

## Depth profiling of chemical structures of ultrathin silicon oxynitride films

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It was deduced from our recent study using fixed wave length(Al K $\alpha$ ) XPS system on oxynitride/Si(100) interface structures formed by the treatment of oxide film in NO ambient at 900°C that the most of nitrogen atoms localize near the interface and have bonding with two Si atoms at the interface and one Si atom bonded with three oxygen atoms located in the overlayer[1]. However, the energy resolution of 0.38 eV attained by the XPS system is not enough to determine the bonding configuration from N 1s photoelectron spectra and the probing depth of 3.4 nm in silicon oxide attained by the XPS system is not large enough to detect N 1s spectra arising from nitrogen atoms localized at the interface with high sensitivity.

In 1984 photoemission studies on the SiO<sub>2</sub>/Si interface was performed using first generation SOR in the photon energy range from 1950 to 3700 eV. However, the line resolution, count rate, and signal stability at that time were extremely deficient compared to the fixed wave length XPS system. [2]

Figure 1 shows Si 2p photoelectron spectra, which were excited by third generation SOR, with photon energy as a parameter for 2.7 nm-thick-oxynitride film formed on Si(100) by the treatment of oxide film in NO ambient

at 900°C, which contains 0.69 monolayers of nitrogen atoms. Here, 1 monolayer denotes  $6.8 \times 10^{14} \text{ cm}^{-2}$ , which is equal to the areal density of Si atoms at the interface.

[1] K. Inoue et al.: Jpn. J. Appl. Phys. **40** (2001) L539.

[2] M. H. Hecht et al.: J. Vac. Sci. Technol. A **2** (1984) 584.

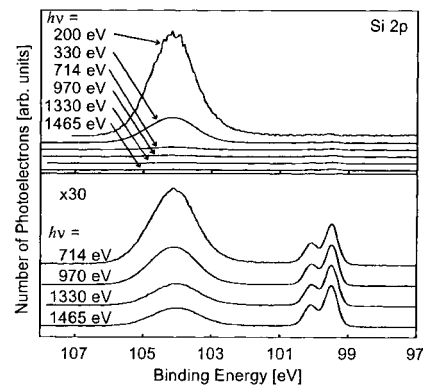


Fig. 1 Upper part shows Si 2p photoelectron spectra with photon energy as a parameter, while lower part shows spectra excited by high energy photons are enlarged by 30 times. Here, number of photoelectrons arising from Si substrate are adjusted to be equal to each other.

## Kinetic energy of F<sup>+</sup> ion produced by ultra-fast dissociation from core-excited CF<sub>4</sub> molecule

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Core-excited species are unstable and decay processes follow rapidly. The most dominant decay process is resonant Auger electron emission. In some case, the nuclear motion is so fast that dissociation takes place on the same scale as Auger electron emission. Such dissociation in core-excited states is termed "ultra-fast dissociation (UFD)" and its time scale is considered to be several femtoseconds [1]. The electronic decay from the core-excited fragment was observed for CF<sub>4</sub> at the F1s →  $\sigma^*$  excitation [2]. This is assigned to the electron emission from core-excited F atom. To elucidate the detail of the ultra-fast dissociation processes for CF<sub>4</sub>, Auger electron-photoion coincidence (AEPICO) measurements have been carried out at the soft x-ray beamline BL27SU.

The apparatus consists of an ion time-of-flight spectrometer equipped with a 2-dimensional (2-D) detector and a cylindrical-mirror electron energy analyzer (CMA). The 3-dimensional components of the linear momentum for each ion

are obtained by analyzing the time of flight and the position of detection.

Fig.1 shows resonant Auger electron spectra of CF<sub>4</sub> in the photon energy region across the F1s →  $\sigma^*$  resonance. A feature indicated by arrows corresponds to an F atomic Auger line that appears as a result of UFD of the core-excited molecules. Kinetic energy (KE) distributions of F<sup>+</sup> are shown in Fig.2 measured at the atomic Auger line and at the parallel direction relative to the electric vector of an incident light. A feature indicated by arrows would be ascribed to an F<sup>+</sup> that is produced by UFD. The obtained KE value increases almost linearly with an increase in photon energy. Distributions of the excess energy in the core-excited state will be discussed in detail.

### References

[1] P. Morin et al., *Phys. Rev. Lett.* **56**, 1913 (1984).

[2] M. Kitajima et al., to be published.

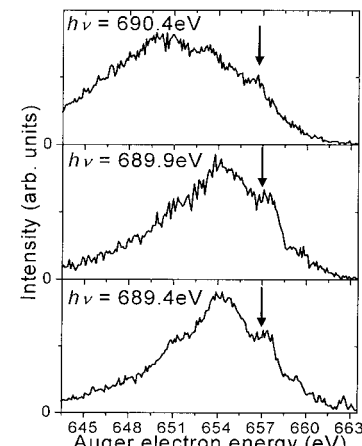


Fig.1 Auger electron spectra

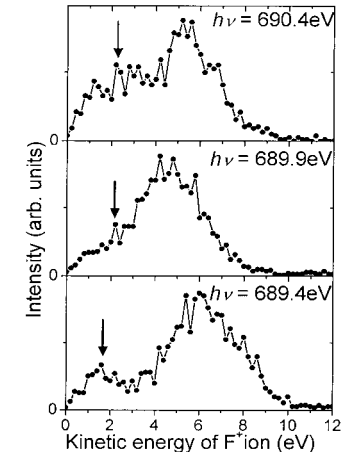


Fig.2 Kinetic energy distributions of F<sup>+</sup>