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240-nm Pitch Aluminum Interconnects Formation by UHF-ECR Plasma Etching Incorporating TM Bias and Novel-Gas Chemistry

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1. Introduction

Aluminum wiring has been commonly used in ULSI interconnects to reduce costs. It will still be used in memory and low-cost logic devices when wiring pitches reach 240 nm, helping to make such devices competitive in today's price-sensitive marketplace. Aluminum wiring requires 12-inch-wafer processes, so when it is used in the 240-nm pitch interconnects. In such processes it will be better to use resist-mask processes than hard-mask ones because they are simpler. Aluminum etching for such fine-pitch wiring thus requires precise critical dimension (CD) control and at the same time extremely uniform etching characteristics for such a large-diameter wafer. Such fine-pitch aluminum etching also requires higher selectivity to thinner resist masks [1] and the ability to preventing damage caused by charge accumulating through high-density interconnects.

To meet these requirements, we have developed an etching method using UHF-ECR plasma [2], which makes it possible to realize extremely uniform fine-pitch etching characteristics and to suppress device damage caused by charge influence. We also investigated the use of wafer-bias modulation to enhance mask selectivity and examined the effect of introducing a novel-gas addition into the fine-pitch interconnect formation process.

2. Experimental

The UHF-ECR plasma-etching system we developed enable to employ (1) low-pressure process to achieve precise CD control and to maintain (2) medium-low ion-current flux (ICF), in the low-pressure region to suppress the charging damage (see Fig. 1). The system was designed to achieve uniform etching based on the concepts: (3) uniform ICF, (4) uniform by-product re-incidence.

The system consists of a UHF power source, a reactor with an antenna and a solenoid coil, an RF power source for wafer biasing, and a wafer-temperature control unit.

The plasma is generated by interaction between a UHF electromagnetic field and a static magnetic field, which can achieve uniform and medium-low ICF. The reactor with a medium-gap structure was employed to attain uniform by-products re-incidence.

A pulse modulated RF bias (TM bias) was supplied to the wafer to enhance mask selectivity. The TM bias activates the aluminum surface with the incidence of high-energy ion during bias-on period. This activation enhances the aluminum etching by the Cl* radicals during bias-off period while the resist-mask etching is not being enhanced.

We also tested adding a novel gas to the Cl_2/BCl_3 gas process as a mean of obtaining accurate CD control at 240-nm wiring pitch. The addition of a small amount of gas can suppress the side etching, so that low-pressure etching suitable for CD control is achieved. In addition, the gas contains neither fluorine nor nitrogen, both of which cause undesirable particle contamination.

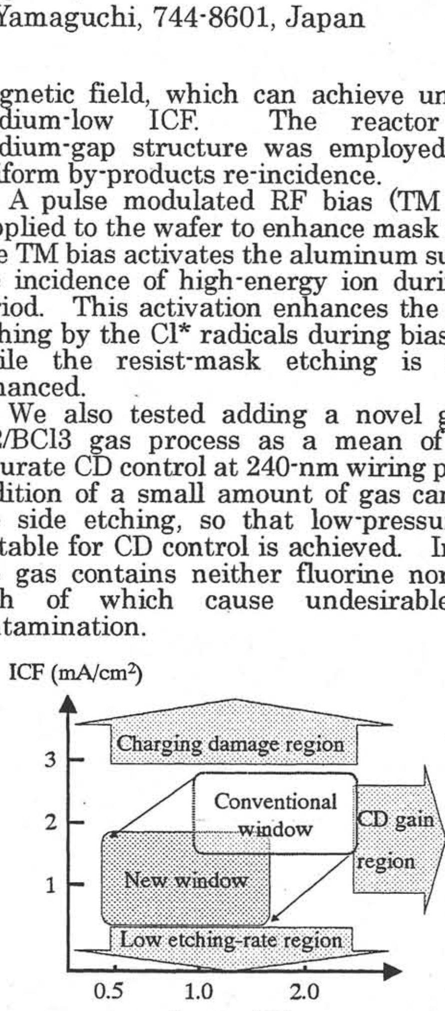

Fig. 1 New window of UHF-ECR metal etching.

3. Results and Discussion

3.1 Uniform etching rate and uniform CD shift

We examined the uniformity of aluminum etching rate on 12-inch wafer and found that uniformity of ±4.6% was obtained (see Fig. 2). Under this condition, a multi-layer of Ti/TiN/Al-Cu/Ti/TiN was etched. The profile of a 360nm-pitch-dense pattern and an isolated pattern of 180nm are shown in Fig. 3. The CD variation across the wafer in the dense pattern and the isolated pattern were estimated to be approximately 0 nm and 10 nm, respectively. These results indicate that uniform etching with uniform CD-shift is obtained through uniform incidence of ions, etching gases, and by-products.

