Design of new membrane housings for a Portable Artificial Kidney

Chemical Engineering

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Introduction

Patients with end stage renal disease (ESRD) are progressively increasing [1]. The most used therapy is hemodialysis (HD) [2]. Studies show that higher frequency HD not only increases the quality of life of ESRD patients but also lowers morbidity and mortality rates [3].

Novel microdevices designed to perform continuously will result in a smoother correction of uremic abnormalities and offer greater mobility for ESRD patients. Early development of a portable artificial kidney (PAK) for the treatment of ESRD is envisioned based on a novel blood purification device that integrates membrane technology in a microfluidic system – the microfluidic membrane device (MFMD).

Materials and methods

Software: Onshape®
Printer: Ultimaker^{2+}
Material: Acrylonitrile butadiene styrene (ABS)

The device was connected to an in-house built experimental system that simulates the extracorporeal blood circulation circuit found in HD machines and is capable of measuring very low pressure variations (< 1 mmHg) under dynamic conditions (Figure 1).

To characterize the membrane housing, experiments were performed by placing a non-permeable polyester transparency film in the place to be occupied by the HD membranes in the future (Figure 2 and 3).

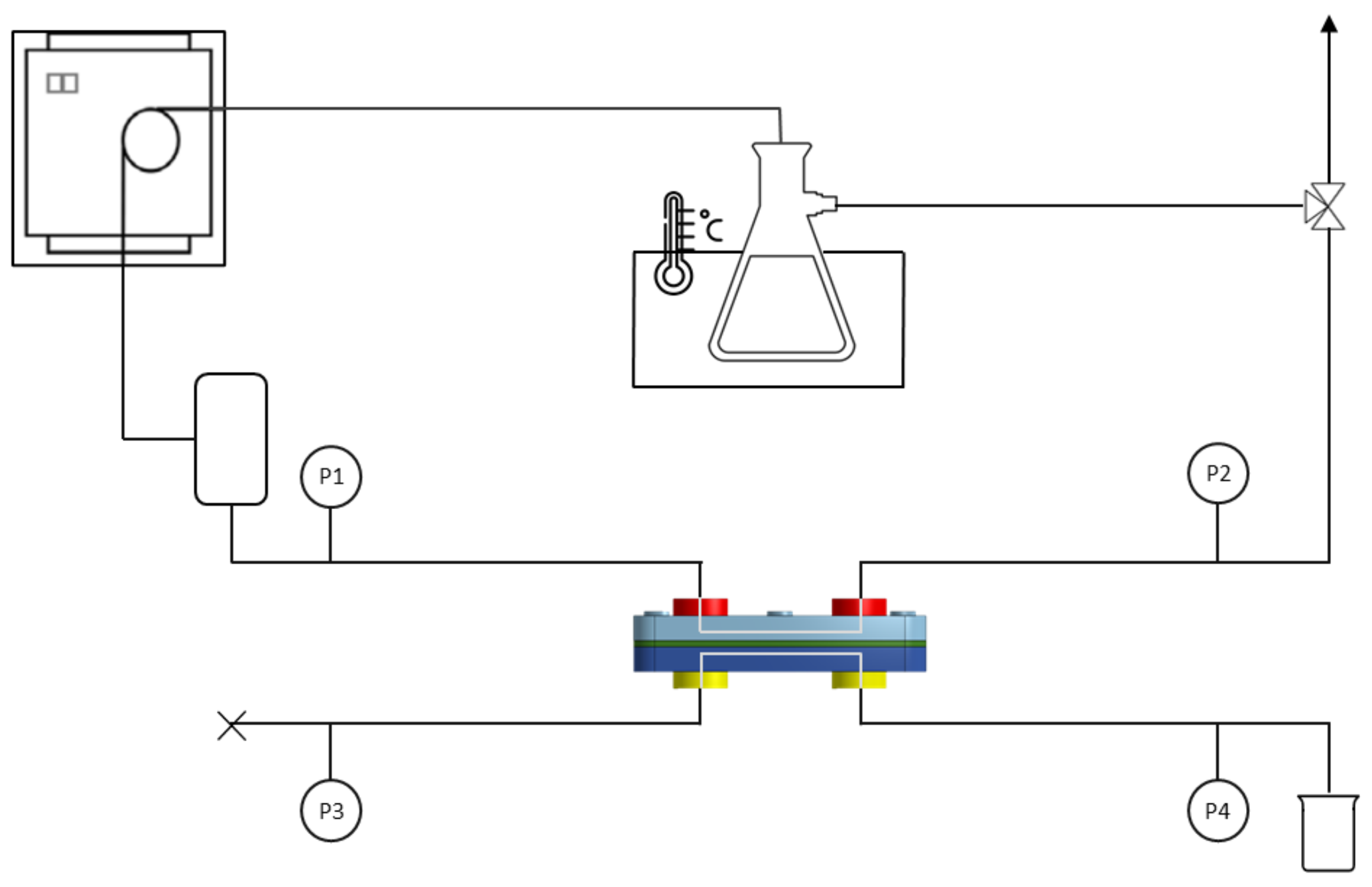

Figure 1 – Schematic representation of the experimental setup used to characterize the MFMD: Blood reservoir: ⚗; Roller pump: ⊡; Pulsation damper: ▯; Pressure sensor: ○; Three-way valve: ⋈; MDFD: ▬.

