Multi-axial micro-forging: a method to engineer microstructural hierarchy

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Abstract

The last few decades have seen a rapid development of techniques to measure material properties at small length-scales, such as thermal analysis at the nano-scale (1), micro/nano-mechanical testing (2), even functional properties of specific microstructural features (3). However, deformation processing of materials has received much less attention at small length-scales: mainly only work-free processes – e.g. thermal – have been carried out in situ in electron microscopes. Indeed, few bulk deformation processing methods are adaptable at the micron or nano-scale, due to the need for complex tooling – e.g. rollers or extrusion dies. However, forging at the micron scale may be considered, even multi-axially, across a range of temperatures (-150 – 700 ∘C currently) and deformation schedules (monotonic or fatigue). Such multi-axial micro-forging is demonstrated here on a micron-scale cube of lamellar γ-TiAl alloy as a method to engineer, in a targeted manner, a hierarchically nanotwinned microstructure. Compared to regular lamellar γ-TiAl, this approach aims to reduce the strength anisotropy measured in subsequent micromechanical tests, which is normally thought to be the cause of poor inter-grain compatibility, and hence a low ductility of such alloys.

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