Multifunctional Lightweight Materials: An overview from KU's Directed Project

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Abstract

In this talk, I will provide an overview on the works conducted under KU's RIC-2D DP4, *Multi-functional Lightweight Materials*. Specifically, I will be focusing on the following topics: application of 2D material-coated lattices, mechanical behavior of multi-phased nanomaterial reinforced interpenetrating composites, and bio-inspired cellular ceramic with 2D materials.

For applications of 2D coated lattices, we have created a functionally driven, variable-cell size, and 2D material coated Triply Periodic Minimum Surface (TPMS) structure (Fig. 1) to realize stepwise longitudinal gradient impedance for electromagnetic interference (EMI) shielding. Absorption-dominant EMI shielding was achieved by coupling the intrinsic properties of $Ti_3C_2T_x$ MXene coating with the benefits of robust macrostructural graded TPMS structure.

We have studied Interpenetrating phase composites (IPCs) rooting on TPMS architectures (Fig.2). Here IPCs incorporating gyroid-structured TPMS lattices, and a 2D-material-reinforced polymer matrix were fabricated via additive manufacturing, followed by an interpenetration process. The fracture behavior of these ICPs were studied in detail, experimentally and numerically using finite element, revealing that 2D material reinforced-IPCs exhibited markedly superior fracture resistance compared to lattice/polymer IPCs.

We have studied cellular ceramics inspired by the *stereom* structure of the sea urchin (*Echinus esculentus*), featuring a core-shell architecture with a ceramic core and polymer coating (Fig.3). The disordered cellular preceramic polymer was additively manufactured and then subjected to high-temperature pyrolysis to form a robust ceramic framework. The mechanical performance was enhanced by coating the ceramic architecture with a thin layer of epoxy resin, thereby creating a core-shell structure. The epoxy-coated ceramic exhibits over three orders of magnitude improvement in specific energy absorption owing to the controlled progressive failure enabled by the epoxy-ceramic interface, which acts as both a crack arrestor and a structural binder.

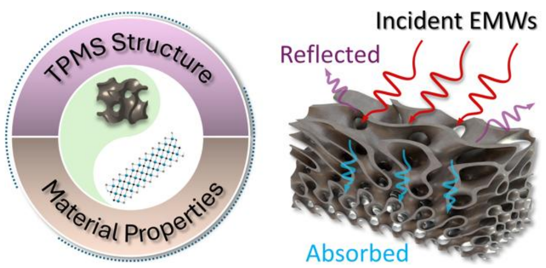

Fig. 1 - graded TPMS structure for EMI shielding.

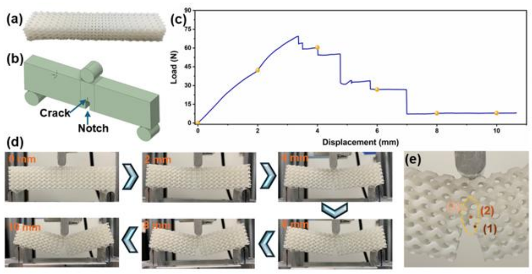

Fig. 2 – fracture of IPC under three-point bend.

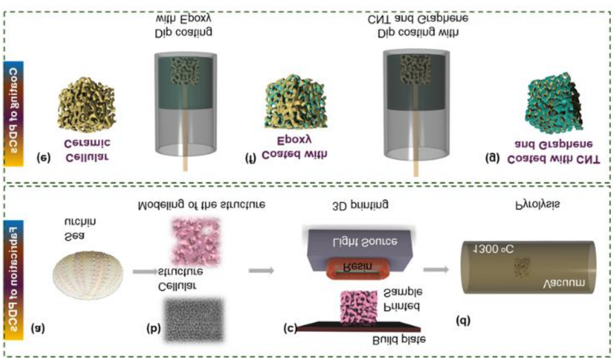

Fig. 3 – fabrication of sea urchin inspired ceramic composite