



Beyond Periodicity: Bioinspired Composites with Controllable Mechanical Behavior

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Abstract: Non-periodic architectures are widespread in biological structural materials, from the irregular foam-like pericarp of citrus fruits to the trabecular network of bone. Shaped by evolution, these structures provide remarkable mechanical performance, including impact absorption, stress redistribution, and damage tolerance. Reproducing these functional advantages in synthetic materials requires both new design tools and a fundamental understanding of how irregularity governs the mechanical and fracture response. In my talk, I will present a new class of two-phase materials, inspired by non-periodic biological materials, that display controllable mechanical [1], fracture [2,3], impact [4], and load-bearing behavior [5], and prove to be a fascinating platform to generate structural materials with tailorable properties.

The composites are designed using algorithms of virtual growth, which assemble simplified building blocks according to connectivity rules on square and/or hexagonal grids, enabling independent control over the topology and geometry of the reinforcing architecture (*Figure 1a*) [1,6]. The generated designs are manufactured using multi-material additive manufacturing, with a rigid polymer for the reinforcing network and a soft elastomer for the matrix phase, and characterized under quasistatic and dynamic testing conditions [1-5] (*Figure 1b*). I will first show how tuning the coordination number controls global mechanical properties like stiffness and strength, while modifying connectivity rules tailors local mechanisms of fracture nucleation and energy dissipation. Irregular composites display a remarkably different fracture response than their periodic equivalents, raising fundamental questions about how network architecture governs damage tolerance and energy dissipation. I will explore these questions across multiple loading conditions — from quasistatic fracture to dynamic impact — and show how the same design framework can be used to translate the non-periodic structure of biological materials into synthetic composites with equivalent functional performance.

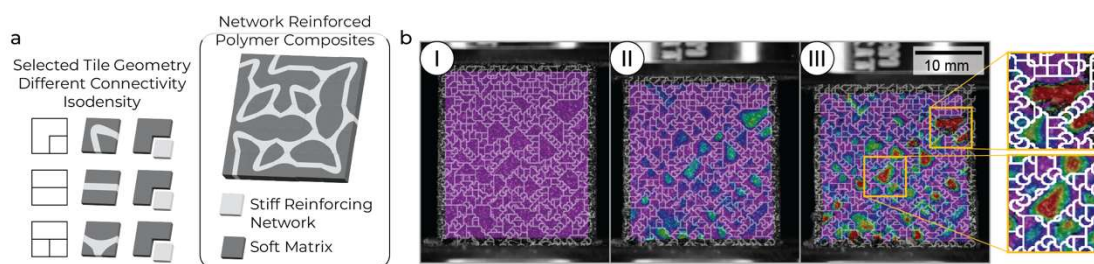


Fig. 1: a) Design of the composites through a virtual growth algorithm. Selected iso-density tile geometries and composite assembly. Adapted from Ref [1]. b) Optical photographs and resulting Digital Image Correlation (DIC) map highlighting the compressive loading in a representative architected polymer

composite. The squares indicate locations within the specimen that display signs of strain localization. Adapted from Ref [3].

Bio: Since 2024, Tommaso Magrini is Assistant Professor in the Department of Mechanical Engineering at the Eindhoven University of Technology (TU/e), where he leads a team that focuses on the multiscale design, fabrication and characterization of architected materials and composites. Before joining TUe, awarded with the Swiss National Science Foundation (SNSF) Postdoc Mobility Fellowship, Magrini conducted his PostDoc in the Department of Mechanical Engineering at the California Institute of Technology (Caltech), in the team of Prof. C. Daraio. Before Caltech, Magrini conducted his PhD in Materials Science at ETH Zurich (ETHZ), with the thesis: ‘Tough and Transparent Nacre-like Functional Composites’, in the group of Prof. A. Studart. During his PhD, he was awarded the Silver Graduate Student Award by the Materials Research Society (MRS), for excellence and distinction during the doctoral studies.

References

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