High Temperature Deformation of
Vitreloy Bulk Metallic Glasses and Their Composite

Thesis by

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ABSTRACT

A complete understanding of the deformation mechanisms of BMGs and their composites requires investigation of the microstructural changes and their interplay with the mechanical behavior. In this dissertation, the deformation mechanisms of a series of Vitreloy glasses and their composites are experimentally investigated over a wide range of strain rates and temperatures, with focus on the supercooled liquid regime, by combining uniaxial mechanical testing with calorimetric and microscopic examinations. Various theories of deformation of metallic glasses and the composites are examined in light of the experimental data.

A comparative structural relaxation study was performed on two closely related Vitreloy alloys, $Zr_{41.2}Ti_{13.8}Cu_{12.5}Ni_{10}Be_{22.5}$ (Vit 1) and $Zr_{46.7}Ti_{8.3}Cu_{7.5}Ni_{10}Be_{27.5}$ (Vit 4). Differential scanning calorimetric studies on the specimens deformed in compression at constant-strain-rate in supercooled liquid regime showed that mechanical loading accelerated the spinodal phase separation and nanocrystallization process in Vit 1, while the relaxation in Vit 4 featured local chemical composition fluctuation accompanied by annealing out of free volume. The effect of the structural relaxation on their mechanical behavior was further studied via single and multiple jump-in-strain-rate tests.

The deformation and viscosity of a new Vitreloy alloy were characterized using uniaxial compression tests in its supercooled liquid regime. A new theoretical model named Cooperative Shear Model, which correlates the evolution of the macroscopic mechanical/thermal variables such as shear modulus and viscosity with the configurational energies of atom clusters in an amorphous alloy, was critically examined in this investigation. The model was successful in predicting the Newtonian and non-Newtonian viscosities of the material, as well as the shear moduli of the deformed specimens, in a self-consistent manner.

The plastic flow of an *in-situ* metallic glass composite, β-Vitreloy, was investigated under uniaxial compression in its supercooled liquid regime and at various strain rates

($10^{-4} \sim 10^{-1} s^{-1}$). The composite, with ~ 25% volume fraction of crystalline β-phase dendrites exhibited superplastic behavior similar to that of amorphous Vit 1. Significant strain hardening was observed when the material was deformed at high temperatures and low strain rates. A dual-phase composite model was employed in finite element simulations to understand the effect of the composite microstructure on its mechanical behavior.

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