VIDEO ARTICLE

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Homogeneous Plastic Deformation of Pd-Si Nanoglass under Tribological Deformation

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Abstract Graphic

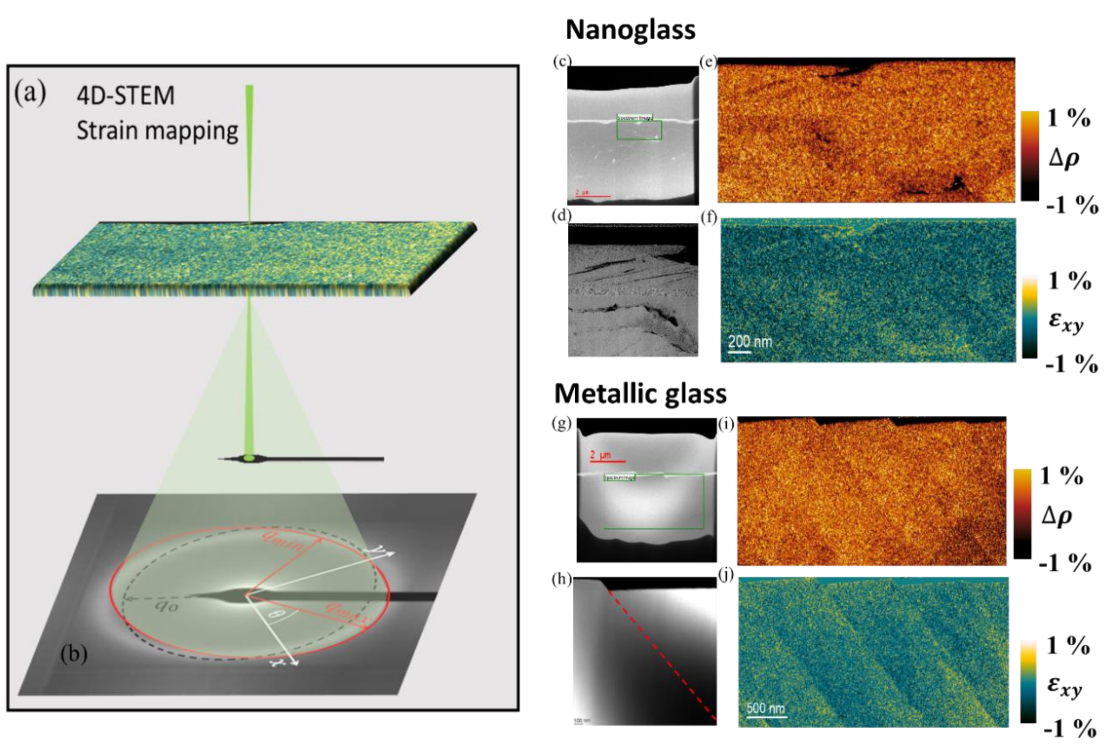

Fig. 1. 4D-STEM Study for deformation of glassy materials. (a) Schematic illustration of 4D-STEM experiment setup used for this study. (b) Spatially-resolved diffraction patterns are collected in a glassy material. Principal strains are calculated from the elliptic distortion of the diffraction ring indicated by q_{max} and q_{min}. The strain tensors are algebraically obtained from projecting the principal strains to the reference coordinates (x- and y-axis). Two different glasses were compared : (c)-(f) for Pd-Si nanoglass and (g)-(j) for Pd-Si melt-spun glass. (c) STEM-HAADF image of the TEM lamella from the deformed Pd-Si nanoglass. A 4D-STEM map was acquired at a heavily deformed area indicated by the green rectangle. (d) STEM-HAADF image magnified for the worn surface. (e) Map of relative atomic density (Δρ). (f) Map of shear strain field (ε_{xy}). The color code in ε_{xy} indicates shearing: positive values for clockwise shearing and negative ones anticlockwise. (g) STEM-HAADF image of the TEM lamella from the deformed Pd-Si melt-spun glass. A 4D-STEM map was acquired at a deformed area indicated by the green rectangle. (h) STEM-HAADF image magnified for the worn surface. (i) Map of relative atomic density (Δρ). (j) Map of shear strain field (ε_{xy}).

Abstract

Nanoglass was discovered to represent a novel structural modification of conventional glassy materials by having new intrinsic structural features, e.g. planar defects or interfaces, on the nanometer-level length scale [**1**]. Such structural features were noted to delocalize strain and thus enhance deformability of a glassy matrix [**2**]. In fact, recent studies have shown that some nanoglasses deform plastically without generating shear bands and thus result in homogeneous plastic flow [**3**]. Therefore, nanoglasses can exhibit higher ductility and toughness compared to those of fast-quenched glasses. [**4-5**]. The mechanical properties of nanoglasses are interesting because these new glass-type materials can overcome the current limitations of conventional glassy materials. However, to date, the understanding of the atomic-level structure of nanoglasses and its correlation with their deformation behavior are not yet well understood, although they are likely to be crucial for developing the deformation theory of nanoglasses. In this work, a novel nanoglass, Pd-Si, was synthesized using the inert gas condensation (IGC) method and it was deformed by scratch testing. The deformed structure of the Pd-Si nanoglass was studied by correlatively imaging the strain field and the atomic packing density at the nanoscale using 4-dimensional scanning transmission electron microscopy (4D-STEM) as shown in Fig. 1. For a comparative study, the deformed structure of a Pd-Si melt-spun glass was also investigated under the same experimental condition. The results indicate isotropic residual strain fields in the deformed Pd-Si nanoglass after plastic deformation revealing the homogeneous deformation behavior at the nanoscale, whereas the Pd-Si melt-spun glassy ribbon showed localized deformation in the form of shear bands. The observations confirm that the special deformation behavior of nanoglasses is intimately linked to their intrinsic structural features.

Keywords: Nanoglass, 4D-STEM, homogeneous deformation, strain mapping, shear bands.

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