, the extremely anisotropic profile was obtained with high selectivity oxide etching over poly-Si at the planar surface, however, selectivity at the tapered poly-Si closed to the corner of the underlayer is not enough for the requirement of SAC process.

Figure 4 shows the selectivity of SiO_2 to poly-Si on various tapered poly-Si underlayers in a contact hole. This figure indicates the selectivity was decreased with increasing taper. Increasing the taper to the

60 degree, selectivity of SiO_2 to Poly-Si shows the minimum value of 2.

3.2 *Ion incident angle dependence of pressure*

Figure 5 shows the cross-sectional SEM photograph with much higher selectivity than that in Fig.3. In the case, high selectivity was achieved at higher top electrode temperature. The reason is that the excess fluorine is consumed by a heated silicon top electrode gutter in this low-pressure chamber. As a result, a fluorine-rich polymer decreased with the increase of carbon-rich polymer. This figure indicates the increase of selectivity of SiO2 to poly-Si at the taper surface, however, suppressed the proceeding of etching at the narrow bottom of contact hole by the microloading effect.

Generally, the microloading effect generation model explains as a reduction in the number of ions which are attacking the hole bottom. The ion number decreases due to the angle distribution of incident ions for smaller contact holes. The mechanism of microloading effect generation was observed for changing the pressure with the range from 3 to 15 mTorr. Figure 6 shows the incident angle dependence of the etching depth with various pressures by using test samples as shown in Fig.2. The small distribution of ion incident angle is less than 5 degree. Where, difference etching depth at 0 degree show that poly-Si mask retreat from initial position. This figure suggests that poly-Si mask retreat was improved at the pressure of 7.5mTorr.

Figure 7 shows the etching depth of SiO_2 as a function of contact hole diameter under various pressures. In this case, the microloading effect was improved at the higher pressure. However, in the case of 15mTorr, it is difficult to etch the contact hole larger than 1.0μm of diameter with a lower bias power. SEM observation indicates that higher pressure provides the increase of the selectivity of SiO_2 to the corner of mask poly-Si and reduces the angle at the bottom of the contact with deposition of polymer on the tapered surface. For optical emission spectroscopy, the stronger intensity of C_2 (517nm)/F (686nm) was observed at high pressure rather than that at lower pressure. It is considered that the deposited polymer is effective for protecting the surface from ion attack and results in increasing the selectivity at tapered surface.

Figure 8 shows the cross-sectional SEM photographs with optimized etching condition at the pressure of 7.5mTorr. Complete contact filling could be achieved with fine profile.

4. Conclusions

A SAC etching has been studied by inductive coupled plasma. The summary of the results are shown below.

1. Increasing the taper to the 60 degree, the selectivity shows the minimum value of 2.
2. The ion incident angle distribution is less than 5 degree with the pressure range from 3 to 15 mTorr.
3. The selectivity at the corner decreased with reducing pressure.

5. References

1) J.Marks et al., SPIE Microelect. Process., P.1803, Sept. 1992

2) Y. Gotoh, T. Kure and S. Tachi : Jpn. J. Appl. Phys. Vol. 32(1993) pp. 3035

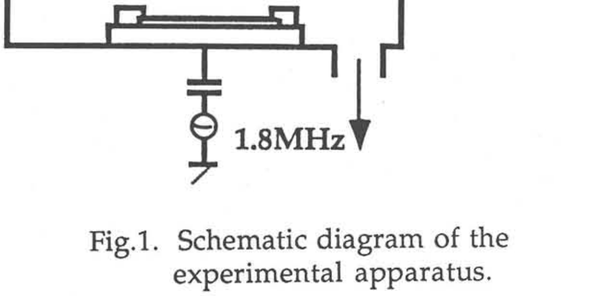

Fig.1. Schematic diagram of the experimental apparatus.

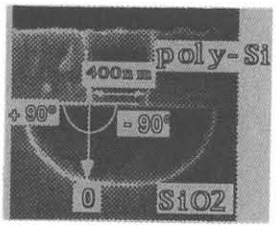

Fig.2. Test sample structure.

