High Rate Selective Etching of a-Si:H and Modification Effect of a-SiNx:H Surface by Hydrogen Radical

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High rate selective etching of a-Si:H was achieved by using a hydrogen microwave afterglow technique. This indicates the strong etching effect of hydrogen radicals. To clarify the effect of modifying an a-SiNx:H surface by hydrogen radicals, ultrathin a-SiNx:H layers were stacked intermittently on a substrate by a NH3 microwave afterglow method, hydrogen-radical treatment was carried out between each layer deposition cycle. The atomic composition (N/Si) and hydrogen-bond density of the prepared films changed with the number of incident radicals introduced in hydrogen treatment. This suggests that the selective etching by hydrogen radicals occurs on the SiNx:H surface.

1. INTRODUCTION

In the fabrication of thin-film transistors (TFTs) for liquid crystal displays (LCDs), a dry etching method offering a high etch rate and high selectivity is required to obtain high throughput. One method commonly used for dry etching semiconductor devices is the reactive ion etching method (RIE). However, this method makes it difficult to obtain a high selectivity ratio.

In this paper, we first present a novel high rate selective etching method for a-Si:H which employs a hydrogen microwave afterglow technique.

Next, to clarify how selective etching affects the a-SiNx:H surface, we prepared a-SiNx:H films by intermittent deposition with subsequent H-radical treatment. We then examined the atomic composition (N/Si) and hydrogen-bond density (Si-H and N-H) of the films.

2. EXPERIMENTAL

The experimental apparatus is a stainless steel chamber equipped with a 1/2-inch-diameter quartz discharge tube. A 2.45-GHz microwave is introduced into the discharge tube through a coaxial cable and a microwave cavity surrounding the tube. The substrate temperature is controlled between 150-350°C using a heater and a thermoelectric element.

In measuring the etch rate of a-Si:H and its selectivity against other materials, films made of a-Si:H, a-SiNx:H, a-SiC0.5:H, SiO3, and of Al were used. These films were prepared by plasma-CVD, microwave afterglow CVD, H-radical CVD and thermal CVD, respectively.

To examine the effect of modifying the surface of a-SiNx:H film surface, ultrathin a-SiNx:H layers were stacked intermittently on a substrate by the NH3 microwave afterglow method. Hydrogen-radical treatment was carried out between each layer deposition cycle. The film preparation sequence and deposition conditions are shown in Fig. 1 and Table I, respectively. The change in composition (N/Si) and hydrogen-bond density of the film as a function of hydrogen treatment conditions and the layer thickness per deposition cycle were analyzed. The film composition was estimated by ESCA and the hydrogen-bond density by FT-IR.

3. RESULTS & DISCUSSION

3.1 High rate selective etching of a-Si:H by hydrogen radical

Figure 1 shows the etch rate of a-Si:H as a function of temperature. The etch rate is less than 2×10^{-6} μm/min when the temperature is below 20°C and drastically increases as the temperature increases above 20°C, saturating around 100°C.

A very high a-Si:H etch rate of 2.7 μm/min was obtained at a microwave power of 170 W at 50°C. However, a-SiNx:H, a-SiC0.5:H, SiO3, and Al were...
The microwave hydrogen radical etching of a-Si:H was performed using a microwave afterglow method. The etch rate and hydrogen-bond density of a-Si:H were measured and analyzed as a function of temperature and microwave power. The etch rate decreases with increasing temperature, and the hydrogen-bond density increases with increasing microwave power. These effects are enhanced when the film is thinner than 30 Å.

**Fig. 2** The etch rate of a-Si:H as a function of temperature.

**Fig. 3** The N/Si and hydrogen-bond density of a-SiNx:H prepared by intermittent deposition as a function of microwave power during hydrogen-radical treatment. NH₃/SiH₄=20/20

**Fig. 4** The N/Si and hydrogen-bond density of a-SiNx:H film deposited by intermittent deposition as a function of Si:N:H thickness per deposition cycle. NH₃/SiH₄=20/20 (A); with (B); and without hydrogen radical treatment.

**3.2 Modification effect of a-SiNx:H surface by hydrogen radical**

Figures 3 and 4 show the characteristics of the SiNx:H films deposited by intermittent deposition when the source-gas flow ratio of NH₃/SiH₄ is 20/20. The films continuously deposited in this condition are silicon rich and contain many Si-H bonds. Figure 3 shows the N/Si ratio and hydrogen-bond density of a-SiNx:H as a function of the microwave power during hydrogen-radical treatment. With increasing microwave power, the N/Si ratio increases and the Si-H bond density decreases. This suggests that these characteristics change according to the number of incident hydrogen radicals.

Figure 4 shows the composition and hydrogen-bond density as a function of Si:N:H thickness per deposition cycle. The N/Si ratio increases and Si-H bond density decreases with increasing Si:N:H film thickness per deposition cycle. Moreover, those effects are enhanced when the film is thinner than 30 Å. This indicates that surface modification with hydrogen radicals has a greater effect when using this deposition method. This means that the hydrogen radicals selectively etch surplus Si atoms on the SiNx:H surface by forming Si-H bonds such as Si-H₄ or Si-H₂.
selective etching by hydrogen radicals is the mechanism of the surface reactions, affecting the Si-H or N-H bond density and N/Si composition.

REFERENCES

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4. CONCLUSION

High rate selective etching of a-Si:H was achieved by using a hydrogen microwave afterglow method. In this method, we clarified the effects of modifying an a-SiNx:H surface by hydrogen radicals.

In a Si-rich film surface, containing many Si-H bonds, Si atoms forming Si-H bonds are removed by hydrogen radicals as SiH4. On the other hand, on the near stoichiometric film surface, containing many N-H bonds, N atoms forming N-H bonds are removed by hydrogen radicals as NH3. This clarifies that