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Keramische Werkstoffe und Bauteile
Prof. Dr.-Ing. Kurosch Rezwan
Fachbereich 4 - Produktionstechnik

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DFG GRK 1860
Optimal design of micro-architected materials

Professor Lorenzo Valdevit

Associate Professor, Mechanical and Aerospace Engineering
Associate Professor (Joint Appointment), Chemical Engineering and Materials Science

University of California, Irvine
Mechanical and Aerospace Engineering Department

ABSTRACT

Recent progress in additive manufacturing enables fabrication of macro-scale cellular materials (both single-phase and hybrid) with unprecedented dimensional control on the unit-cell and sub-unit-cell features, thus yielding topologically architected materials with structural hierarchy spanning six orders of magnitude in length scale (from tens or hundreds of nanometers to tens or hundreds of centimeters). As mechanical properties of materials often exhibit beneficial size effects at the nanoscale (e.g., strengthening of metals and toughening of ceramics), these novel manufacturing approaches provide a unique opportunity to translate these beneficial effects to a macro-scale structural or multifunctional material. The enormous design space for micro-architected materials, and the strong relationship between the topological features of the micro-architecture and the effective physical and mechanical properties of the material at the macro-scale, present both a huge opportunity and an urgent need for the development of suitable optimal design strategies. This presentation will focus on the optimal design of lightweight micro-architected materials with unique combinations of stiffness, strength and damping. Different optimal design strategies will be discussed, from geometric optimization of cellular materials with predetermined unit-cell architecture to formal topology optimization of single and double-phase cellular materials with entirely arbitrary architectures.