Low-dielectric constant organosilicate glass incorporated with fluorine films as bottom antireflective coatings for sub-65 nm interconnection processes

H. L. Chen[1], C. Y. Li[2], C. C. Cheng[2], G. S. Lai[1], C. H. Lin[3], and C. Y. Lee[1]*
[1]Department of Materials Science and Engineering, National Taiwan University, Taipei, Taiwan
[2]Chung Hua University, Hsinchu, Taiwan
[3]National Nano Device Lab., Hsinchu, Taiwan
*Tel: 886-2-33663240, Fax: 886-2-23634562, *E-mail: hsuenlichen@ntu.edu.tw*

In the recent ITRS roadmap, the ArF lithography combining with the immersion technique would lead IC technologies to the generation of sub-32 nm [1]. The problems of critical dimension control caused by highly reflective substrates are far more serious in the sub-50 nm generation than the larger critical dimension generation. It is therefore important to find a high performance bottom antireflective coatings (BARC) working in this spectral regime. For reduction interconnect signal delay, low dielectric constant (low-K) materials have been used to replace conventional dielectrics in advanced IC technologies [1]. For sub-50 nm interconnection processes, a high performance BARC for patterning low dielectric materials is also essential.

Organosilicate glass incorporated with fluorine films (F-SiOC:H) is one of the major candidates of low-K materials because of its low dielectric constant and good electrical and mechanical properties [2]. The optical constants of various F-SiOC:H films measured at 193 nm are shown in Figure 1. When the gas flow rate ratios (O_2/ trimethylsilane, Z3MS) increased, the extinction coefficient (k) is decrease. The higher gas flow rate ratios (O_2 /Z3MS) in the HDP-CVD process would get a oxygen-rich F-SiOC:H film, which is with smaller extinction coefficient. The extinction coefficient has a tuning range from 0.12 to 0.42, which is suitable to be used as a double layer BARC structure for interconnection processes as shown in Figure 2. In the double layer BARC, a thick carbon-rich F-SiOC:H layer and a thin oxygen-rich F-SiOC:H layer are as a absorption-layer and destructive interference layer, respectively. As shown in Figure 3, the capacitance-voltage (CV) curve of the F-SiOC:H films were measured by Hg probe at 50 kHz. Comparing with single-layer structure, we find that the dielectric constant of double layer F-SiOC:H is only increase from 2.3 to 2.4. The K values of both structures are also found about 2.8 at the frequency of MHz. As shown in Figure 4, the measured reflectance is about 11 % after adding a single-layer F-SiOC:H film on a silicon substrate. By adding an optimized thin oxygen-rich F-SiOC:H film, the reflectance of less than 1 % can be achieved. As shown in Figure 5, the swing effect in the resist is also shown significantly reduced at 193 nm by adding a F-SiOC:H-based BARC layer. As summarized in Table 1, F-SiOC:H-based low-K films would reduce the reflectance from the interface of the resist/high reflective materials to less than 1% at 193 nm for various highly reflective substrates that are commonly used in metal interconnects. Therefore, it is easy to reduce substrate reflectance without adding an extra BARC structure for patterning low dielectric materials in advanced interconnection processes. Detailed analysis and results will be reported in the conference.

1. “International Technology Roadmap for Semiconductor,” 2006 Updated (Lithography and Interconnect sections).
2. S. K. Jangjing *et. al.*, J. Appl. Phys. 94 (2003) 732.

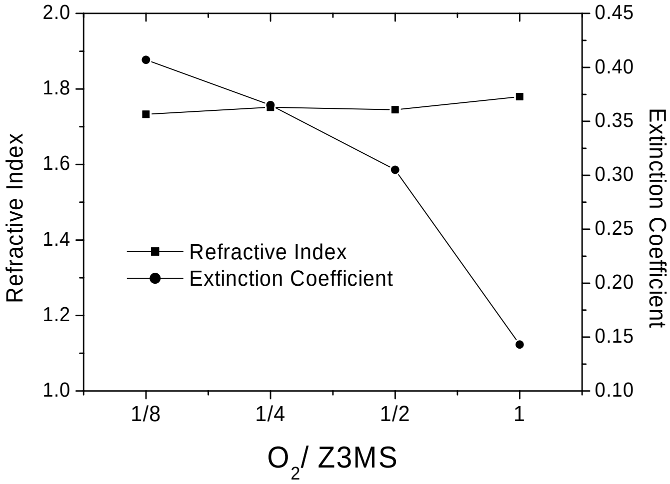

Figure 1 Optical constants dependence of F-SiOC:H films on gas flow rate ratio.

