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Faster, Energy-Efficient Manufacturing of Thermoset Composites Based on Frontal Polymerization

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ABSTRACT:

Current manufacturing techniques of thermoset-matrix fiber-reinforced composites rely primarily on the bulk polymerization of the resin. In addition to the substantial capital investments associated with the need for autoclaves, ovens, or heated molds, the long and complex heat and pressure cycles involved in the thermal curing process result in a time-consuming and energy-intensive manufacturing process. Frontal Polymerization (FP) has been recently proposed by the Autonomous Materials Systems research group at the University of Illinois (Robertson et al., Nature, 2018) as an alternative approach to reduce the large capital investments and make the process substantially (orders of magnitude) faster and more energy efficient. FP is a process in which a localized reaction zone, driven by the heat generated through an exothermic reaction, propagates through the monomer by converting it into the polymer. Due to its self-sustaining nature, FP eliminates the need for autoclaves and other external sources of heat during polymerization and greatly speeds up the manufacturing process.

In this talk, I will discuss recent results obtained in the experimental and computational investigation of FP-based manufacturing of composites made of carbon or glass fibers embedded in a dicyclopentadiene (DCPD) matrix. In particular, I will present a homogenized reaction-diffusion model introduced to capture the effects of the material and process parameters on the overall performance of the FP-based manufacturing process, including how the properties and volume fraction of the reinforcing fibers impact the speed, temperature and intrinsic length scales of the polymerization front. I will also summarize recent advances in the development of a FP-based 3D printing process for composites, and discuss current efforts in achieving FP-driven morphogenesis.

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BIOGRAPHY:

Originally from Belgium, Philippe Geubelle got his B.Sc. in mechanical engineering at the Catholic University of Louvain in 1988, and his M.S. and Ph.D. in aeronautics at Caltech in 1989 and 1993, respectively. After a year as Postdoctoral Research Associate at Harvard, he joined the University of Illinois at Urbana-Champaign in January 1995, where he is currently Bliss Professor in the Department of Aerospace Engineering, with joint appointments in Mechanical Science and Engineering and at the Beckman Institute of Advanced Science and Technology. He served as the Head of the AE Department from 2011 to 2018, and was appointed as the Executive Associate Dean of the Grainger College of Engineering in January 2019.

His research interests pertain to the theoretical and numerical treatment of complex problems in solid mechanics and materials, and, in particular, the multiscale analysis and design of materials, dynamic fracture mechanics, biomimetic multifunctional materials, composite manufacturing, and thin films for MEMS and microelectronics applications.