University of Crete
Department of Physics

Physics Colloquium

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Topology of dislocation ensembles and the understanding of work hardening in metals

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ABSTRACT

The phenomenon of "work hardening" has been labeled as one of the great remaining problems of classical physics, due mainly to the fact that the intrinsic deformation defects, dislocations, like behaving as twigs and form "bird's nests" inside crystals. If the sample volume is small and such a nest cannot even fit inside it, then the crystal starts behaving abnormally by displaying larger strength and abrupt avalanche dynamics. These "size effects" have been a subject of intense research for almost two decades. Nevertheless, the understanding of these effects has remained elusive, as much these dislocation "nests" or "forests" are elusively defined. I will present a novel topological observable, labeled as Λ, that can help "see" a bird's nest made of dislocation twigs. The mathematical structure of Λ has a long history in the characterization of helicity in gauge theories and fluids, with a large variety of applications in other fields of science. By introducing and using Λ, I will explain how to understand size effects in terms of this novel topological viewpoint. I will present validation studies of arbitrarily complex initial dislocation microstructures in pillars of multiple sizes, using three-dimensional discrete dislocation dynamics simulations for finite volumes. Finally, I will demonstrate how to engineer nanoscale dislocation ensembles that are independent from sample dimensions, either by biased-random dislocation loop deposition or by sequential mechanical loads of compression and torsion.