Ion Energy Dependence of the Etch Selectivity of Low-*k* Polymer to Si_3N_4 Etch Stopper by N_2 and NH_3 Plasma Beam Irradiation

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ABSTRACTS

Interconnect with Cu wiring and low-*k* dielectric interlayer is needed to reduce RC delay in LSIs. In the interconnect structure, a trench etch stopper layer, Si_3N_4, is introduced to form good profile, but the stopper film enhances effective *k* of the interconnect because the stopper has a higher *k*. One way to reduce effective *k* is to make the thickness of the stopper as thin as possible. To obtain high selectivity by optimizing ion energy (*Ei*) and gas chemistry, we investigated the *Ei* dependence of etch yield (EY) of low-*k* polymer and selectivity to stopper film by N_2- and NH_3-plasma beam irradiation.

Figure 1 shows schematic diagram of the plasma beam irradiation apparatus[1]. Plasma was produced by an ECR type source in a plasma chamber (5-7 mTorr). The plasma chamber can be biased to control the *Ei*. Therefore, narrow ion energy spread of less than 2 eV was obtained. An irradiation chamber was connected to the plasma chamber via an orifice of 1.5mm in diameter. The extracted ion and neutral beam was irradiated to the sample with normal incidence in the irradiation chamber (3×10^{-6} Torr during the beam irradiation). The ion flux density (Γi) was controlled by changing the ion beam diameter using an electrostatic focusing lens. The ratio of neutral flux to ion flux, Γn / Γi, at the substrate position ranged in about 1-10. The incident ion beam (species and energy) was analyzed by quadrupole mass spectrometers with an energy analyzer placed behind the sample. Charge build-up of the sample species was neutralized by a tungsten filament electron gun. Films of Si_3N_4 and low-*k* polymer (260 nm-thickness GX-3™, *k*=2.6, Honeywell Electronic Materials) were evaluated. The GX-3™ is composed of carbon and hydrogen and its atomic composition ratio is C:H = 1:0.8. The dominant incident ion species were found to be N_2^+ (81%) and NH_4^+ (93%) for N_2 plasma and NH_3 plasma, respectively.

Figure 2 shows dependence of the EY of GX-3™ and Si_3N_4 on the *Ei*. The EY of GX-3™ showed a threshold energy of about 120 eV for both plasmas and saturated over *Ei* > 250 eV for N_2 plasma and *Ei* > 400 eV for NH_3 plasma. The EY at the saturated region for NH_3 plasma was about 60 % higher than that for N_2 plasma. This EY enhancement is considered to be due to the synergy of the entering hydrogen and nitrogen together into GX-3™ surface would enhance the etching reaction. On the other hand, the EY of Si_3N_4 increased monotonously with the *Ei* for both plasmas. The Si_3N_4 EY for NH_3 plasma was lower than that for N_2 plasma. The result is considered that lighter mass ions are advantageous to suppress the stopper etching by assuming that the etching of Si_3N_4 by N_2^+ or NH_4^+ ions is due to physical sputtering rather than chemical effects.

Figure 3 shows etch rate selectivity of GX-3™ to Si_3N_4 normalized by the Γi. The selectivity decreased steeply with increase of the *Ei*. From the results of experiments using the monochromatic ion energy plasma beam irradiation, it is suggested that the *Ei* should be set to 300-400 eV and employing NH_3 plasma is desirable compared to N_2 plasma to obtain high etch yield of GX-3™ low-*k* polymer and high selectivity against Si_3N_4.

(1)K.Kurihara, et.al., Proc. Symp. Dry Process, 141(2001)
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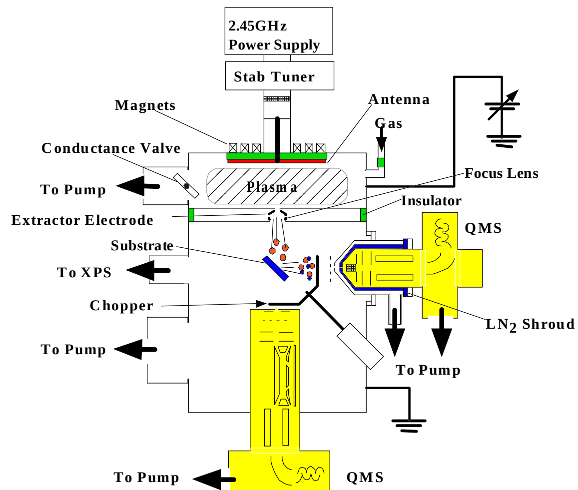

Figure 1 Schematic diagram of plasma beam irradiation apparatus.

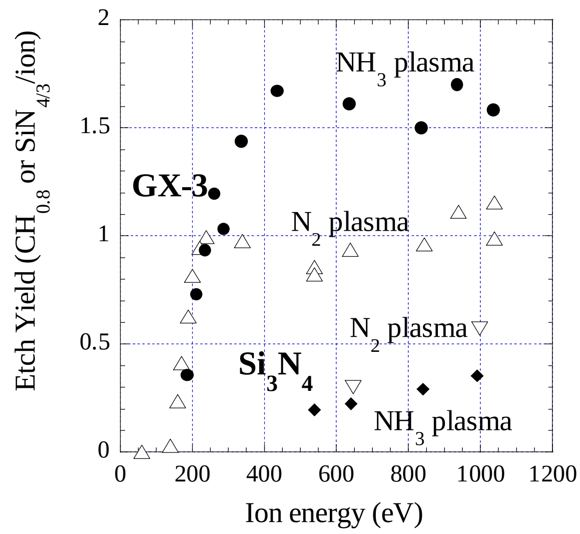

Figure 2 Ion energy dependence of etch yield of GX-3™ and Si_3N_4.

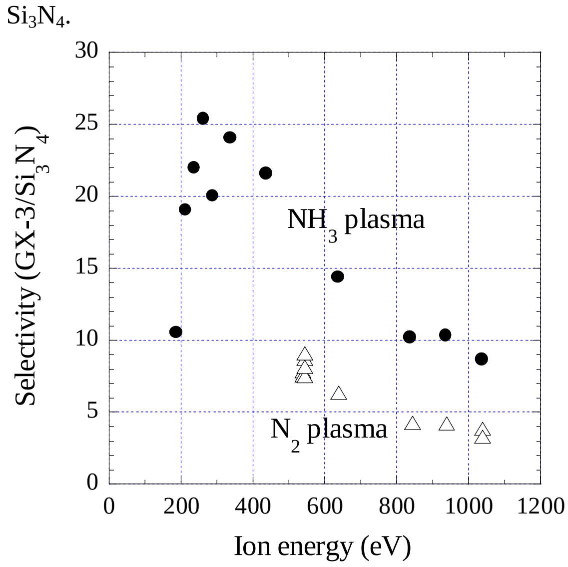

Figure 3 Ion energy dependence of selectivity of GX-3™ to Si_3N_4 normalized by ion flux.