Direct observation of the transformation toughening of tetragonal stabilized zirconia under shock deformation condition by ns time-resolved XRD.

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The enhancement of strength and toughness was found in oxide-doped tetragonal stabilized zirconia, with the suggestion that the absorption of energy during the martensitic transformation contribute to the increment [Gravie et al., 1975; Gupta et al., 1977]. Using transmission electron microscopy (TEM), in recovery sample, it was observed that the stress-induced transformation from stabilized tetragonal phase to monoclinic phase can be occurred around the crack tip [Porter et al., 1977], and the transformation-toughening model were devised [McMeeking et al., 1982; Hannink et al., 2000]. In high-pressure experiments, the phase transformation behavior of tetragonal stabilized zirconia has not been clarified in both static and shock compression because a lack of in-situ observation [Ohtaka et al., 1988; Grady et al., 1992]. We tried to observe the behavior of tetragonal stabilized zirconia under shock compression condition using time-resolved XRD method.We performed the experiments at NW14A beamline at PF-AR (Photon Factory Advanced Ring), High Energy Accelerator Research Organization (KEK), Japan. Nd:glass laser with the wavelength of 1064 nm, pulse energy of 16 J, pulse width of 12 ns was used for shock-driving source. The laser beam was focused by optical lens to the size of 500 μm × 500 μm on the sample surface. For TR-XRD experiments, the synchrotron X-ray pulse of PF-AR was used as a probe source. The energy, the pulse width, and the size on the sample were 15.68 keV, about 100 ps, and 450 μm (H) ×250 μm (W), respectively. The irradiation timing between laser pulse and X-ray pulse on the sample surface were controlled by delay generator at ns time scale. The targets consisted of an 25 um PET film ablator with Al coated on the surface and 50 um polycrystalline 3 mol% yttria doped tetragonal stabilized zirconia.
The XRD change were observed up to 35 ns after shock compression started. Before shock, the (101), (002), (110), (102), (112), (200) diffraction of tetragonal phase were observed. 6.5 ns after shock, the diffraction from compression region appeared with maximum compression of 6%. No phase transition occurred at compression states. At release states (~11.4 ns), on the other hand, the (-111), (111), (022), (-221) diffraction peaks of monoclinic phase were appeared. We will discuss the detail of the experimental results and the transformation toughening mechanism.

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