QUANTIFYING THE COMMONALITIES IN STRUCTURE AND PLASTIC DEFORMATION IN DISORDERED MATERIALS

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The nonequilibrium nature of kinetically frozen solids such as metallic glasses (MGs) is at once responsible for their unusual properties, complex and cooperative deformation mechanisms, and their ability to explore various metastable states in the rugged potential energy landscape. These features coupled with the presence of a glass transition temperature, above which the solid flows like a supercooled liquid, open the door to thermoplastic forming operations at low thermal budget as well as thermomechanical treatments that can either age (structurally relax) or rejuvenate the glass. Thus, glasses can exist in various structural states depending on their synthesis method and thermomechanical history. Nanocrystalline (NC) metals, also considered to be far-from-equilibrium materials owing to the large fraction of atoms residing near grain boundaries (GBs), share many commonalities with MGs both in terms of plastic deformation and its dependence on processing history. Despite these similarities, the disorder intrinsic to both classes of materials has precluded the development of structure-property relationships that can capture the multiplicity of energetic states that glasses and GBs may possess.

Here, we report on experimental studies of MG and NC materials and novel synthesis and processing routes for controlling the structural state – and as a consequence, the mechanical properties. A particular focus will be on strategies for rejuvenation of disorder with the goal of suppressing shear localization and endowing damage tolerance. We also describe a microscopic structural quantity designed by machine learning to be maximally predictive of plastic rearrangements and further demonstrate a causal link between this measure and both the size of rearrangements and the macroscopic yield strain. We find remarkable commonality in all of these quantities in disordered materials with vastly different inter-particle interactions and spanning a large range of elastic modulus and particle size.