New Opportunities in Additive Manufacturing of Hybrid Materials

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Nearly every aspect of our society is being revolutionized by emerging additive manufacturing (AM) technologies. AM effectively decouples geometric complexity from time and cost by relaxing design constraints that have existed since man first started making tools. AM technologies build parts from the ground up by depositing or fusing material only where it is needed to form the desired part in a layer-by-layer, additive fashion. Building components from the ground up in this way offers vast new potential to design and incorporate functional architecture into new hybrid materials and structures by enabling the deposition of multiple constituent materials with disparate properties and functions in precise arrangements that have not previously been possible. Hybrid materials, in this context, comprise combinations of two or more materials combined in a prescribed morphology and topology to achieve properties not offered by either constituent alone. Fiber composites, foams, and lattice materials are examples of common hybrid engineering materials that we encounter regularly, but the natural world is full of a staggering variety of multifunctional hybrid materials that have evolved over millennia to efficiently meet the survival needs of specific organisms with minimal energy expenditure. Examples include wood and bone, which provide both structural robustness and efficient fluid transport through graded cellular architecture and hierarchical organization of stiff and compliant domains; as well as nacre, which employs hierarchical, staggered, discrete domains of calcium carbonate embedded in compliant biopolymer to achieve unprecedented combinations of stiffness, strength, and toughness. Until recently, our ability to characterize and model such natural hybrid materials has far outpaced our ability to fabricate synthetic analogues using engineering materials. New materials and processes in additive manufacturing are changing that paradigm and bringing true “materials by design” within reach.

This talk will begin with an overview and historical context of additive manufacturing technologies and a motivation for hybrid materials across several application spaces. The state of the art and current challenges will be briefly discussed in AM of biological, functional, and structural materials with examples from leaders in the field. The remainder of the talk will explore the development of lightweight, fiber-reinforced polymer composite feedstocks for AM of hierarchical structural hybrids with controlled fiber orientation. The talk will conclude with a summary of open questions in AM of hybrid materials as well as an outlook on what exciting new developments may be expected in the next several years.