Supplying Key Experimental Data to Calibrate Micron Scale Plasticity Theories

B. Zhang, W.J. Meng, Louisiana State University

Award Title:	RII Track -1: Louisiana Materials Design Alliance (LAMDA)
NSF Award Number:	NSF OIA-1946231
Principal Investigator:	Michael Khonsari
Lead Institution Name:	Louisiana State University
Award Start Date:	August 1, 2020
Award End Date:	July 31, 2025
Highlight Submission Date:	February 28, 2024

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

We developed a new mechanical testing protocol to quantify torsional response of materials down to the micron scale and generated the first dataset of single crystal torsional response down to a characteristics size of two microns.

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

Developing sound plasticity theories governing material deformation at the micron length scales would offer foundational support to micro manufacturing technologies and is of fundamental significance. Reliable and accurate measurement of micron scale torsional response offers key data to differentiate different theories and is critical to theory development.

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)

Researchers at LSU, in collaboration with leading scientists in the field from the Technical University of Denmark and Harvard University, have developed a new testing protocol for accurately measuring materials' torsional response down to the micron length scale for the first time. Using this protocol, they obtained the first set of torsional response data on single crystal specimens as small as two microns in characteristic size. In addition, this test protocol allows the effect of surface passivation on deformation response to be probed quantitatively.

In addition to experimental testing, an accompanying finite element analysis of the experimental configuration was conducted by implementing a state-of-the-art micron plasticity theory. The combined experimentation-simulation study serves to illustrate the predictive power of present micron plasticity theories as well as highlight the need for further theoretical development so that *micron plasticity theory can function as well as conventional plasticity theory at the macroscopic scale. This work has been published in the Proceedings of the National Academy of Sciences in 2023.*

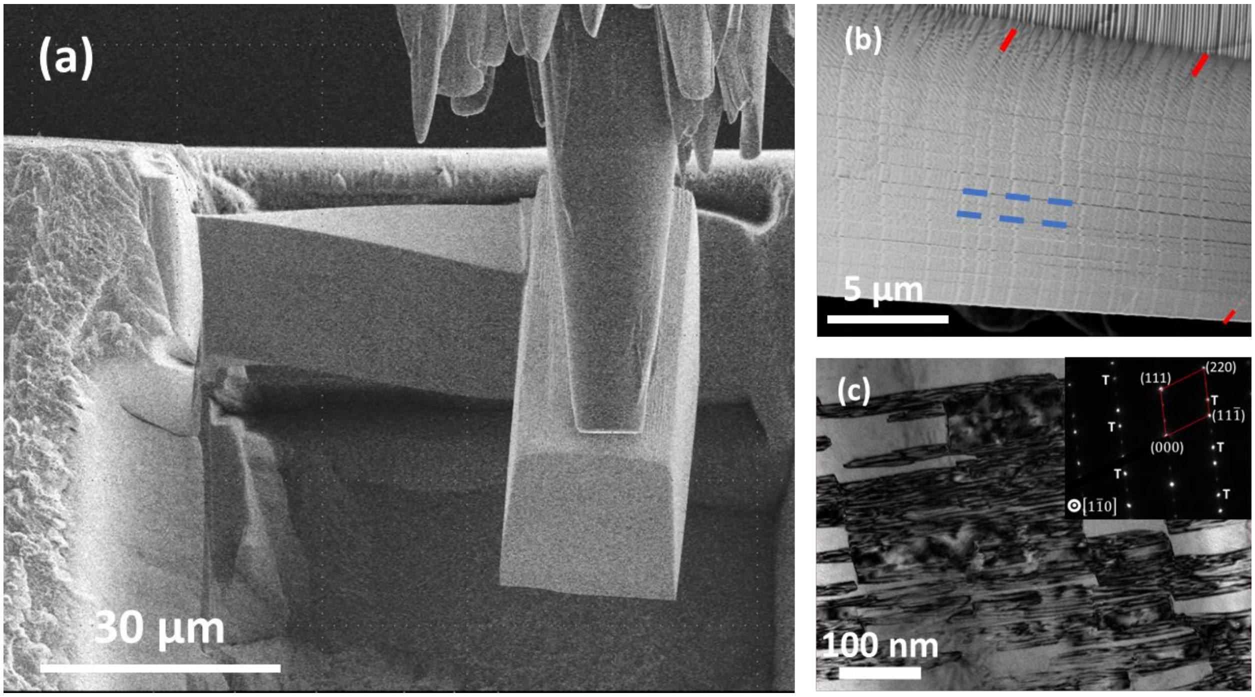

Fig. 1. The "L-beam" torsion/bending test: (a) one frame of a video file showing compression loading in-situ a scanning electron microscope of a single crystal Cu L-beam specimen, generating a predominant torsional response with secondary bending; (b) front surface view of one L-beam after torsional loading. Short dashed lines highlight surface slip steps due to dislocation activities on distinct groups of Cu slip planes; (c) a longitudinal cross-section TEM bright field image showing internal twinning caused by torsional deformation of the Cu L-beam specimen. The inset shows a selected area diffraction pattern from the twinned region.