Reliable Thickness Measurement of Ultra-thin SiO2 Films using XPS by Precise Setting of the Surface Normal

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The control of high-k gate oxide thickness is one of the most important issues for the enhancement of electronic properties of semiconductor devices. Recent international technology roadmap for semiconductor (ITRS) showed that the reliable measurement of ultra-thin gate oxide thickness below 1 nm is required for the next generation of semiconductor devices.[1] The rapid scaling-down in the development of semiconductor devices needs a new methodology applicable for the measurement of gate oxide thickness below 1 nm to compensate the limitation of ellipsometry which is the most common method for the quality control of oxide thickness measurement.[2] X-ray photoelectron spectroscopy (XPS) is an ideal candidate for that purpose because of the surface sensitivity due to the shallow detection depth of low energy photoelectrons. The measurement of SiO_2 films is the first subject for the pilot study in the SAWG (surface analysis working group) of CCQM. The calibration curve of XPS can be expected to pass the origin theoretically and was examined by experimentally.[3] This point is critical for the measurement of thickness of ultra-thin gate oxide films.

In this study, the thickness measurement of SiO_2 films were investigated using amorphous SiO_2 films grown on amorphous Si films to avoid the diffraction effect of photoelectrons due to the crystalline effect. The films were grown by ion beam sputter deposition at room temperature. *In-situ* XPS analysis enables us to measure the film thickness without surface contamination. The nominal thickness of the films was estimated by the growth rates deduced from the high resolution-TEM. The thickness of the SiO_2 films found to be defined quantitatively at the sub-nm range.

A new method to determine the surface normal has been developed using an amorphous SiO_2 film grown on an amorphous Si film. Using this method, the surface normal can be determined precisely within the accuracy of 0.05°.

References

1. International Technology Roadmap for Semiconductors. http://public.itrs.net/
2. M. P. Seah, "Practical Surface Analysis I", edited by D. Briggs and M. P. Seah (John Wiley & Sons, 1992).
3. K. J. Kim, K. T. Park and J. W. Lee, Thin Solid Films 500, 356-359 (2006).