Nanoscale pattering and blistering phenomenon of gold films on silicon dioxide layer using focused helium ion beam

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To realize arbitrarily nanoscale patterning on gold (Au) surfaces, the helium ion microscope (HIM, Carl Zeiss ORION PLUS at AIST SCR station) was carried out in our works. Through the previous studies, it was revealed that the highly implanted helium (He) ions (> 1.0×10^{20} ions/cm^2) into single crystal silicon (Si) layer blow up Si structure forming blistered shape. [1] And more, the implanted He ions do not form blister in the silicon dioxide (SiO_2) layer owing to the existence of oxygen. From the view point of helium (He) ion projection rage, patterning width and blistering phenomenon were evaluated on thin and thick Au films in this report.

From the results of two-body collision calculation, [2] the projection range of He ion in Au layer would be 500 nm with 30kV acceleration voltage. So that, thin and thick Au films (160 and 700-nm-thick) were deposited on 500-nm-thick SiO_2 layer. After the focused He ion beam irradiation (1.0×10^{19} and 10^{20} ions/cm^2, acceleration voltage: 30kV, beam current: 2.5 pA, 1 line scan), the cross section shape was evaluated with the Z-contrast transmission electron microscopic (TEM) images (Figure 1). And also, the etched shape as a function of the depth and width of trenches were evaluated (Figure 2).

In case of low ion dose (1.0×10^{19} ions/cm^2), sub-10 nm scale notches (width: 17.1 nm, depth 7.7 nm for the thin Au layer) appeared on the surface of the Au layers. In case of high ion dose (1.0×10^{20} ions/cm^2) funnel shape with nanoscale slit appeared on the on the top and bottom of thin Au layer. The funnel shape of the top of Au layer (width: 42.5 nm, depth: 37.5 nm) can be related to the beam shape of the focused He ion beam. And also, the funnel shape of the bottom of Au layer can be described by the ion mixing phenomena at the interface of Au and SiO_2 layer. The measured narrowest gap from Z-contrast TEM image with thin Au layer was 1.4 nm. Unlike the thin Au film, thick Au film showed blistered shape in the middle of the layer as expected. The fissures in the thick Au layer could be related to the blistering phenomena as seen in the Si substrate. The thickness of thick Au layer is larger than the penetration depth of the He ion with 30kV acceleration voltage. The He ions which could not path through thick Au layer were gasified in the thick Au layer.

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[1] E. Maeda, T. Iijima, S. Migita, S. Ogawa, and R. Kometani, MNC 2016, 10P-7-63.

[2] J. F. Ziegler *et al.*, Nucl. Inst. Methods Phys. Res. B, 268, 1818, 2010.

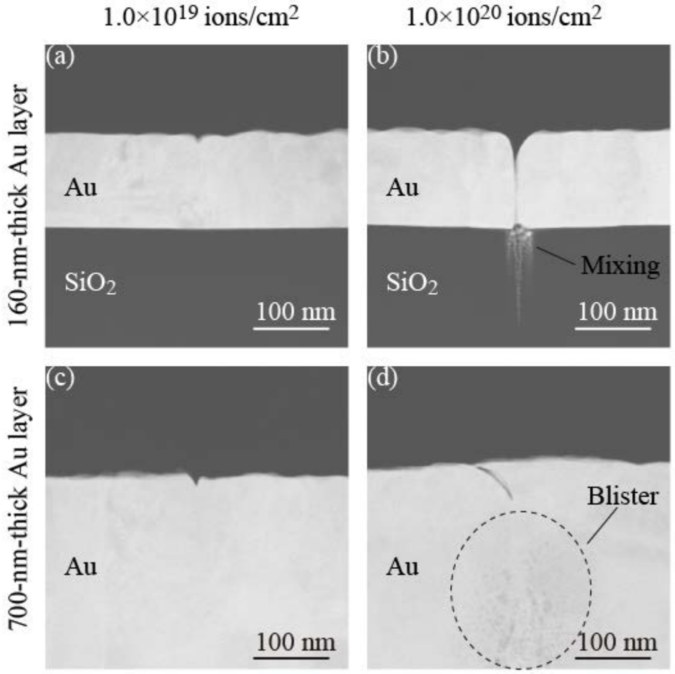

Figure 1: Z-contrast TEM images of cross section after focused He ion beam irradiation. (a) and (b) were1.0×10^{19} and 10^{20} ions/cm^2 He ion dose with 160-nm-thick Au layer respectively. (c) and (d) were were1.0×10^{19} and 10^{20} ions/cm^2 He ion dose with 700-nm-thick Au layer respectively.

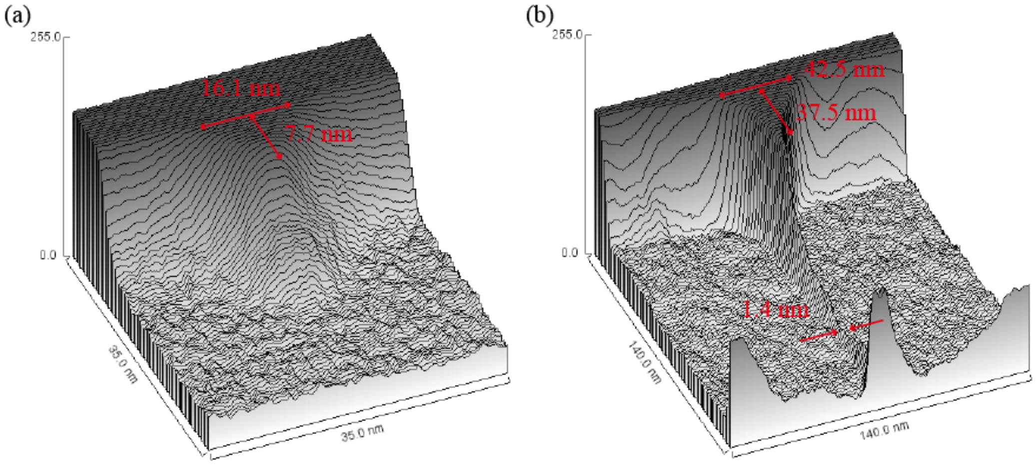

Figure 2: Estimated etched shape as a function of the depth and width of trenches from the Z-contrast TEM data of Figure 1 (a) and (b).