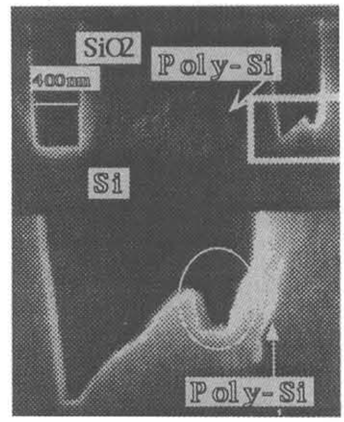

Fig.3. Cross-sectional SEM photograph of the etched profile.

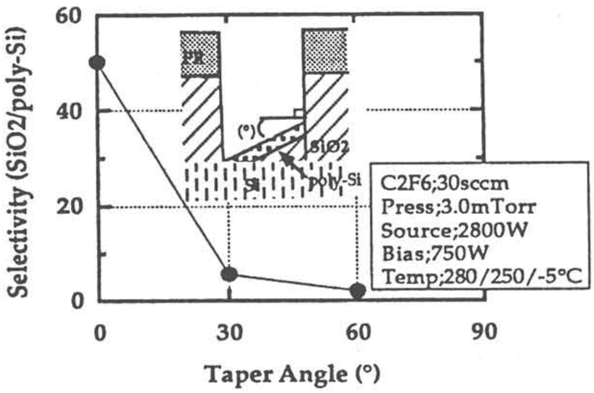

Fig.4. Selectivity of SiO_2/poly-Si as a function of taper angle.

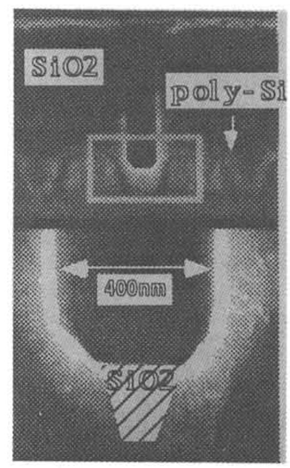

Fig.5. Cross-sectional SEM photograph of the etched profile.

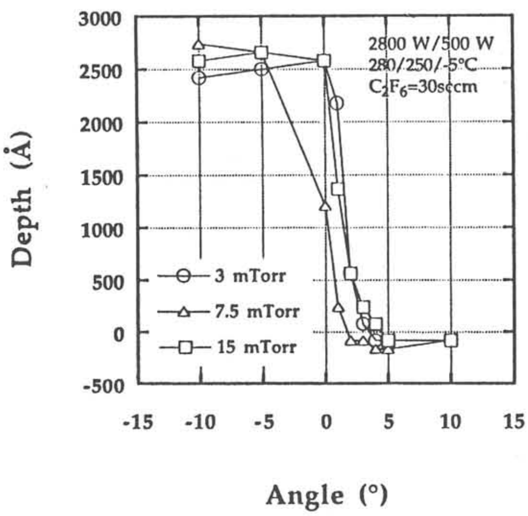

Fig.6. SiO_2 etched depth as a function of angle.

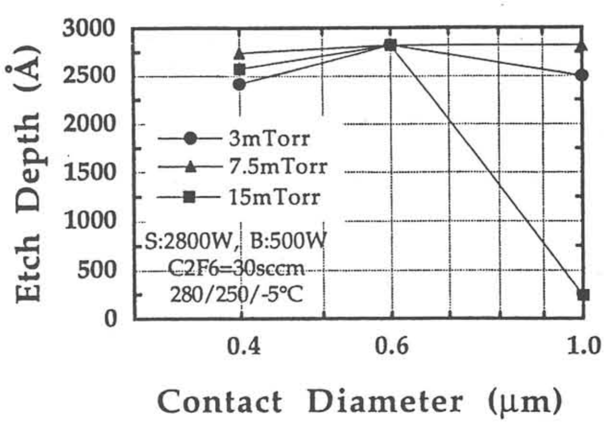

Fig. 7. Pressure dependence of etch depth.

Fig.8. SAC etched profile.