Morphological changes of Cu surfaces by comparison of Ar^+ and Xe^+ ion irradiation induced by photoemission-assisted plasma

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A photoemission-assisted plasma (PAP) ion source with Xe excimer lamp ($h\nu$ =7.2 eV)[1] has been developed to flatten Cu surfaces below 1 nm for achieving surface activated bonding at RT without pressurization. For this sake, ion beams with ion energy E_{ion} < 50 eV are demanded to avoid sputtering-induced roughening. In this study, the momentum transfer effect of ion irradiation on flattening of Cu surface has been clarified by comparison of Ar^+ and Xe^+ ion irradiation.[2]

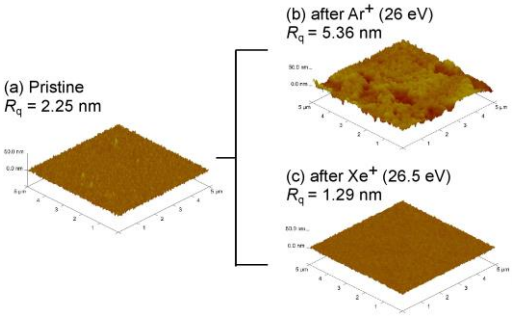

Fig. 1 AFM images of Cu surface (a) as pristine (b) after Ar^+ ion (E_{ion} = 26 eV), and (c) Xe^+ ion (E_{ion} = 26.5 eV) irradiation, respectively. The scan size of AFM is 5×5 μm^2.

Ar^+ and Xe^+ ion was generated by PAP under pressure of 180 and 100 Pa at bias voltage of 400 V, respectively. Consequently, the E_{ion} was estimated based on the charge transfer collisional ion sheath model, which was 26 and 26.5 eV for Ar^+ and Xe^+ ion. Pristine Cu surface with surface root mean roughness (R_q) = 2.25 nm (Fig. 1(a)) were irradiated by Ar^+ and Xe^+ ion, respectively. As shown in Fig. 1(b) that pristine Cu surface was roughened due to the crater formation after Ar^+ ion irradiation at ion fluence (F_{ion}) about 3.12×10^{18} ions/cm^2. On the other hand, by Xe^+ ion irradiation at same F_{ion}, the R_q of Cu surface decreased from 2.25 to 1.29 nm.

This is realized by the difference of the ratio between sputtering yield and adatom yield. Comparison with Ar^+ ion irradiation, more movable adatoms induced by momentum transferred from Xe^+ ion irradiation. It contributed to enhancement of surface migration leading to a surface flattening. Adatom induced surface migration is so-called ion beam induced collision motivated diffusion.[3] It is considered that the higher ion mass, the higher collision motivated diffusion in the range of E_{ion} < 50 eV.[2] Lateral diffusion of surface atoms induced by momentum transfer effect has been considered as a main mechanism for surface flattening. Furthermore, for the large area surface flattening, 3-inch sized Cu substrate surface was also irradiated by Xe^+ ion, showing an initial surface R_q = 4.32 reduced to 1.78 nm. In accordance with rms roughness, the results of height distribution and power spectra density analysis indicated a reduced surface height and a surface flattening for all spatial wavelength components covered by AFM measurements.

[1]Y. Ohtomo *et al.*, Surf. Interf. Anal. **44** (2012) 670.

[2]Saijian Ajia *et al.*, submitted to Appl. Phys. Express.

[3]F. Frost *et al.*, J. Phys. Condens. Matter **21**, 224026 (2009).