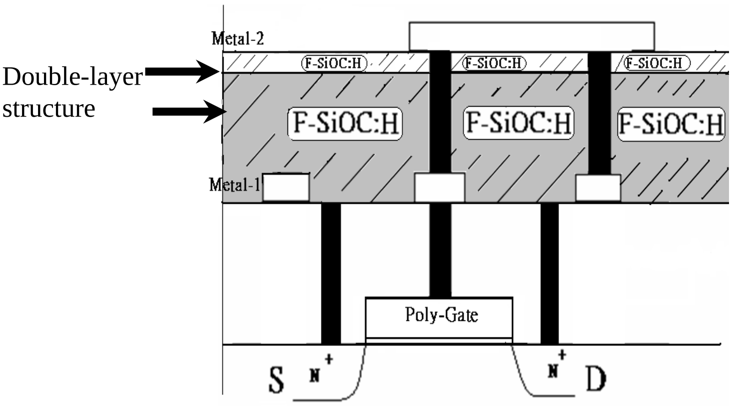

Figure 2 Schematic of a bilayer F-SiOC:H films for metal interconnect structure.

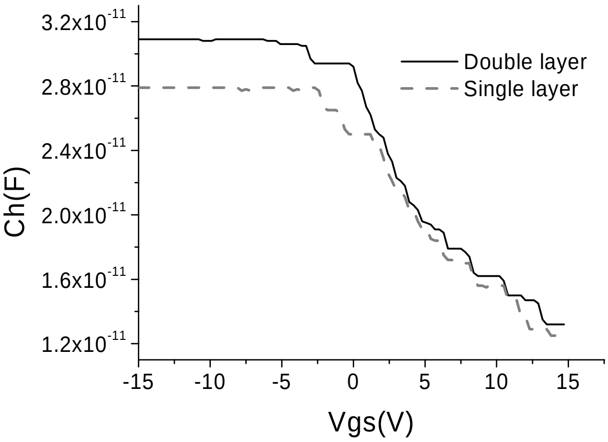

Figure 3 The capacitance-voltage curve of F-SiOC:H films were measured by Hg probe.

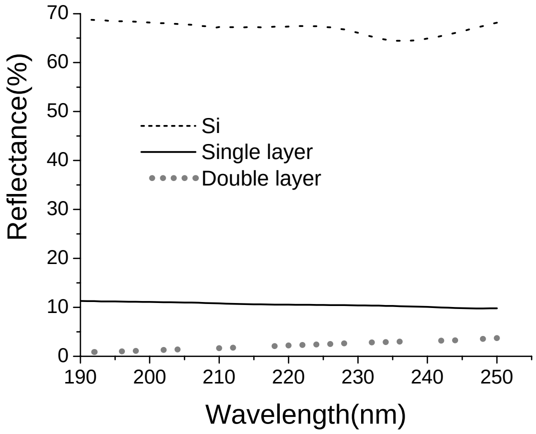

Figure 4 Reflection spectra of a silicon substrate before and after adding F-SiOC:H-based BARC layers.

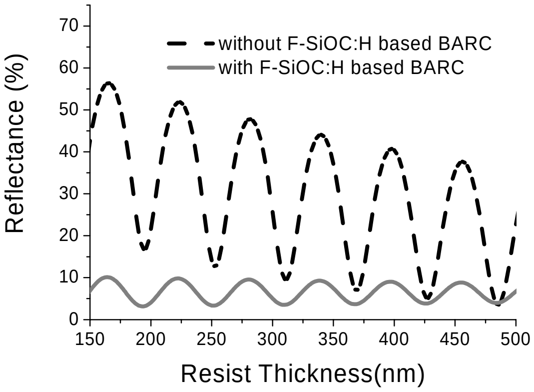

Figure 5 Reflectance swing curves of the resist coated on silicon a substrate without and with a F-SiOC:H-based BARC layer.

Table 1 F-SiOC:H-based BARC layers for highly-reflective substrates.

Substrates	**Cu**	**Al**	**TiN**
Optical constant at 193 nm	**(0.958, 1.37)**	**(0.110, 2.17)**	**(1.58, 1.31)**
Reflectance without BARC	**27.142 %**	**90.687 %**	**14.109 %**
Reflectance with F-SiOC:H based BARC	**0.9749 %**	**0.9750 %**	**0.9749 %**