Plasma Technologies for Low-k Dry Etching

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1. INTRODUCTION
The need for reliable low-k/Cu interconnects technologies is increasing. Many kinds of low-k materials have been proposed and we need to etch various materials with various film densities and compositions. Therefore, the etching mechanisms of SiOCHs must be quantitatively clarified.

2. EXPERIMENT
Dual frequency RIE was used in this study. Plasma density, CF sub 4 radicals, densities, and ions were measured using PAP, IRLAS, OES and QMS. SiOCH films of various compositions and densities were etched using C4F8/Ar/O sub 2 (N2) plasma. The etch rates, selectivity, and surface polymers were analyzed.

3. RESULTS AND DISCUSSIONS
The surface reaction of SiOCH depended both on the incident fluxes from the plasma and on outflux from the SiOCH (Fig.1). Changing the total number of incident CF sub 4 fluxes by varying the C4F8 flow rates in C4F8/Ar/O sub 2 (or N2) allowed us to classify etching reaction as:

I: thin stable polymer,
II: transition from I to III (or IV),
III: thick steady state polymer, and
(IV: deposition).

The etch rate changed significantly around “critical point (Pc, see Fig.2)”, where the incident total C became equivalent to the thermal removal ability of O and N (see Fig.3). We can use etching condition I to solve problems with residue and etch stop. Porous material (p-SiOCH) is more sensitive to changes in the number of incident fluxes. Therefore, we must predict the Pc and control the incident fluxes precisely for each material that has different Si, O, C, and H compositions1,2, film densities, and etched structures, such as the aspect ratios.

4. CONCLUSION
A model to predict the process window of SiOCH etching was proposed. The optimum flux condition (Pc) depended not only on the balance in the incident flux from the plasma (C, F, O, and N), but also on the density and composition of the SiOCH films. To ensure a reliable interconnects, we need to quantitatively control the uniform plasma.