doi: 10.1017/S1431927609097426
Microsc Microanal 15(Suppl 2), 2009

Bubble formation in He implanted Cu and Au

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It has been reported that bubble lattice can form in He implanted Cu and Au under certain irradiation conditions[1-3]. However, this information was obtained from plan view TEM images and bubble distribution along penetration depth was lacking. Furthermore, the dependence of bubble lattice on temperature is less studied. Here we show that, with cross-sectional TEM samples made by ultramicrotome, bubble lattice can only form before or after the peak position of implanted He. In addition, *in situ* TEM annealing reveals the development of faced bubbles that can be attributed to the preferential receding of crystals in which the facets of crystals with a low surface energy occupy more of the surface area of the resulting bubbles.

Fig. 1 shows cross-sectional images of 30 keV He irradiated Cu up to 5×10^{17} ions/cm^2 with a flux of 1.5×10^{13} cm^{-2}s^{-1}. Broad size distribution of bubbles can be observed in the peak depth of implanted He while uniformly distributed bubbles are formed before and after the peak position. Because the peak position has more implanted He ions as interstitials, the direct absorption of implanted He instead of He diffusion is mainly responsible for bubble formation. The uniform size is a prerequisite for the ordered pattern formation. Thus ordered bubble lattice can only form before or after peak depth of implanted He. This conclusion can be further confirmed by Fig. 1b and c. A domain with perfect hexagonally ordered bubbles with lattice constant of 10 nm was observed before the peak depth. The lattice layers along penetration depth can be up to 10. Fig. 1c shows partially ordered bubbles before the peak position.

Fig. 2 shows the dependence of bubble evolution with conditions of thermal annealing. With increasing temperature, the bubble grows following Ostwald ripening model, i.e. the large bubbles grow at the expense of small bubbles. Due to the pressure inside bubbles and the small thickness of sample, when the bubble reaches a certain size, it will explode and disappear. As shown in Fig. 3, the faceted bubble is evident. By tilting the sample to different zone axis, it was confirmed that facets have special orientations with the matrix. The faceted bubble consists of sides with the low surface energy. Following the Gibbs-Wulef model of crystal growth under thermal equilibrium, the growth of bubbles can be described as the following: at high temperature, mobility of He ions and matrix atoms increases. In order to minimize the surface energy, the matrix needs to adjust the shape of bubbles once a bubble meets He ions or another bubble. Under this condition, the facets with low surface energy will survive and occupy most of surface.

[1] P. B. Johnson, R. W. Thomson, and D. J. Mazey. *Nature* 347, 265 (1990)
[2] N. M. Ghoniem, D. Walgraeef. and S. J. Zinkle. *J. Comput. Aided Mater. Des.* 8, 1 (2002).
[3] P. B. Johnson, A. L. Malcolm, and D. J. Mazey. *Nature* 329, 316 (1987)
[4] This study was supported by the US DOE BES with grant #DE-FG02-02ER46005.

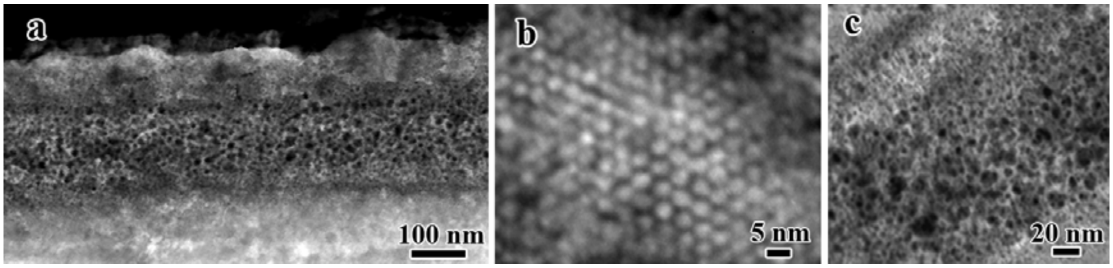

Fig. 1. Cross-sectional image showing bubble distribution in 30 keV He irradiated Cu. (a) HAADF image. (b) Bright field TEM image showing a domain of ordered bubble lattice. (c) HAADF image showing partially ordered bubbles.

