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Hard carbon mask for next generation lithographic imaging

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For hardmask materials, various Diamond-like Carbon (DLC) films deposited from different source gases were compared with commercial Amorphous Carbon Layer (ACL) film. However etching selectivity of DLC film was a little worse, the optical properties of DLC was much better than commercial ACL film. Specially, addition of silicon into DLC film showed good selectivity properties and similar optical properties

1. Introduction

As the feature size of semiconductor devices ranges in sub-100 nm scale, thin hardmask layer of performance beyond conventional polymer photo resist is required [1]. For etch resistant hard mask, a material should meet several stringent requirements such as high etch selectivity, easy ashing-off after the dielectric etching process and transparency at visible range [2]. Recently, Park et al reported that the properties of carbon film deposited by PECVD were strongly dependent on both the source gases and physical bias power [3]. In this study, various DLC films deposited by different hydrocarbon sources were tested for hardmask application and compared with conventional ACL deposited by commercial PECVD system.

2. Experimental

DLC films for hardmask materials in this study were deposited by 13.56 MHz r.f. PECVD system. Details of the deposition equipment and properties of films were previously described elsewhere [4]. Substrates were placed on the water-cooled cathode, where r.f. power was delivered through the impedance matching network. Pure DLC(a-C:H) films were deposited from n-hexane(C_6H_{14}), or benzene(C_6H_6), and silicon-incorporated DLC (Si-DLC) films were deposited from a mixture of benzene and silane(SiH_4) gas. Si concentration in Si-DLC film was 2 at.%. For the comparison of etch behavior of DLC films, ACL film was deposited by commercial AMAT's Producer APF PECVD system. Deposited carbon films were analyzed using Raman spectroscopy and FT-IR for bonding structure and spectroscopic ellipsometery for optical properties.

Using metal lines/space pattern of 0.16um of Samsung Electronics, hardmask film was patterned by dielectric ARC (D-ARC) and KrF lithography process and etched by inductively coupled plasma source AMAT's DPS of 13.56 MHz etcher system. The oxide layer was etched using a triple frequency capacitive coupled plasma source etcher system with 2MHz /100MHz of the bottom and top electrode. The oxide layer was etched at 20mTorr using a mixture of C_4F_6 and CHF_3 gas. And the etch loss was measured on feature using SEM cross-sections.

3. Results and discussion

The structure of DLC film and ACL film was

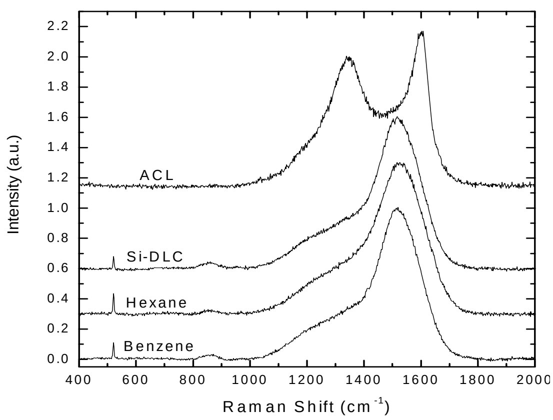

Fig. 1 Raman spectra of DLC and ACL films

analyzed by Raman spectroscopy. Fig.1 shows the Raman spectra of DLC film and ACL film. The spectra of ACL film was completely separated into G-peak and D-peak. Thus the ACL film was mostly composed of sp^2 bonding. In contrast to ACL film, DLC films deposited from hexane and benzene showed typical Raman spectra of diamond-like structure. This result means the bonding structure of DLC films was a mixture of sp^2 and sp^3 bonding. For lithography overlay control, the extinction coefficient

