The structure of thin tantalum oxides on silicon substrates

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The realization of reliable thin-film gates is one key issue for the down-scaling of ICs. Tantalum oxide is among the prospective gate materials, because of its high dielectric constant. Its electrical characteristics depend on processes where tantalum oxides are fabricated on silicon substrates. It implies that the structure of tantalum oxides varies with process parameters, such as substrate temperature, ambient pressure during deposition, and annealing. In this study, the structure of thin tantalum oxide films on silicon substrates was investigated by X-ray diffraction.

Tantalum oxide films were grown by the low pressure chemical vapor deposition (LPCVD) method. (100) silicon substrates measured 25 mm × 25 mm, and the film thickness was around 150 Å.

X-ray diffraction measurements were carried out using a diffractometer and an imaging-plate camera at the BL02B1 beamline. The wavelength selected through a double-crystal monochromator centered on 0.5 Å. An incidence beam was fixed at a glancing angle around 0.6° with the samples.

Figure 1 shows a diffraction pattern obtained from a sample with an incidence angle of 0.6°. Thermal diffuse scattering from the silicon substrate overwhelms Debye rings from the film across the figure; only a couple of inner rings are observed on the left side. This thermal diffuse scattering should be suppressed to obtain sufficient intensity for the diffraction patterns from the film and to determine its structure.

Fig. 1

It should be required for a thin-film-on-substrate sample to make a grazing incidence angle with an incidence beam to allow the incident beam not to penetrate deep into the substrate. This is not fulfilled at this station, as it is. For realizing this experimental condition, an ω-axis goniometer with a higher angular resolution, or an attachment such as a tangential-bar will be prepared in the future study. A reflection intensity curve from the sample should also be monitored and be compared with a calculated one to select the penetration depth for the beam.

We believe that this study was fruitful to know how feasible the station is, albeit the present data could not be used for the outright structure analysis. The imaging-plate camera at the BL02B1 beamline is quite promising for the structural study of thin films on substrates. A future station planned for powder diffraction is also expected to meet the above requirement.