New quantitative assessment imaging technique for dislocation accumulations in materials

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What is the outcome or accomplishment? (1-2 short sentences describing it and why it is transformative; 50-word maximum suggested)*

While dislocation imaging with transmission electron microscopy has been performed for over 50 years, quantitative assessment over large areas remains difficult. LSU researchers applied a new orientation imaging microscopy methodology to assess dislocation density in a quantitative and statistically significant manner over much larger areas in severely plastically deformed materials.

What is the impact? (1-2 simple sentences describing the benefits for science, industry, society, the economy, national security, *etc.*; suggested 50-word maximum)

Severely plastically deformed materials exhibit mechanical responses that deviate from conventional plasticity and fracture behavior. The LSU team performed orientation imaging microscopy and obtained a quantitative and statistically significant assessment of dislocation accumulation within such materials. This assessment methodology provided an understanding of observed mechanical anomalies and has broad applications.

What explanation/background does the lay reader need to understand the significance of this outcome? (1-2 paragraphs that might include, for example, more on who, when, where; NSF's role; support from multiple directorates/offices; what makes this accomplishment unique; additional intellectual merits; or broader impacts such as education, outreach, or infrastructure improvement that are integral to this outcome; suggested 150-word maximum)

Severe plastic deformation (SPD) of metals and alloys leads to rapid microstructural modifications, including grain size refinement and dislocation accumulation. In particular, quantification of dislocation density and dislocation structure over large specimen areas in a statistically significant manner has remained difficult, despite over 50 years of dislocation imaging with transmission electron microscopy. Electron backscatter diffraction (EBSD) has increasingly been used to assess density of geometrically necessary dislocations (GNDs), but rarely applied to SPD materials. The LSU team obtained EBSD datasets on material slices site-selectively extracted from SPD Cu, and devised a new analysis methodology to quantitatively assess GND density. Using this new methodology, it is shown that GND accumulation within Cu deformed under different geometries depends on its grain size. This result provides a structure-based rationale for experimentally observed mechanical anomalies during deformation. The new methodology can be applied to a broad range of SPD materials, including friction-stir-based 3D printing.

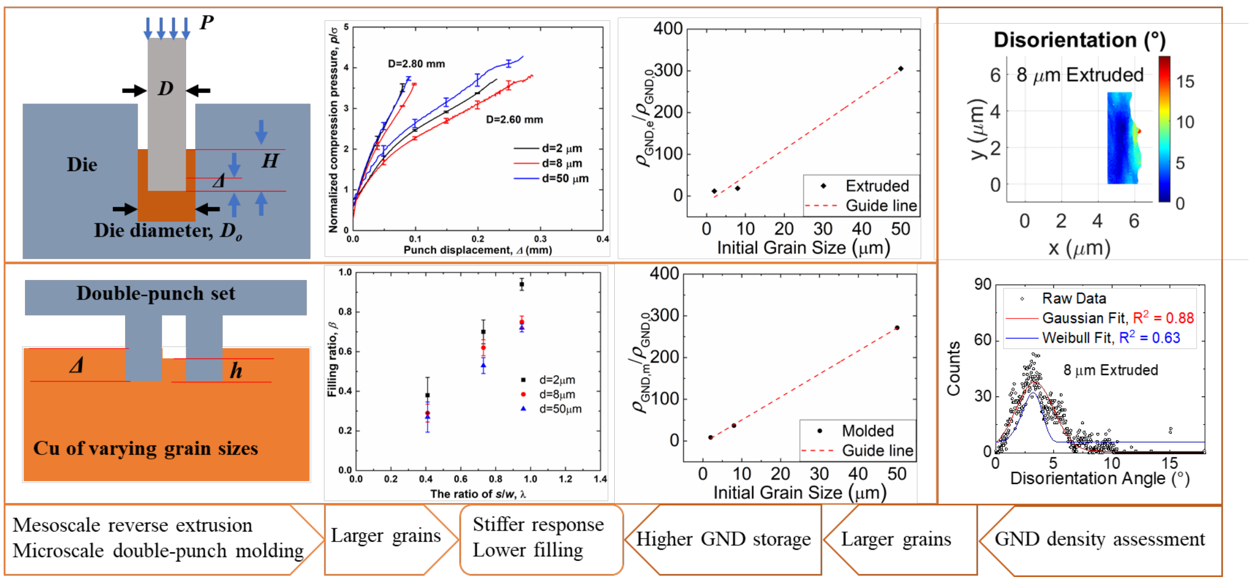

Illustration: A new methodology for applying electron backscatter diffraction (EBSD) based orientation imaging microscopy (OIM) to severe plastic deformation (SPD) of materials: (upper left panel from left to right) a mesoscale axisymmetric reverse extrusion setup, showing higher normalized extrusion pressure for Cu with larger grain size while its bulk flow stress is lower, the stored GND density within the deformed Cu is, however, higher at the larger grain size; (lower left panel from left to right) a microscale double-punch molding setup, showing lower punch gap filling ratio for Cu with larger grain size while its bulk flow stress is lower, the stored GND density within the deformed Cu is, however, higher at the larger grain size; (right panel) manually segmented disorientation angle map constructed from one EBSD dataset and the associated disorientation angle distribution together with a fitting methodology to obtain a quantitative assessment of GND density; (bottom) logical flow for how GND storage with SPD Cu provides a structure-based rationale for understanding experimentally observed mechanical anomalies.