**Zr61Ti2Cu25Al12 bulk metallic glass: Failure under torsional loading and Mode III fracture toughness**

***Jian Xu* ∗,**Zhen-Qiang Songς, Evan Ma+

∗ Institute of Metal Research, Chinese Academy of Sciences, Shenyang, 110016, China.

Email: jianxu@imr.ac.cn

ς Institute of Metal Research, Chinese Academy of Sciences, Shenyang, 110016, China.

Email: zqsong10s@imr.ac.cn

+ Department of Materials Science and Engineering, The Johns Hopkins University, Baltimore, Maryland 21218, USA.

Email: ema@jhu.edu

From torsional tests of cylindrical samples, we have determined the torsional properties of high-toughness Zr61Ti2Cu25Al12 (ZT1) bulk metallic glass (BMG), including its shear yield strength, *τ*y=950 MPa, its shear elastic strain limits, *γ*C=3.0%, and its shear modulus, *G*=31.5 GPa. Under torsional loading, the BMG fails via a major shear band, without obvious macroscopic plasticity on the specimen surface. The shear band maintained stable propagation by a distance of ~300 μm (~20% of cylinder radius) before final catastrophic failure, owing to the constraint of stress gradient along the radial direction. The intrinsic mode III fracture initiation toughness is measured for the Zr61Ti2Cu25Al12 BMG, which is known to have a high mode I fracture toughness (*K*IC). The plastic strain intensity factor *Γ*III was used as a measure of the fracture resistance under elastic-plastic conditions. The intrinsic mode III fracture initiation toughness of ZT1 BMG, *Γ*IIIC, is found to be 29 μm, equivalent to a *K*IIIC of 51 MPa√m. The corresponding fracture energy release rate is similar to or higher than that of conventional engineering metals such as high-strength aluminum alloys and some steels. The subcritical crack growth in ZT1 prior to catastrophic fracture is characterized by an extension of a microscopically zig-zag crack front. ZT1 exhibits a relatively low ratio of *K*IIIC/*K*IC of ~0.39, indicating that the material is more susceptible to mode III fracture. In engineering design with BMGs, the mode III fracture toughness is thus a useful baseline to ensure the reliability of structural components.

*Keywords: Bulk metallic glass, Fracture toughness, Torsion, Shear band, Zirconium*