FULL-FIELD STRAIN AROUND PROPAGATING SHEAR BANDS AND VON MISES CRITERIA FOR METALLIC GLASSES

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In contrast to crystalline metals where structural defects such as dislocations, grain boundaries or stacking faults act as the carriers of plasticity, in amorphous metallic alloys plastic deformation occurs through formation of shear bands (SBs) – narrow bands of high shear displacement. Despite intensive research during past two decades the nanoscale mechanisms responsible for initiation and propagation of SBs in metallic glasses are not well understood. Current work provides significant new insights through capturing of full-field strain within and around the propagating shear bands, enabled by digital image correlation in SEM (SEM-DIC).
Thin amorphous PdSi films were employed as a model metallic glass material (Fig. 1a). They were sputter deposited on a polymer substrate and covered with nanoislands of indium that served two aims: (i) formation of a speckle pattern for SEM-DIC and (ii) detection of potential significant temperature rise caused by shear band formation. In order to localize the region of interest (ROI), the films were pre-structured by means of FIB milling using three different patterns, as depicted in Fig.1b. Straining steps were applied using a custom made manual tensile straining device.

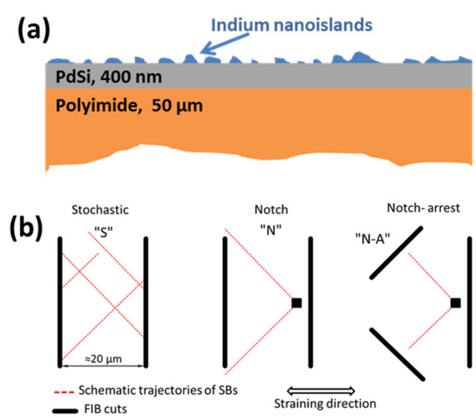

Fig. 1. Schematic cross-section of the sample (a) and three types of FIB patterns applied to the film (b)

First of all, no melting of In nanoislands were observed in the vicinity of shear bands and cracks confirming that temperature stays far below the glass transition temperature during a shear banding event. Dynamic states of a propagating SB were unambiguously captured by the DIC analysis, as exemplarily demonstrated in Fig. 2. In Fig. 2a the SB tip just entered the ROI from the bottom left point marked by the symbol “A”. Within the next loading step, the SB extended over the ROI towards point “B” (Fig. 2b). The strain distribution after unloading the sample is depicted in Fig. 2c. The profile of Mises strain between points “A” and “B” under different values of applied global strain is shown in Fig. 2d demonstrating homogeneous relaxation of total strain within the SB during unloading (compare “8.8%” and “full unload” curves).

Apart from demonstration of shear band propagation under different conditions (Fig. 1b) quantitative analysis of local strain enabled formulation of von Mises criterion for **shear band initiation** and **shear band arrest**. A model connecting macroscopic sample behavior (i.e., the measured stress-strain curve) with initiation and propagation of shear bands at the microscale and explaining the universality of the “2%-yielding phenomenon” in metallic glasses is suggested. Further work will be focused on exact measurements of critical strains required to initiate a shear band for different metallic glasses as well as on the interplay between von Mises yielding criterion and highest resolved shear stress criterion depending on the ratio of principal strain components (ε_{xx} and ε_{yy}).

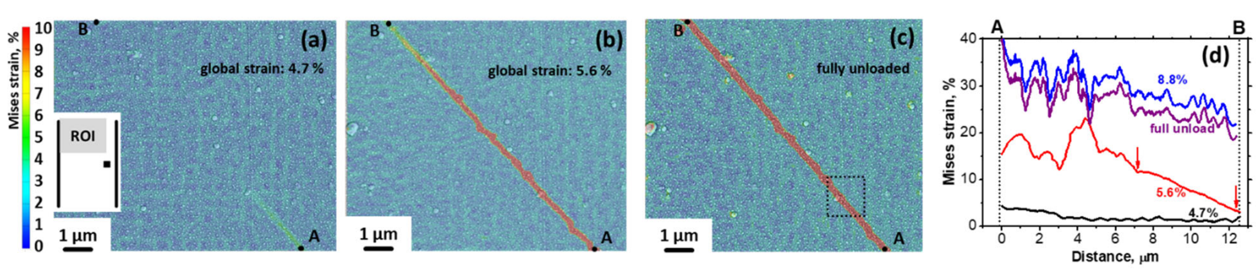

Fig. 2. Distribution of Mises strain within the ROI containing a propagating shear band (a-c). Mises strain profiles between the points “A” and “B” at different values of applied global strain (d)