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Investigation on Microstructure and Mechanical Property Evolution of Pure Metals during High-Pressure Torsion and Correlations with Physical Parameters

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Abstract

Pure metals of 29 elements with different crystal structures are processed by high-pressure torsion (HPT) and the evolution of microstructures and mechanical properties is investigated in different processing conditions. It is shown that the hardness and the mechanical properties of pure metals processed by HPT are represented by unique functions of the equivalent strain. For most of the metals, the hardness increases with an increase in the equivalent strain at an early stage of straining and levels off and enters into a steady state at large strains. However, for metals with low melting temperatures such as Al, a static softening at the steady state occurs after processing by HPT. It is shown that the hardness at the steady state is a characteristic of each metal and is reasonably the same irrespective of the pressure, of the initial states before HPT and of the deformation modes (monotonic or cyclic), provided that the strain per cycle is large. However, the hardness at the steady state is influenced by temperature, by static softening after HPT and by phase transformation during HPT. The hardness values at the steady state can be expressed as a function of metal parameters and temperature using four types of relations: first, relations based on the atomic bond energy, second, relations based on the activation energy for kink pair formation, third, relations based on the shear modulus and homologous temperature, and fourth, relations based on the creep. The first two relations directly reveal the importance of the atomic bond energy and Peierls stress in processing by HPT, and the two latter relations indirectly reveal that the steady state occurs because of a balance between the rate of strain hardening and the rate of recovery.