In-situ synchrotron X-ray micro-diffraction investigation of the microstructure evolution during low strain deformation of laminated Ti-Al composites

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Abstract

Laminated metal composites offer a unique opportunity to combine the desired properties of different metals in one material, with a possible further benefit from the constraint of the layer interface. To explore this constraint effect, the microstructural evolution of a laminated Ti-Al composite was investigated by a synchrotron-based micro-diffraction technique, namely differential aperture X-ray microscopy (DAXM) of a very high angular resolution (0.01○). An ultra-low-strain deformation microstructure was revealed non-destructively in the bulk interior in the "fully recrystallized" Al layer. This ultra-low-strain deformation microstructure was found to result from the thermal stress, induced during cooling after annealing, due to the different coefficients of thermal expansion for the Ti and Al layers. The annealed sample was subsequently tensile deformed to a strain of 1.66% and followed by in situ DAXM. The results pointed to the important effects of the initial microstructure and the interface constraint, as well as the grain size and crystal orientation, on the plastic deformation. A gradient in dislocation density from the layer interface to the center was found in the Al layer of the annealed sample, and this gradient increased slightly during tensile deformation. The variation of the dislocation density is discussed based on the activation and interaction of dislocations in grains of different sizes and orientations during plastic deformation. Moreover, deviatoric elastic strains were estimated based on polychromatic microbeam diffraction, while lattice strains along the normal direction of the tensile sample were directly measured using monochromatic microbeam diffraction. The estimated deviatoric strains show large spatial variations, and the mean values are consistent with the external loading conditions. The directly measured lattice strains also show large spatial variations, although the magnitude of this variation is smaller than that for the estimated deviatoric strain. It is discussed how the findings advance the understanding of constraint effects within laminated metal composites and may be used to design novel composite materials.

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