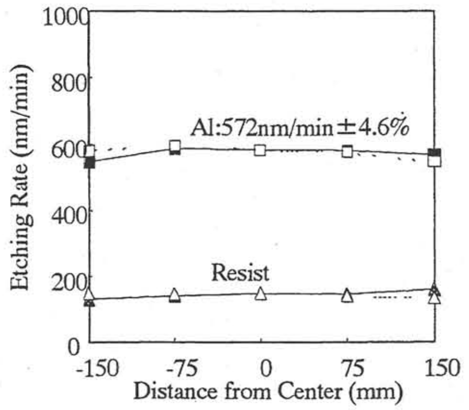

Fig. 2 Aluminum/resist etching rate.

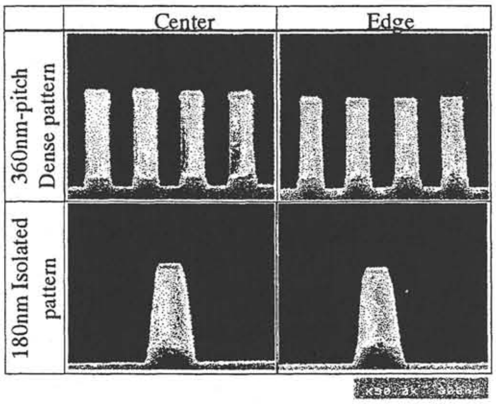

Fig. 3 Etched profile of Ti/TiN/Al-Cu/Ti/TiN films.

3.2 Highly selective etching with TM bias

Figure 4 shows the dependence of the etching rate and the Al/resist selectivity on the supplied power of TM bias and conventional continuous-wave (CW) bias. The aluminum etching rate with TM bias was found to be 50nm/min higher than that with CW bias while

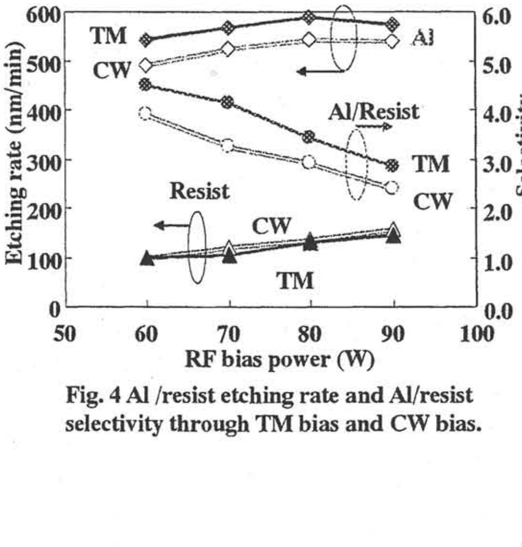

Fig. 4 Al /resist etching rate and Al/resist selectivity through TM bias and CW bias.

the resist-etching rates were identical for both cases. Consequently, high selectivity of 4.1 was obtained at a bias power of 70W. We assume this can be attributed to the surface condition under which aluminum is etched during the bias-off period while the resist mask not. This result indicates that the use of TM bias achieves selectivity sufficiently high for extremely thin resist-mask process.

3.3 240nm-pitch aluminum etching with the novel-gas addition process

A metal layer with a fine pitch pattern of 300nm-thick resist was etched using the novel gas addition process. The profile of a 240nm-pitch-dense pattern is shown in Fig.5. In this pattern, near vertical profile was obtained, while the mask remains sufficiently thick. Thus, we verified that the UHF-ECR plasma etching system incorporating TM bias and novel-gas chemistry can provide precise etching up to a pitch of 260-240nm.

4. Conclusion

Aluminum wiring of the 260-240nm pitch can be fabricated by UHF-ECR plasma etching that incorporates TM bias and novel-gas chemistry. The use of this method achieves selectivity and precision sufficiently high for 260-240nm-pitch aluminum etching. The method also provides extremely uniform etching within 10-nm CD-shift variation across a 12-inch wafer. We thus conclude that the fine-pitch etching method we have developed should enable the aluminum wiring to be extended up to the end of a 130nm node.

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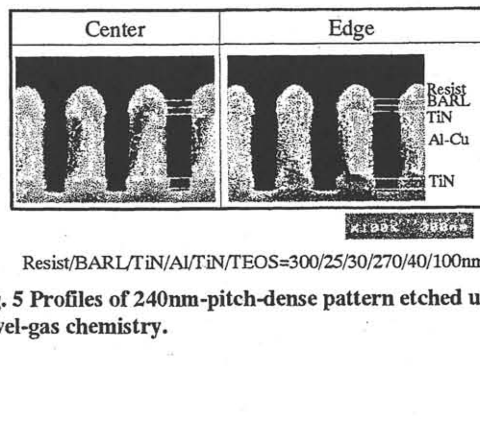

Resist/BARL/TiN/Al/TiN/TEOS=300/25/30/270/40/100nm

Fig. 5 Profiles of 240nm-pitch-dense pattern etched using novel-gas chemistry.