Capacity Area A3 Topic 3.1 Deliverable 2 / Milestone 3

Report on heterogeneous architecture of bio-inspired composites

Engineering applications demonstration milestone

Heterogeneous architecture of bio-inspired materials: We have successfully developed a layer-by-layer additive manufacturing technique that allowed us to create heterogeneous material architectures that best respond to the local strains imposed by specific mechanical loading conditions. This has been accomplished by fabricating laminated plates of which print architecture follows the stress lines that develop around structural defects during mechanical loading. By processing a liquid-crystalline polymer using a fused-deposition modelling (FDM) printer, we showed that the intrinsic mechanical properties of the printed filament can be significantly increased through alignment of the polymer chains along the printing direction. Heterogeneous laminated architectures with printed filaments along stress lines leads to a remarkable 10-fold increase in strength as compared to isotropic plates. In addition to the remarkable increase in strength, the heterogeneous architectures of such laminates prevents catastrophic failure by promoting crack-arresting mechanisms within the material along the interface of the printed filaments and leads to an increase of 30-55-fold in toughness as compared to their isotropic counterparts. In addition to a remarkable mechanical performance, the architecture laminates develop in this project exhibit added value of recyclability, automated manufacturing and lower carbon footprint.

Engineering application demonstration: The shaping capabilities of additive manufacturing allows the fabrication of parts with complex geometries and application-specific architectures that exhibit a significant potential for reducing the weight of structural parts in transportation systems. In contrast to conventional fused-deposition modelling (FDM) printed laminates, the anisotropic filament architectures implemented in these heterogeneous parts can be specifically designed to maximize their mechanical response in challenging loading conditions. Using this approach, we have fabricated liquid-crystalline printed parts exhibiting twisted plywood arrangement architectures to increase impact resistance and biomedical implants prototypes with enhanced loading bearing that are achieved through programmed arrangement of printed filaments along the direction of stress lines developed around structural holes (please refer to the publication for images of these demonstrators). This approach opens up possibilities to fabricate high performance and lightweight parts to replace metallic and denser parts in the automotive industry while ensuring a sustainable life cycle of the material.