Application of SPELEEM to high-*k* gate dielectrics: relationship between surface morphology and photoelectron spectra during Hf-silicide formation

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We have performed real-time observation of surface morphology and micro-region photoelectron spectra of HfO_2/Si gate stacks with and without poly-Si top electrodes during thermal annealing under ultra-high vacuum (UHV), using Spectroscopic PhotoEmission and Low Energy Electron Microscope (SPELEEM). The silicidation of HfO_2 involves local phase separation and change in surface morphology [1, 2]. Thus, it is important to investigate the electronic states of small region (micron ~ sub micron) and to compare the photoelectron spectra and the lateral distribution of constituent elements, in order to elucidate the mechanism of Hf-silicide formation. The experiments were performed using SPELEEM installed at BL17SU of SPring-8. Figure 1 shows mirror images of the samples without poly-Si electrodes in a Mirror Electron Microscope (MEM) mode of SPELEEM, together with their Hf 4*f* photoelectron spectra in a dispersion mode with the aperture of around 1 micron. In an as-grown sample, surface morphology was completely flat, and no Hf-silicide peaks were observed. During the thermal annealing process at around 700 ^{o}C, the surface morphology became rough with increasing the Hf-silicide peaks. By measuring the photoelectron spectra and observing the surface morphology at a time, the direct relationship between changes in the surface morphology and the chemical states was clarified.

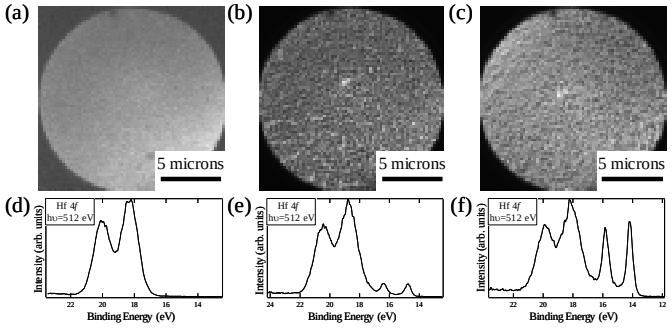

Fig. 1. MEM images (FOV: 15 microns) of (a) as-grown, (b) early stage, (c) mid stage of the silicidation, together with Hf 4*f* photoelectron spectra at each stage (d ~ f).

[1] N. Miyata *et al*., Appl. Phys. Lett. **82**, 3880 (2003).
[2] H. Takahashi *et al*., Appl. Phys. Lett. **87**, 012903 (2005).