

THREE DIMENSIONAL MICROVASCULAR COMPOSITES WITH SACRIFICIAL FIBERS: MANUFACTURING AND MATERIALS

Aaron P. Esser-Kahn^{1,2}, Hefei Dong^{1,3}, Piyush R. Thakre^{1,4}, Jason F. Patrick^{1,4}, Nancy R. Sottos^{1,2,4}, Scott R. White^{1,4,5} and Jeffrey S. Moore^{1,2,3}

¹Beckman Institute for Advanced Science and Technology, University of Illinois at Urbana-Champaign

²Department of Chemistry, University of Illinois at Urbana-Champaign

³Department of Materials Science and Engineering, University of Illinois at Urbana-Champaign,

⁴Department of Mechanical Science and Engineering, University of Illinois at Urbana-Champaign, ⁵Department of Aerospace Engineering, University of Illinois at Urbana-Champaign, Urbana, IL, 61801, USA

Email: jsmoore@illinois.edu

Keywords: Poly(lactic acid) (PLA), Sacrificial fiber, Microvascular network, Thermal depolymerization, Fiber treatment procedures

ABSTRACT

Self-healing microvascular material systems have attracted attention for their ability to achieve multiple healing cycles in response to mechanical damage. Current microvascular fabrication methods are limited in their ability to integrate microvascular networks¹ into commercial composite materials. Here we show that the introduction of sacrificial fibers into woven preforms enables the seamless fabrication of 3D microvascular composites that are both strong and multifunctional. Underpinning the method is the efficient thermal depolymerization of catalyst-impregnated polylactide (PLA) fibers with simultaneous evaporative removal of the resulting lactide monomer. The hollow channels produced are high-fidelity inverse replicas of the original fiber's diameter and trajectory². The method has yielded microvascular materials with channels over one meter in length that can be subsequently filled with a variety of liquids including aqueous solutions, organic solvents for applications such as self-healing and thermal management.

This talk will focus on the technical hurdles overcome during the creation of the sacrificial fiber system with a particular focus on manufacturing procedures, materials systems, channel morphology, and clearance efficiency³. The overall goal of the research presented is the maximization of length-to-diameter ratios in fiber clearing experiments. Chemical treatments² as well as industrial additives are shown to improve vaporization of PLA and clearance of channels. Channel morphology and connectivity is affected by this chemical treatment of PLA and both are detailed.

We have surveyed various polymeric materials to determine which ones are compatible with our sacrificial fiber approach. A detailed list of materials and possible industrial applications will be presented alongside adjustments in the standard sacrificial fiber approach that were necessary to accommodate each material system. Increasing the number of material matrices that are compatible with sacrificial fiber technology will expand microvascular approaches to industrial and societal problems as well as expand the scope of self-healing materials.

The result of these advances is the expansion of this technique to large-scale composites and materials. [Figure 1] Examples will be given of the limits of sacrificial fiber technology and how

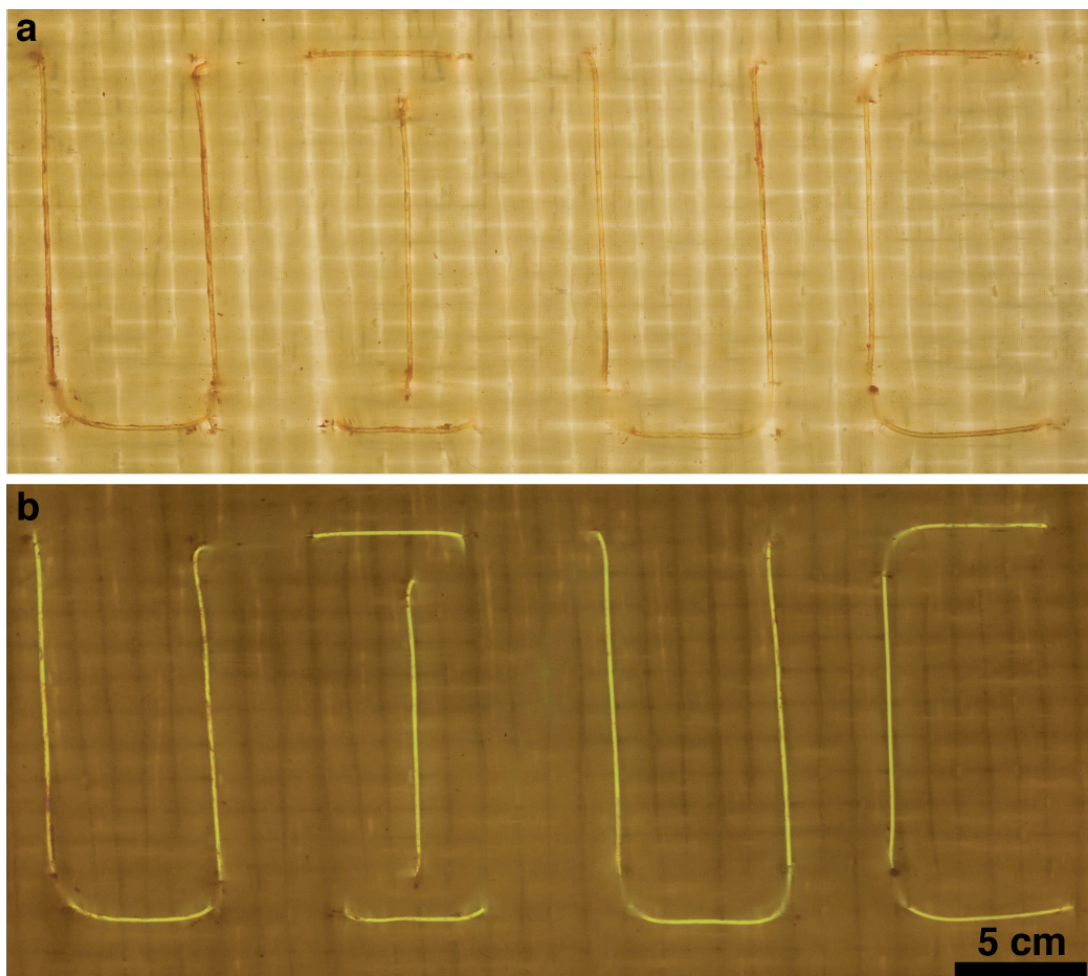


Figure 1: Channel length and composite integration. a) An empty microvascular network formed via weaving of sacrificial fibers. b) The same network filled with a chemiluminescent solution.

have overcome some of them, while others still remain. A comparison of all the different approaches will be presented with the goal of making fiber treatment, integration and clearance choices easy for all researchers.

References

- [1] K. S. Toohey; N. R. Sottos; J. A. Lewis; J. S. Moore; S. R. White, Self-healing Materials with Microvascular Networks, *Nature Materials*, **6**, 2007, pp. 581–585.
- [2] A. P. Esser-Kahn, P. R. Thakre, H. Dong, J. F. Patrick, V. K. Vlasko-Vlasov, N. R. Sottos, J. S. Moore and S. R. White, Three-Dimensional Microvascular Fiber-Reinforced Composites, *Advanced Materials*, 2011, submitted on Mar. 11.
- [3] H. Dong, A. P. Esser-Kahn, P. R. Thakre, J. F. Patrick, N. R. Sottos, S. R. White and J. S. Moore, Chemical Treatment of Poly(lactic acid) Fibers to Enhance Thermal Depolymerization, *ACS Applied Materials and Interface*, 2011, pending submission.