Transactions on Additive Manufacturing Meets Medicine
Trans. AMMM, 2025, Vol. 7, No 1, Suppl. 1, Article ID 2103, 1 Page

Abstract

Hybrid manufacturing approach for multi-scale bio-inspired blood contacting membrane designs

K. P. Barbian[1*], U. Steinseifer[1] and S. V. Jansen[1]

[1] *Department of Cardiovascular Engineering, Institute of Applied Medical Engineering, Medical Faculty, RWTH Aachen University, Aachen, Germany ("CVE")*
[*] *Corresponding author, email: barbian@ame.rwth-aachen.de*

Extracorporeal membrane oxygenation is an effective treatment option for patients with severe respiratory diseases. Here, the blood is supplied with oxygen while carbon dioxide is removed inside an artificial lung (AL), outside of the human body. This process currently makes use of hollow fiber membranes (HFM). However, suboptimal blood flow conditions exist within the HFM structures which lead to reduced gas transfer efficiency and increased thrombosis-risk reducing device durability [1,2]. Additively manufacturing enables the creation of tailored blood flow channels for improved hemocompatibility [3,4]. However, additive AL fabrication remains challenging due to the wide range of feature sizes and limited material options.

In this study, we propose a novel concept for ALs that are based on custom designed, bio-inspired 3D membrane structures. The structures were fabricated with a hybrid additive-conventional process. For the creation of functional, miniaturized prototypes, we utilized high precision stereolithography to fabricate a sacrificial tool geometry. Afterwards, the membrane structure was formed in a dip-coating process step. After etching of the sacrificial part, only the 3D membrane structure was preserved that is made from a biocompatible, gas permeable siloxane. The manufacturing results were characterized concerning overall built quality, surface roughness and membrane thicknesses using optical- and scanning electron microscopy. Finally, we carried out in-vitro performance testing concerning gas transfer rates and pressure drops according to ISO 7199 with porcine blood.

Using our hybrid manufacturing strategy, watertight 3D membrane structures were successfully fabricated with membrane thicknesses around 100 µm across a total structural length of 50 cm. In-vitro tests demonstrated gas transfer rates of up to 2 ml/min and low pressure drops (<20 mmHg per l/min). The size of the laboratory prototypes as well as their gas transfer performance are still below clinical applicability. However, once scaled, this approach may lead to next-generation ALs with higher durability and lower complication rates. Moreover, regulatory admission can be simplified, as already approved membrane materials can be used within the manufacturing process.

Author's statement

The authors state no conflict of interest. The blood used in the testing was collected at a slaughterhouse with no animals being harmed specifically for this experiment. The blood testing lab at CVE holds unrestricted approval for the use of slaughterhouse blood from the responsible veterinary office. This project was supported by the German Research Foundation (DFG) under project number 347368182.

References

[1] T. Tonetti et al, *Current knowledge gaps in extracorporeal respiratory support*, ICMx 11, 77 (2023)
[2] Tulman, D.B. et al. *Veno-venous ECMO: a synopsis of nine key potential challenges, considerations, and controversies*, *BMC Anesthesiol* 14, 65 (2014)
[3] L. Hirschwald et al, *Enhanced Hemodynamics of Anisometric TPMS Topology Reduce Blood Clotting in 3D Printed Blood Contactors*, Adv Healthc Mater. 2025 Jan;14(2)
[4] F. Hesselmann et al, *Structure-dependent gas transfer performance of 3D-membranes for artificial membrane lungs*, J. Membr. Sci. 634 (2021) 119371

DOI: 10.18416/AMMM.2025.25062103