Extremely Sensitive Detection of Gate Insulator/Si Interface Structures for Future MOSFETs

Takeo Hattori
Musashi Institute of Technology, Tokyo, Japan

Among several interface-sensitive techniques, cross-sectional transmission electron microscopy of the SiO_2/Si interface is indispensable for the detection of imperfections at and near the interface. On the other hand, the chemical probing of the SiO_2/Si interface using photoelectron spectroscopy has not been used until now for the improvement of the oxidation process because of its relatively low sensitivity in the detection of the SiO_2/Si interface structures.[1] In order to detect the dependence of the SiO_2/Si interface on the oxidation process, the thickness of the silicon oxide film should exceed the thickness of 1-nm-thick structural transition layer,[2,3] which is most sensitive to the oxidation process. Thus, to perform highly sensitive detection of the SiO_2/Si interface, extremely high energy resolution of 100 meV and probing depth of more than 1 nm is necessary.

Recently, we succeeded for the first time in detecting the dependence of the SiO_2/Si interface structure on the oxidation process by performing high-resolution photoelectron spectroscopy using third generation synchrotron radiation at Super Photon Ring 8 GeV (SPring-8), where high density photon flux is available. The silicon oxide films we studied included those formed in a microwave-excited (2.45 GHz) oxygen plasma at 300 °C, in a microwave-excited (2.45 GHz) krypton-mixed oxygen plasma ($Kr:O_2$ = 97:3) at 300 °C, as well as by dry oxidation at 900 °C. Furthermore, by analyzing angle-resolved photoelectron spectra based on the depth profile of elements in the high-κ dielectric films such as La_2O_3, Gd_2O_3 and Lu_2O_3 determined by high-resolution Rutherford backscattering, we were able to determine the atomic-scale depth profile of composition and chemical structure of these oxide films. Based on these studies, key factors relevant to the future development of gate insulators will be discussed.

---

1 T. Hattori, *Critical Rev. Solid State Mat. Sci*. **20**, 339 (1995).

2 K. Hirose *et al*., *Phys. Rev. B* **64**, 155325 (2001).

3 K. Takahashi *et al*., *Jpn. J. Appl. Phys.* **41**, L223 (2002).