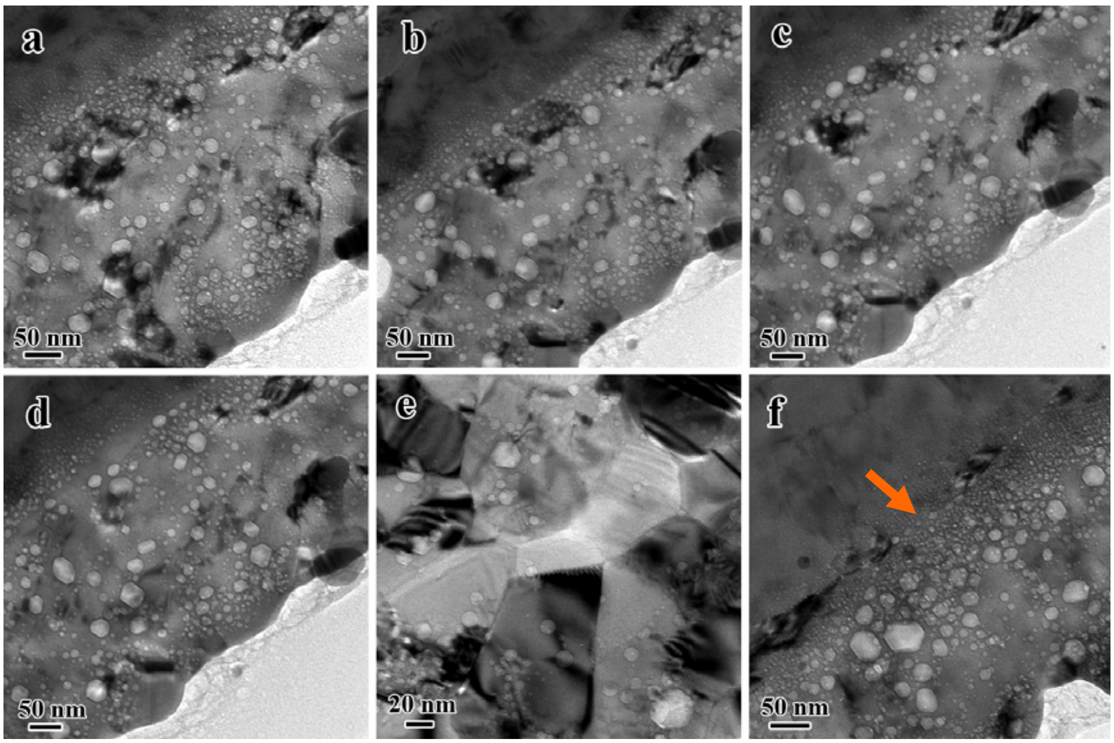

Fig. 2. Dependence of Bubble growth during thermal annealing (under-focused TEM images): (a) 400°C for half hour. (b) 450°C for half hour. (c) 500°C for 10 minutes. (d) 500°C for 20 minutes. (e) Bubble formation in polycrystalline Cu at 450°C. (f) Bubble formation on the grain boundary at 450°C (indicated by arrow).

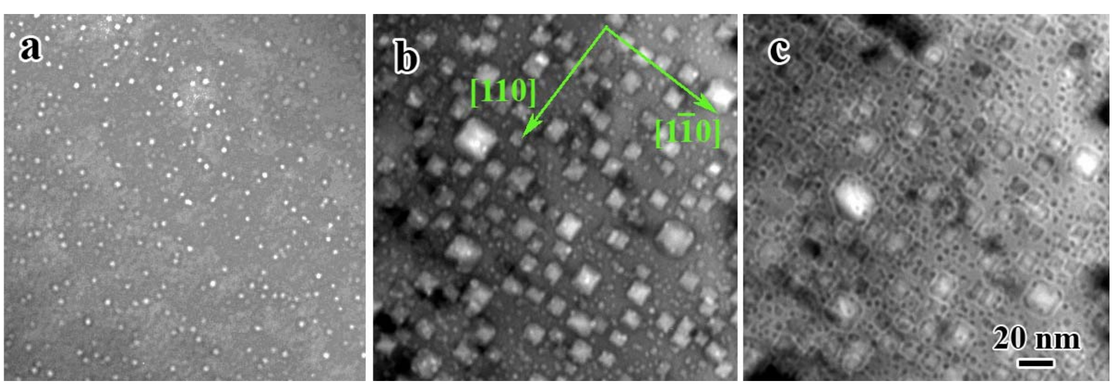

Fig. 3. Plan view TEM image in 130 keV He implanted Au: (a) before annealing, (b) 400°C for half hour (under focus), (c) over-focused image of (b). Arrows show orientation of facets.

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