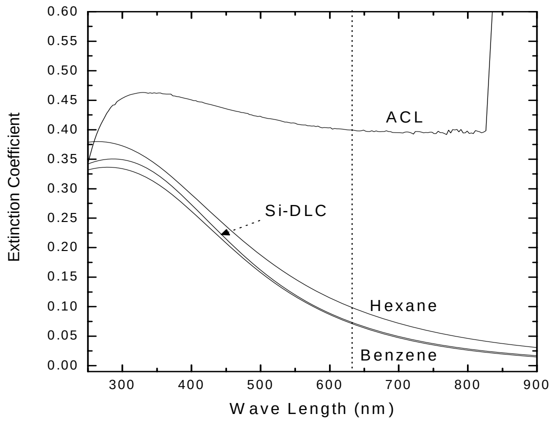

Fig. 2 Extinction coefficient of DLC and ACL films

of hardmask is important, because patterns in scanner are aligned through the 300 to 633 nm ray. [1]. Fig. 2 shows the extinction coefficient of each film. The extinction coefficients of DLC films were much lower than ACL film. This result means that DLC films are more transparent than ACL film and DLC films are more suitable for hardmask material. This transparency of DLC film may result from high sp^3 fraction in the film.

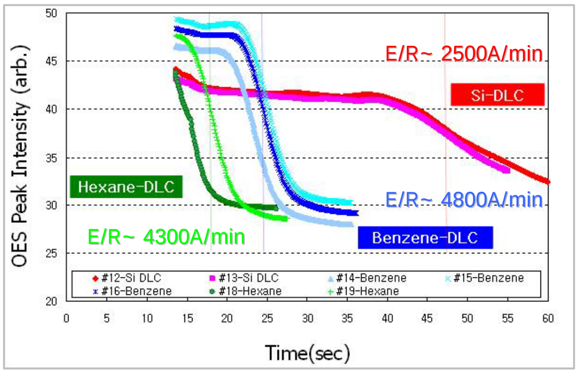

Fig.3 OES Peaks (CO*) of DLC films

Fig.3 shows that O2/N2 plasma etchs different DLC films at 6-inch patterned wafers and Si-DLC etchrates the lowest among the DLCs. Also the etch selectivity is the most important properties among the requirement for hardmask. The etch loss at patterned profile after etching process was shown in Fig.4. In Fig. 4, the etch loss of DLC film deposited from benzene was higher than that of DLC film deposited from hexane. And etch loss of DLC films was slightly higher than that of ACL film in spite of good optical properties. This difference of etch rate resulted from difference of the structure of carbon bond in film during deposition. The analysis using FT-IR revealed that the structure of DLC film from benzene was more polymeric than DLC film from hexane. The significant result in this figure is that the small amount of Si in DLC film remarkably decreased the etch loss of DLC film. Thus we could propose that small addition of Si in DLC would be desirable for hard carbon mask.

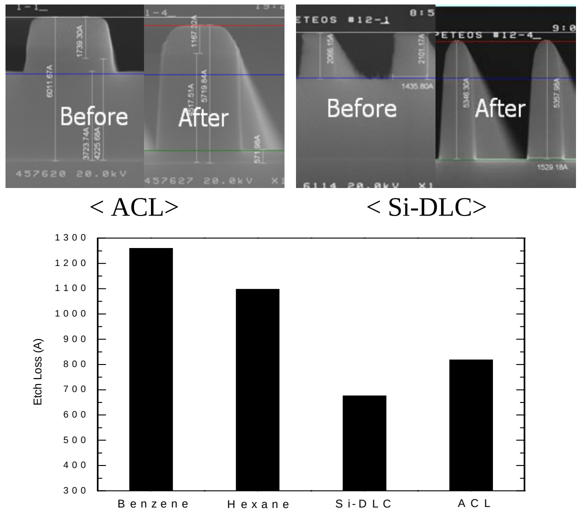

Fig.4 Etch loss of DLC and ACL films

4. Conclusions

Various DLC films were deposited from hexane, benzene and a mixture of silane and benzene gas. The deposited DLC films were compared to commercial ACL film for next generation hardmask. However etching selectivity of DLC film was little worse, the optical properties of DLC were much better than commercial ACL film. Specially, addition of silicon into DLC film showed good selectivity properties and optical properties

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