Proceedings of the Canadian Society for Mechanical Engineering International Congress
32nd Annual Conference of the Computational Fluid Dynamics Society of Canada
Canadian Society of Rheology Symposium
CSME-CFDSC-CSR 2025
May 25–28, 2025, Montréal, Québec, Canada

Mechanisms of nanoscale deformation in bulk metallic glasses investigated using pillar compression

Udo Schwarz
Mechanical Engineering Department, Yale University, New Haven, United States of America
*udo.schwarz@yale.edu

ABSTRACT

Metallic glasses accommodate most of their macroscopic plastic deformation through the activation of shear bands. These shear bands, however, first need to form before they can get activated, and the mechanisms of how this happens are still researched. To help fill this gap, we systematically investigated the deformation behavior of Pt57.5Cu14.7Ni5.3P22.5 metallic glass under micro-/nanopillar compression, where pillars were prepared using a novel method based on thermoplastic forming. This manufacturing method not only produces better-defined pillar geometries with lesser structural flaws that previous methods yielded, but it also enables the fabrication of a large number of identical pillars. At higher strain rates, local yielding happens in the areas featuring the biggest flaws due to a lack of time to properly accommodate the external pressure, which causes the distribution of yield loads to become more scattered. Interestingly, fracture stress exhibited a different pattern, showing no significant strain rate sensitivity. Additionally, annealed pillars displayed more closely clustered fracture loads, consistent with the understanding that annealing-induced structural relaxation enhances atomic packing, reduces defects, and increases resistance to compression. Overall, the findings suggest a three-phase deformation mechanism, where the pillars first deform elastically until plastic deformation starts in less dense areas of the pillar. This plastic deformation evolves in a combination of smooth, continuous flow alternating with abrupt, larger-scale atomic reordering, where the abrupt reordering processes continuously increase in size. Finally, shear bands form that cover the entire width of the pillar, which ultimately leads to its collapse.