

## THERMAL AND MECHANICAL RESPONSE OF THREE-DIMENSIONAL MICROVASCULAR COMPOSITES

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### ABSTRACT

Microvascular networks for the transport of functional fluids are widely observed in biological systems (e.g. leaf venation and blood vasculature) that enable a wide variety of functions including temperature regulation, waste removal, and delivery of nutrients for growth and healing. One of the key challenges for creating synthetic microvascular systems lies in the replication of complex 3D networks at the structural scale. Fabrications of synthetic microvascular networks have been reported using several methods [1, 2] such as, embedding hollow glass/carbon fibers, direct write assembly using fugitive inks, and laser micromachining. However, none of the reported techniques provides the capability to create complex three-dimensional microvasculatures in large-scale structural composites using current commercial manufacturing techniques. Here we report a novel approach to introduce bio-inspired three-dimensional microvascular networks in structural composites that satisfies these requirements.

The method relies on the thermal depolymerization and vaporization of sacrificial fibers of polylactide (PLA) that are chemically treated via catalyst impregnation to optimize degradation conditions. We report the results of single fiber mechanical testing of treated commercial and laboratory solution-spun fibers to assess the effect of chemical treatment on mechanical integrity of fibers. Sacrificial fibers are then woven with structural reinforcement fibers (glass fibers) in 3D architectures and composites are manufactured using the vacuum assisted resin transfer molding process. Fabrication of hollow microvascular channels, as shown in Figure 1, is achieved through thermally triggered de-polymerization of the sacrificial fibers and *in vacuo* removal of the resulting monomer in vapor form [3].

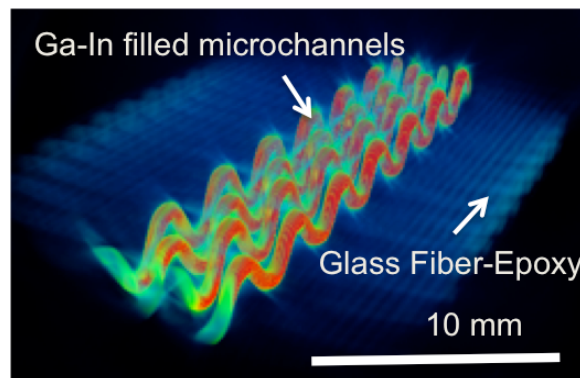


Figure 1: MicroCT image of glass/epoxy composite embedded with Ga-In filled 3D microvascular network.

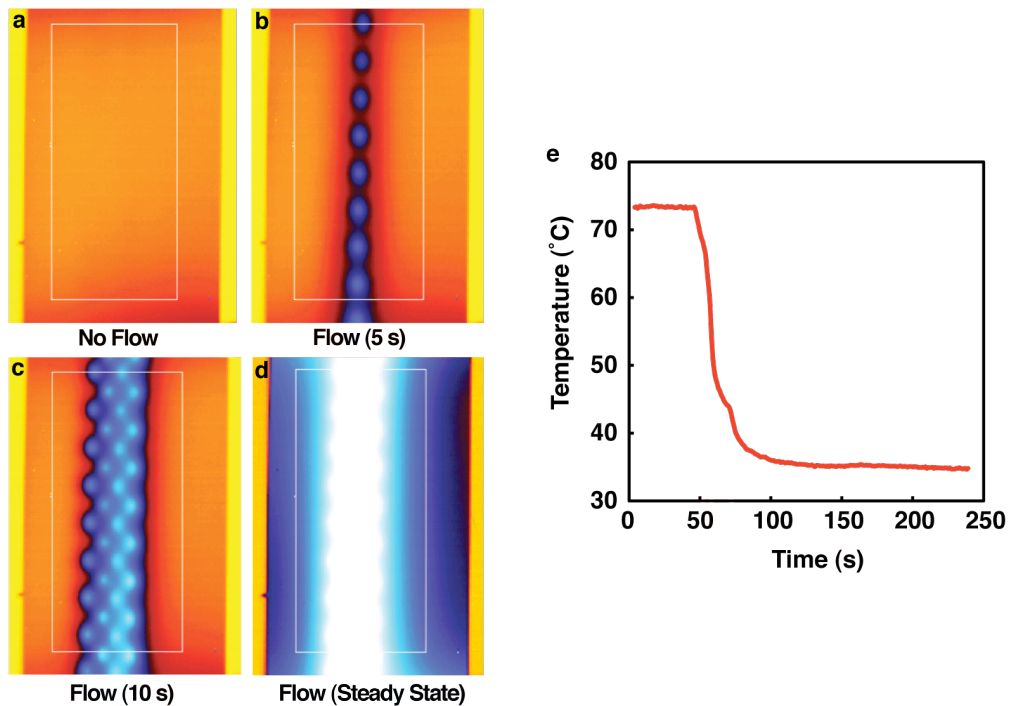


Figure 2: Cooling response of a 3D microvascular composite. IR images showing (a) no flow (b) 5s of flow (c) 10s of flow (d) steady state flow (e) average temperature of composite versus time [3].

Figure 2 illustrates the active cooling behavior of 3D microvascular composites via circulation of a coolant through a heated composite while monitoring surface temperatures using an infrared camera [3]. Microvascular composites that are actively cooled show promise for increasing the operating temperature of traditional polymer matrix composites.

There have been studies [4, 5] reporting the effect of hollow microvasculatures on the mechanical properties, such as, tension, compression, fatigue and fracture toughness, however, such studies have been reported only for straight microchannels. The effect of incorporating three-dimensional microvascular network on the mechanical integrity of structural composites is also presented in this work.

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