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Strong and tough lightweight composites: from a microstructure- to an architecture-based materials' design

In most of structural applications, materials that can attain high strength, stiffness and toughness with minimum weight are often sought. The design of materials that fulfill these requirements is usually achieved through different strategies: one can manipulate the chemistry, vary the microstructure and/or potentially think of tailoring the architecture of multiphase materials to create composites with enhanced mechanical properties. Here, I address both microstructure and architecture as effective pathways towards designing materials with high engineering potential. In my talk, I first show how adding high concentration (i.e. 56-62) of unbounded ceramic particles to a metal can produce a composite material that is both strong and tough. An interesting, yet so far unexplored, aspect of the deformation of such a composite is that it combines features of conventional dense two-phase materials with those of the granular matter that it contains, namely the close-packed bed of touching ceramic particles. Specifically, I present experimental measurements that quantify the effect of a 200 MPa fluid pressure on the compressive deformation of Al2O3-Al composites under either triaxial or pure hydrostatic stress states, together with a simple, yet faithful, analysis that transposes to the metal matrix composite the theory of fluid-saturated granular media mechanics and explains data quantitatively.

In the last part of the talk, I present my current work on hierarchical-instabilities, where architecture enables design of soft structures with tunable surface patterning, and use this to give an outlook on how architecture can be further exploited to design damage-tolerant cellular materials.