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Nanomechanics of Slip Avalanches in Amorphous Plasticity

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Abstract

Discrete stress relaxations (slip avalanches) in a model metallic glass under uniaxial compression are studied using a metadynamics algorithm for molecular simulation at experimental strain rates. The onset of yielding is observed at the first major stress drop, accompanied, upon analysis, by the formation of a single localized shear band region spanning the entire system. During the elastic response prior to yielding, low concentrations of shear transformation deformation events appear intermittently and spatially uncorrelated. During serrated flow following yielding, small stress drops occur interspersed between large drops. The simulation results point to a threshold value of stress dissipation as a characteristic feature separating major and minor avalanches consistent with mean-field modeling analysis and mechanical testing experiments. We further interpret this behavior to be a consequence of a nonlinear interplay of two prevailing mechanisms of amorphous plasticity, thermally activated atomic diffusion and stress-induced shear transformations, originally proposed by Spaepen and Argon, respectively. Probing the atomistic processes at widely separate strain rates gives insight to different modes of shear band formation: percolation of shear transformations versus crack-like propagation. Additionally a focus on strain-rate dependence as a function of a crossover avalanche size has implications for nanomechanical modeling of spatially and temporally heterogeneous dynamics.

Keywords: Strain-rate effects, Metallic glasses, Slip avalanches, Serrated flow, Shear band

1. Introduction

Although the plastic response of amorphous solids such as metallic glasses has been under study for some time [1, 2, 3], quantitative details of the elementary deformation processes at

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