Universal and Non-universal Aspects of Plasticity in Microcrystals

Even though it was recognized almost 100 years ago that plasticity is discrete in both space and time, deformation models were/are primarily based on homogenizing flow. Driven by novel experimental techniques, intermittent plasticity has received renewed interest because it seems to have a lot in common with entirely different physical processes, such as magnetic domain switching or earthquakes. At the bulk scale, the signature of intermittent flow is generally not seen in stress-strain data, but it is directly visible as strain-discontinuities in flow curves of small-scale crystals. Statistical investigations of intermittent deformation reveal that they indicate scale-invariance, which is a paradigm shift away from traditional concepts that homogenize plastic flow and rely on well-defined average quantities. Many investigations have shown scale-free distributions of slip-size magnitudes that all seem to have the same power-law exponent and therefore allow to place plasticity into a general universality class with many other intermittently evolving systems. In this talk we will present recent observations made during mechanical characterization that trace plastic instabilities in small-scale crystals in real time, allowing to assess the underlying collective dislocation dynamics, that is dislocation avalanches. We will discuss results from fcc and bcc single crystals, and in particular focus on slip-size magnitude distributions, their involved time scales, slip-velocity distributions, and avalanche shapes. Assessing the avalanche velocity-relaxation reveals unexpected differences between lattice types, giving first insights into non-universal aspects of plasticity. The experimental results are combined with dislocation dynamics simulations, and compared to predictions from statistical physics. We further discuss the appearance and disappearance of discrete plastic behavior at the small scale, and what implications this may have for macroscopic bulk plasticity.

Bio: Robert Maass received a triple diploma in Materials Science and Engineering from the Institut National Polytechnique de Lorraine (INPL-EEIGM, France), Luleå Technical University (Sweden) and Saarland University (Germany) in 2005. In 2009, he obtained his PhD from the Materials Science Department at the École Polytechnique Fédérale de Lausanne (EPFL) in Switzerland. During his doctoral work, Robert designed and built an in-situ micro-compression set-up that he used to study small-scale plasticity with time-resolved Laue diffraction at the Swiss Light Source. From 2009-2011 he worked as a postdoctoral researcher at the Swiss Federal Institute of Technology (ETH Zurich) on plasticity of metallic glasses. Subsequently, he joined the California Institute of Technology as an Alexander von Humboldt postdoctoral scholar to continue his research on plasticity of metals. He joined the faculty of the University of Illinois at Urbana-Champaign as Assistant Professor of Materials Science and Engineering in 2015.