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Controlled Shock Loading Conditions for Microstructural Correlation of Dynamic Damage Behavior[1]

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Materials performance is recognized as being central to many emergent technologies. Future technologies will place increasing demands on materials performance with respect to extremes in stress, strain, temperature, and pressure. In this study, the dynamic ductile damage evolution of OFHC Cu is explored as a test bed to understand the role of spatial effects due to loading profile and defect density. Well characterized OFHC Cu samples of 30 μm, 60 μm, 100 μm, and 200 μm grain sizes were subjected to plate impact uniaxial strain loading at 1.5 GPa. This spall geometry produced early stage (insipient) damage in the Cu samples that could be correlated to microstructural features in metallographic analysis. The recovered damaged microstructure was examined using traditional 2D metallographic techniques (optical and electron microscopy) as well as 3D x-ray microtomography. Calculated spall strength from the free surface velocimetry (VISAR) showed no change with respect to changes in grain size, however, the magnitude of the peak after the first pull-back as well as rate of re-acceleration are dependent on grain size and can be correlated to damage observed in the recovered samples. These results reveal a critical length scale for the transition from a nucleation dominated regime to a growth dominated regime for the damage evolution process. The results show that for samples with small (30 μm) and large (200 μm) grain sizes the growth of voids is dominated by coalescence, whereas for medium (60 μm and 100 μm) grain sizes the growth is restricted to a much slower process of individual void growth. Electron backscatter diffraction reveals that voids preferentially nucleate at grain boundaries with high misorientation angles while special boundaries (low angle $\sum 1$ and high angle $\sum 3$) proved to be resistant to void nucleation. Based on these findings, mechanisms for the void nucleation/growth and coalescence are proposed.

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