Dedicated TEM study from the core structure of adiabatic shear bands in dynamical deformed Ti6Al4V

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Metals and alloys deformed at high strain rates, which are occurring during impact or metal forming situations can suffer from premature failure due to the introduction of so called adiabatic shear bands (ASB). Very high strains occur in these narrow bands of localized deformation. In case of Ti6Al4V these bands are a known mechanism of failure [1,2], Although the main mechanism for adiabatic shearing is the competition between strain hardening and thermal softening, a detailed model of their structure and its role in the formation mechanism is not yet known. In this work a dedicated TEM study of the core structure in these adiabatic shear bands is presented.

Ti6Al4V with 93% of alpha phase (hcp structure) and 7% of beta phase (bcc structure) is deformed at high strain rates using the split hopkinson pressure bar technique. Two types of sample geometries are used: more common cylindrical shaped samples and samples with a hat shape specially developed to induce shear localization in a certain region [3]. In case of the cylindrical specimen a TEM sample was made using a focused ion beam (FIB) apparatus, it was obtained close to the tip of a crack formed in the ASB (Fig 1). In case of the hat shaped samples more traditional specimen preparation techniques were used. More conventional TEM imaging techniques reveal a strongly fractioned structure in the core of the shear band. Selected area diffraction (SAED) reveals ringlike patterns indicating a very small grain size, which is also confirmed by HRTEM. Analysis of these patterns shows that the reflections are originating from the alpha phase as well as from the beta phase. The change to smaller grain sizes has the intention to be gradual and the width of the region in which the grain size can be called nano-crystalline is around 1µm in case of the area presented in Fig 2. In case of the hat shaped samples this width was varying between 1µm and 3µm depending on the location in the shear band. An energy dispersive x-ray (EDX) study using STEM line scans and mapping reveals narrow elongated bands with changes in composition of V, Al, Ti and the presence of Fe. These changes in composition are consistent with the difference in composition between alpha and beta phase. This in combination with the observation of faint beta reflections indicates that the beta phase is still present but is very thin in one direction and strongly elongated in another being consistent with the imposed shear. This observation might indicate that thermal recrystallisation has not taken place. In case of the region observed in Fig 3 these narrow beta grains seem to occur in a well defined band and not outside of it indicating there might be a more strictly defined boundary.

Both sample geometries yield similar results concerning the structure of the ASB its core; nano-sized grain structure and preservation of the beta phase, but strongly elongated.

References

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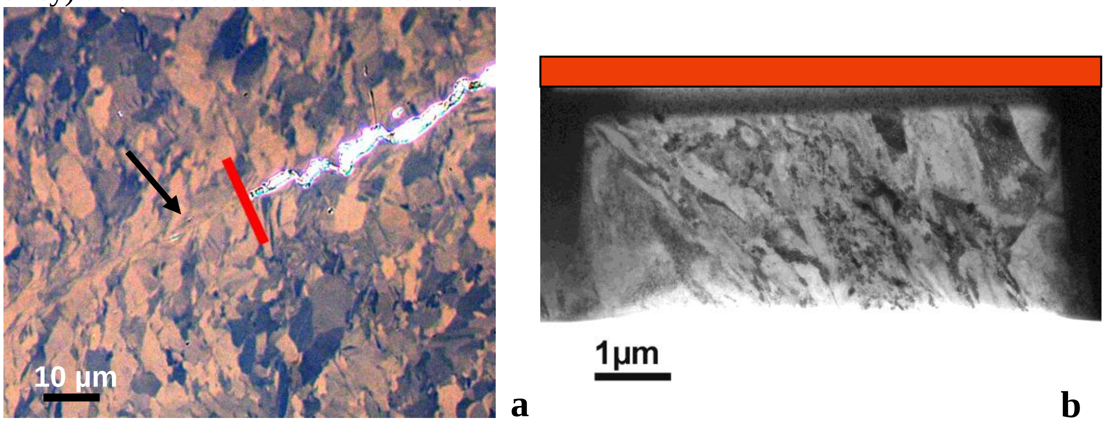

FIG. 1. a) Optical image of the shear band, indicated by the black arrow, and resulting crack in a Ti6Al4V cylinder specimen. b) FIB sample obtained from the region indicated by the red line.

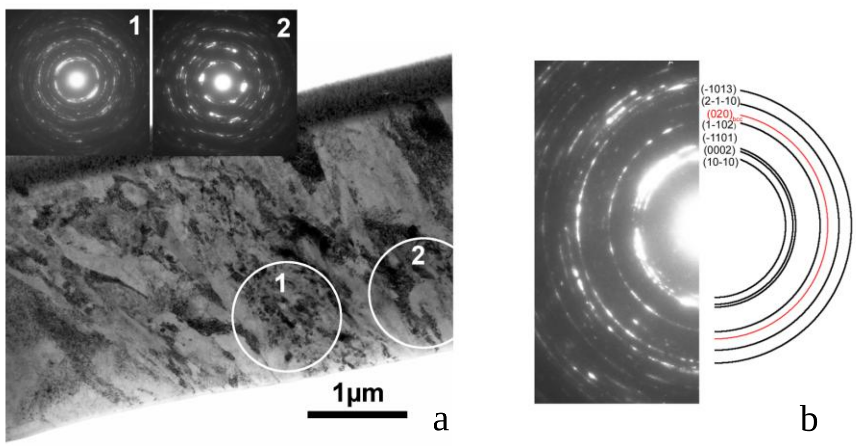

FIG. 2. a) BF image of the FIB sample with DP of area 1 and 2 b) DP of area 1 indicating a very narrow grains size with the presence of both alpha and beta phase.

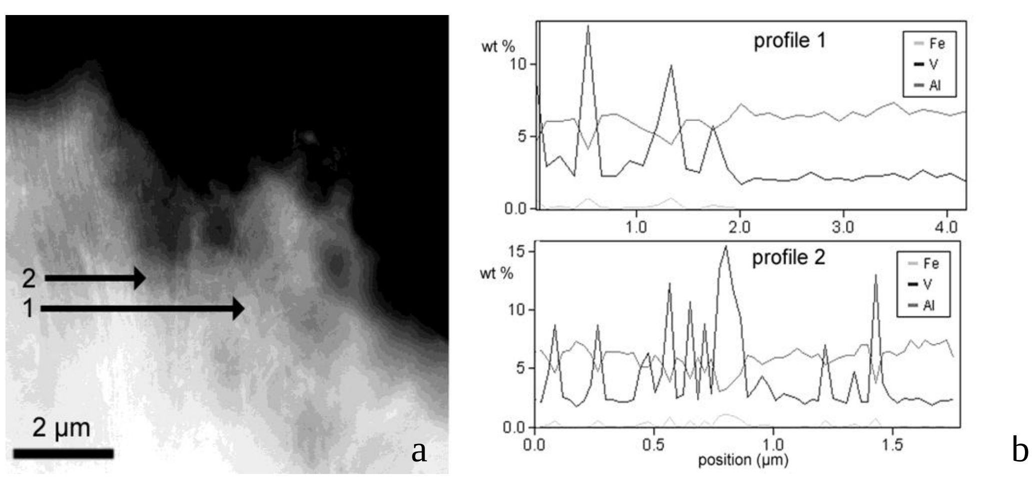

FIG. 3. a) HAADF STEM image of the shear band in a hat shaped sample with indication of the EDX line profiles b) EDX line profiles of V, Al and Fe in wt %