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Stabilization of metastable phases by pressure and shear

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ABSTRACT

Numerous metallic systems possess allotropic phases that are stable at high temperatures or high pressures and that are endowed with unique properties that cannot be currently exploited because the reverse transformations take place once the pressure is released or the temperature decreases to ambient levels. Devising new processing methods that could lead to the stabilization of such phases would open new avenues for the fabrication of materials with still unforeseeable properties. It has been recently reported that the simultaneous application of pressure and shear by high pressure torsion (HPT) can be utilized to induce bulk allotropic phase transformations and thereby to stabilize metastable phases under ambient conditions. In particular, HPT processing allowed the stabilization of the high pressure phases ω and β in pure Zr and in Zr–2.5wt.% Nb. Furthermore, the application of shear under pressure led to a drastic reduction of the pressure levels with respect to those required under hydrostatic conditions. Similar results were obtained in pure Ti. HPT has also been recently employed to transform partially stabilized tetragonal zirconia into a monoclinic structure and to stabilize the Si-III and Si-XII phases in a Si (100) wafer. TEM studies have further revealed the occurrence of localized shear-induced phase transformations in HPT processed specimens. Among others, the α-BCC to γ-FCC phase transformation was reported in pearlitic carbon steel leading to a nanocrystalline austenitic structure. Finaly, precipitation of hcp Mg and a low temperature HCP Li-rich phase was observed in single phase BCC Mg–Li alloys. This discussion reviews successful examples of the stabilization of metastable phases by the simultaneous applications of pressure and shear, or by pressure alone. The influence of the processing parameters as well as of microstructure characteristics such as composition, texture, and grain size will be discussed.