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Shear bands operation in metallic glasses

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Abstract – Scanning electron microscopy observations of shear steps on Zr-based bulk metallic glasses after compression showed direct evidence of shear band melting due to heat generated by elastic energy release. Calculations indicated that a 0.2 μm layer melts in the vicinity of a shear band forming a 1 μm shear step. The morphology of shear steps depends on various factors including composition of metallic glasses and samples' size. Shear steps morphology differs for metallic glasses with different glass transition and melting temperatures implying that these properties affect the viscosity drop induced by the temperature rise in the shear bands.

Metallic glasses (MGs) exhibit high strength, fracture toughness and high elastic limit at ambient temperature, as well as good formability through viscous flow in the supercooled liquid state [1]. However, their limited ductility, especially in tension, serves as a major impediment to wider application of metallic glasses. This behavior is related to work-softening and inhomogeneous flow localized in shear bands [2]. One important aspect of the deformation mechanism in metallic glasses is the temperature rise in the shear bands, which may be related to shear softening [3]. A long debate has been raised, with estimates of the local temperature rise ranging from less than 0.1 K to a few thousand Kelvin [4].

Using high resolution scanning electron microscopy (HRSEM) observations of shear steps on Zr-based bulk metallic glasses (BMG), we have recently reported clear and direct evidence of melting due to elastic energy release in the form of heat in the shear zones [5]. Shear steps were found at several instances to have been formed in successive increments with evident wear and tear on a thickness scale larger than the expected thickness of the shear band itself. The estimated range of attained temperatures and the observed morphologies are consistent with shear steps forming at a subsonic speed limited by a required redistribution of local microscopic stresses. Calculations indicated that a 0.2 μm layer melts in the vicinity of a shear band forming a 1 μm shear step.

Examining a large number of shear steps of several metallic glasses we observed a strong dependence of various factors on the morphology of the shear steps, including the composition of metallic glasses and samples' size. Shear steps morphology differs for metallic glasses with different glass transition and melting temperatures implying that these properties affect the viscosity drop induced by the temperature rise in the shear bands.

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