MS88.O02

Macroscopic and microscopic strain of SiO2 glass under uniaxial compression

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Although SiO2 glass is brittle due to its covalency and the lack of dislocation movement seen in crystals, it can deform without fracturing when compressed to high pressures. The phenomenon may be attributable to the well-known permanent densification by the reconstruction of the network structure consisting of SiO4 tetrahedra. To explore so-called plastic deformation without permanent densification, we measured the change in size (macroscopic strain) of uniaxially-compressed disk-shaped SiO2 glass by an optical microscope [1]. Also, to understand the anisotropy in structure (microscopic strain), we measured the azimuth-angle dependence of the position of the first sharp diffraction peak (FSDP) of uniaxially-compressed SiO2 glass with a radial X-ray diffraction technique [2]. In the microscope observation, the glass was found to deform largely without fracturing up to at least 20 GPa from 6-8 GPa, where uniaxial conditions were achieved. In the X-ray diffraction observation, a large anisotropy was found in the FSDP which corresponds to the intermediate-range network structure of the glass. The recovered glass was examined by the radial X-ray diffraction up to a high-Q range and was found to remain largely anisotropic (equivalent to about 2 GPa in differential stress) in the intermediate-range network structure and not to remain anisotropic in the short-range SiO4 tetrahedral structure. It seems intuitive that the residual anisotropy is due to the anisotropic reconstruction of the network structure during permanent densification. However, the macroscopic strain measured in the microscope observation was an order of magnitude larger than the microscopic strain in the X-ray diffraction observation, and therefore it cannot be explained solely by the anisotropic permanent densification. The permanent densification may also enhance the reconstruction of the network structure and therefore plastic deformation.

[1] *D. Wakabayashi, N. Funamori, T. Sato, in preparation,* ***[2]*** *T. Sato, N. Funamori, T. Yagi, J. Appl. Phys., 2013, 114, 103509*

Keywords: Silica glass, Plastic deformation, Residual anisotropy