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Featured Letter

Dislocation-dominated non-crystallographic rotation in shear bands of Cu/Au nanolayered composites

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A B S T R A C T

Shear band, a kind of unstable plasticity behavior, limits deformability of nanoscale materials, however the basic mechanism for such plasticity instability is still not understood well. Here, we found that the plastic deformation within the shear band of 25 nm-Cu/Au nanolayered composites is mainly contributed by the dislocation-dominated non-crystallographic rotation of the Cu/Au interface without destroying the crystallographic orientation. Homogeneous dislocation transmission across the transparent interface led to the non-crystallographic rotation to accommodate the geometrical requirement. The crystallographic relationship and structure in the interface zone can keep intact until the interface zone in the heavily-thinned layers becomes into amorphization.

1. Introduction

The occurrence of shear bands (SB) characterized by highly concentrated plastic flow [1,2] is an undesirable plastic deformation behavior in nanolayered materials. Such deformation instability would degrade the ductility of the ultrahigh strength metallic nanolayered composites (NLCs) [3–6]. Thus, an understanding of the basic mechanism of the plastic deformation instability within SBs is crucial in developing high-performance NLCs. The formation of SBs in NLCs are associated with the length scale of microstructures [5,7–9], the symmetry of slip system and the dislocation-interface interaction [3,4,10], which determine the deformation mechanism [6,8,9], crystallographic variation during the band formation [4]. However, studies on the dislocation-dominated plastic instability inside the SB in NLCs with a cube-on-cube interface structure are still limited and the deformation mechanism remains unknown. In this paper, the unstable plastic deformation zone within SBs in a Cu/Au NLC induced by microindentation loading was observed by a field-emission gun transmission electron microscope (TEM) (FEI Tecnai F20). Based on the experimental evidence and the analysis, we unveiled a basic mechanism for the development of plastic instability within the SBs in the NLC.

2. Experimental

1 μm-thick Cu/Au NLCs with an individual layer thickness of 25 nm were deposited onto single crystal Si substrates using a magnetron sputtering system, and the top layer was an Au layer. A locally large plastic deformation zone was introduced into the NLCs using microindentation testing at a load of 0.5 N for 5 s holding time. TEM characterization shows that the constituent layer thickness of the as-deposited sample is 28.24 ± 4.71 nm and the mean size of columnar grains is 79.30 ± 24.49 nm. These columnar grains have a {1 1 1} out-of-plane texture characterized by X-ray diffraction, as shown in Fig. 1(a).

3. Results and discussion

Fig. 1(b) shows a cross-sectional scanning TEM (STEM) image of the microindentation-deformed Cu/Au NLC. A large number of SBs with an angle ranging from 25.4° to 50.1° relative to the original layer appeared in the NLC, as indicated by arrows in Fig. 1(b). A closer observation of the SB is shown in Fig. 1(b′). The SB width is in the range of 32–88 nm. These deformed Cu and Au layers within the SBs have been thinned to 25–5 nm, and the corresponding shear strain within the SB shown in Fig. 1(b) is measured to be in the range of 5.38–7.51 by the similar method by Li et al. [7].

Fig. 1(c) presents a TEM cross-sectional view of a local region in the SB and Fig. 1(d) shows the HRTEM image of the as-deposited sample. Fig. 1(e) gives a close observation in the red line framed

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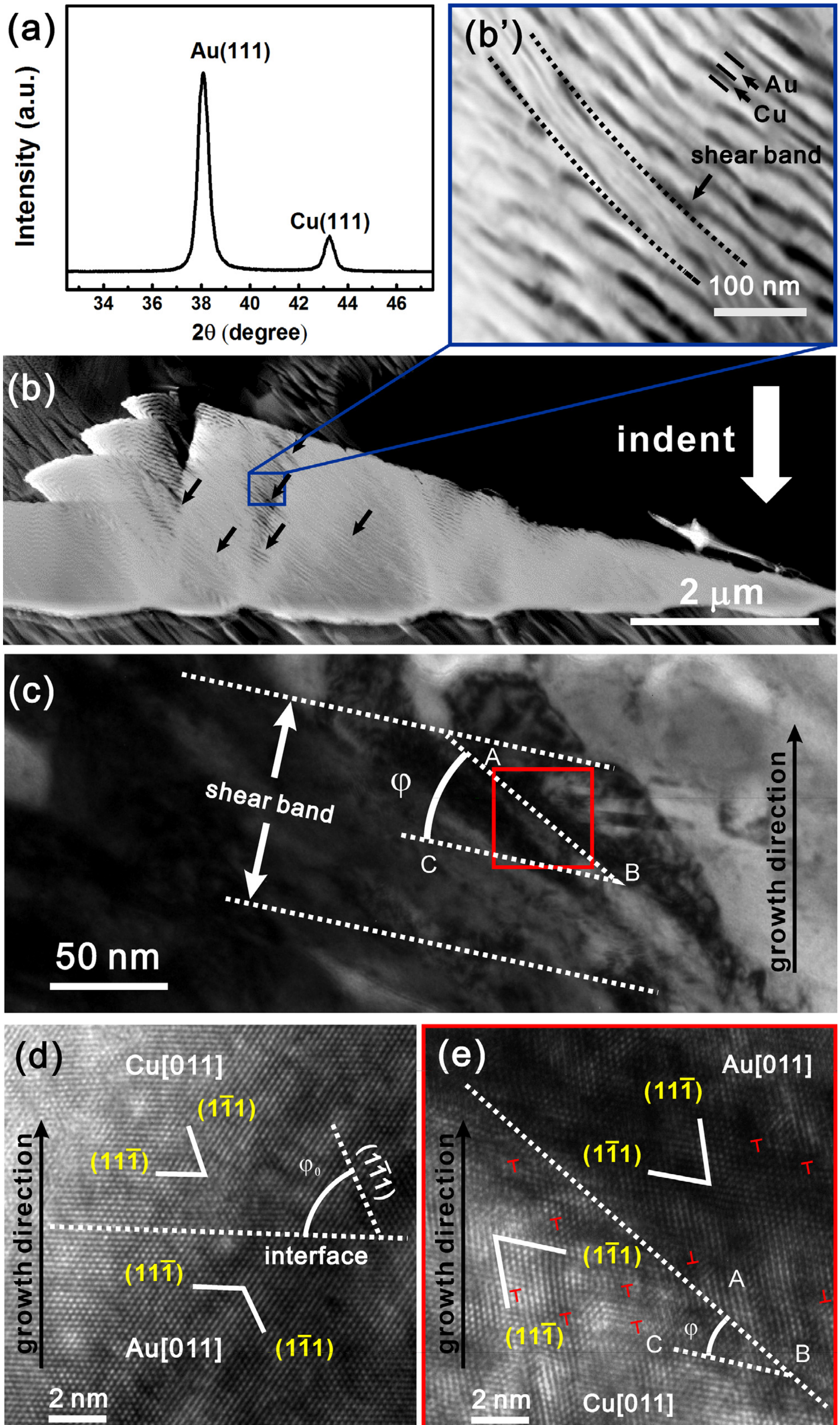

Fig. 1. (a) X-ray diffraction results of Cu/Au NLCs; (b) Cross-sectional STEM image of deformation morphology beneath microindent in Cu/Au NLC with (b′) a closer observation inside the frame. (c) Bright-field TEM image of the shear band; the HRTEM images at the Cu/Au interface in (d) undeformed zone and (e) the shear band. ⊥: dislocation, line AB: interface, line BC: shear band direction.