Abstract

The increasing demand for structural materials with superior mechanical properties has provided a strong impetus to the discovery of novel materials, and innovations in processing techniques to improve the properties of existing materials. Methods like severe plastic deformation (SPD) and surface mechanical attrition treatment (SMAT) have led to significant enhancement in the strength of traditional structural materials like Al and Fe based alloys via microstructural refinement. However, the nanostructured materials produced using these techniques exhibit poor ductility due to the lack of effective strain hardening mechanisms, and as a result the well-known strength-ductility trade-off persists. To overcome this trade-off, researchers have proposed the concept of heterostructured materials (HMs), which are composed of domains ranging in size from a few nanometers to several micrometers. Over the last two decades, there has been intense research on the development of new methods to synthesize HMs, including thermomechanical treatment of cold worked metals, SPD and sintering of powders, SMAT and electrodeposition. However, none of these methods is capable of providing precise control over key microstructural parameters such as average grain size, grain morphology, and volume fraction and connectivity of coarse and fine grains. Due to the lack of microstructural control, the relationship between these parameters and the deformation behavior of HMs cannot be investigated systematically and hence designing HMs with optimized properties is currently infeasible. This work aims to address this scientific and technological challenge and is composed of two distinct but interrelated parts. The first part concerns the development of a broadly applicable synthesis method to produce heterostructured metallic films with precisely defined architectures. This method uses well established microfabrication processes like photolithography and etching, and exploits two forms of film growth (epitaxial and Volmer-Weber) to generate heterostructured metallic films. The second part investigates the effect of different microstructural parameters on the deformation behavior of heterostructured metallic films with the aim of elucidating their structure-property relationships. Towards this end, freestanding heterostructured Fe films with different architectures were fabricated and uniaxially deformed using MEMS stages. The results from these experiments are presented and their implications for the mechanical properties of HMs is discussed.