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IT-7-P-2942 Deformation Behavior of Silica Microparticles under Electron Beam Irradiation

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The studies of irradiation damage in silica are of significant interest because of its application in nuclear reactors, nuclear waste containers, optical fibers, and semiconductor devices. In this work, we investigate plastic flow and failure behavior of amorphous silica particles (1050±30 nm) under compressive stress inside a scanning electron microscopy (SEM). In situ quasistatic compression experiments were conducted using a PI 85 SEM PicoIndenter (Hysitron, Inc., Minneapolis, MN) with 2.5 mm flat punch diamond probe inside an SEM.

The deformation behavior of the particles before and after the experiments with beam on and beam off conditions can be seen in figures 1a-d. A large variation in the total plastic strain and tendency to fracture has been observed which varies with peak loads and beam condition. Here, plastic strain has been calculated as the ratio d/D, where D is the diameter of the particle and d is the amount of compression along the indentation axis. In quasistatic experiments with a 190s hold at 1 mN peak load, a particle deformed plastically to 55.5% strain when the beam was kept on during the test (fig. 1a). However, when the beam was turned off (fig. 1b), a similar diameter particle showed negligible strain (<0.05%). When the peak load is increased to 4 mN peak load with the beam on, a plastic strain of 57.8% strain was found with a crack that appeared on the surface as marked in fig 1c. In beam off condition, a similar sphere deformed plastically to 37% strain, occurring in conjunction with a large fracture which created a wedge-shaped missing segment as observed in figure 1d. The results in this study can be explained with the structural changes of the particles that has been reported in the literature. It has been observed that electron beam with sufficient intensity can change the pore structure of amorphous silica where small pores shrink and larger pores expand. The change in pore structure leads to softening of the particles which causes viscous fluid-type deformation. However, it should be emphasized that all the particles used in this study were exposed to electron beam before testing. So, it can be assumed that irradiation induced damage or defects in all the particles before loading were similar. This leads to a conclusion that the applied stress on the particles is playing a significant role in enhancing the structural changes and/or inducing more defects when electron beam is kept on. An important implication of this study is that electron irradiation under applied stress can induce significant instability and reduction in strength in silica resulting in lower lifetime in many devices where silica is an integral component.

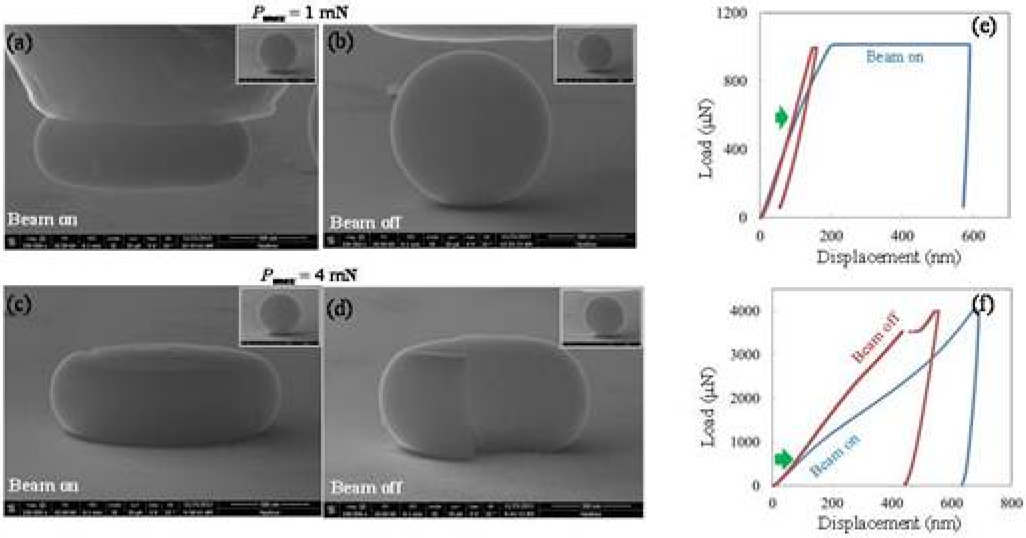

Fig. 1: a-d: Images of deformation behavior of silica particles after quasistatic compression experiments with beam on and beam off conditions 1 mN and 4 mN. Fig e-f: Load-displacement plots at Pmax= 1 and 4 mN shows the effect of electron beam on plastic flow of the materials.