References
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[2] Faria, M.; Monteiro, C.; Eusébio, T.; Brogueira, P. and de Pinho M.N., *Cellulose*, **27**, 3847-3869, (2020).
[3] Jonas, J. P.; Leonard, E.F.; Sandhu, G.; Winkel, G.; Levin, N. W.; Cortell, S., *Blood Purification*, **34**, 325–331, (2013).
[4] Janeca, A.; Rodrigues, F.S.C.; Gonçalves, M.C.; Faria, M., *Membranes*, **11**, 825 (2021).

Theory

The half-height of the microchannel (B) is obtained by an equation analogous to the Hagen-Poiseuille law that describes the laminar flow of a Newtonian fluid in a narrow slit [4]:

$$B=\sqrt[3]{\frac{3}{2}\frac{\mu L\,Q_F}{W\,\Delta P}} \tag{1}$$

The shear stress (τ) exerted to the walls of a microchannel is defined by the shear force generated by the fluid flow on the surfaces [4]:

$$\tau=\frac{3}{2}\frac{\mu\,Q_F}{B^2\,W} \tag{2}$$

Where μ is the viscosity of the fluid, L is the length of the microchannel, Q_F is the feed flow rate, W is the width of the microchannel and ΔP is the pressure drop across the microchannel.

Results

Both channels were approximately 100 µm in height and that flow rates between 14 and 60 mL/min impose shear stresses between 6.3 and 27.8 Pa.

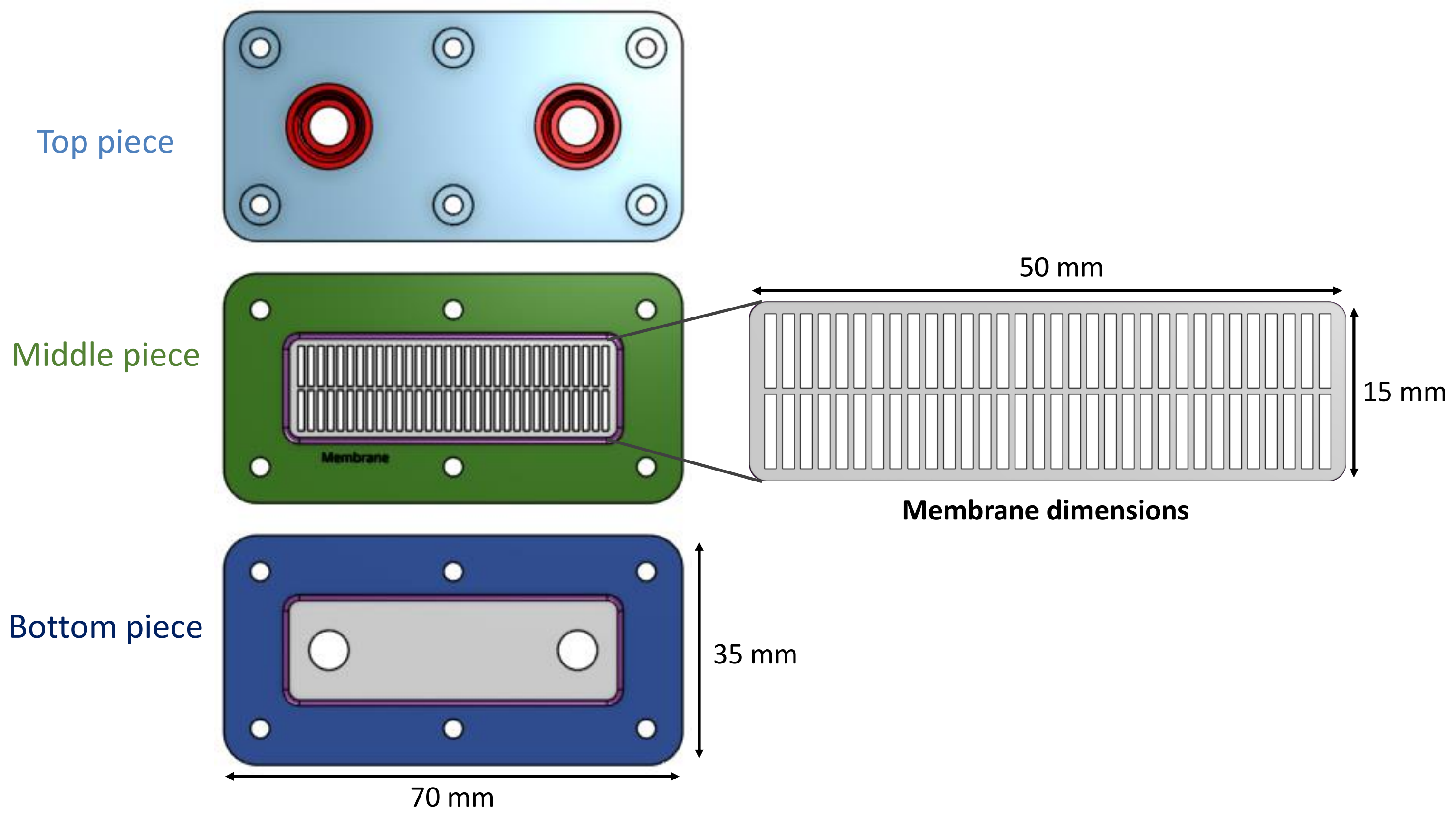

Figure 2 – Illustration of the separate pieces of the MFMD, top view.

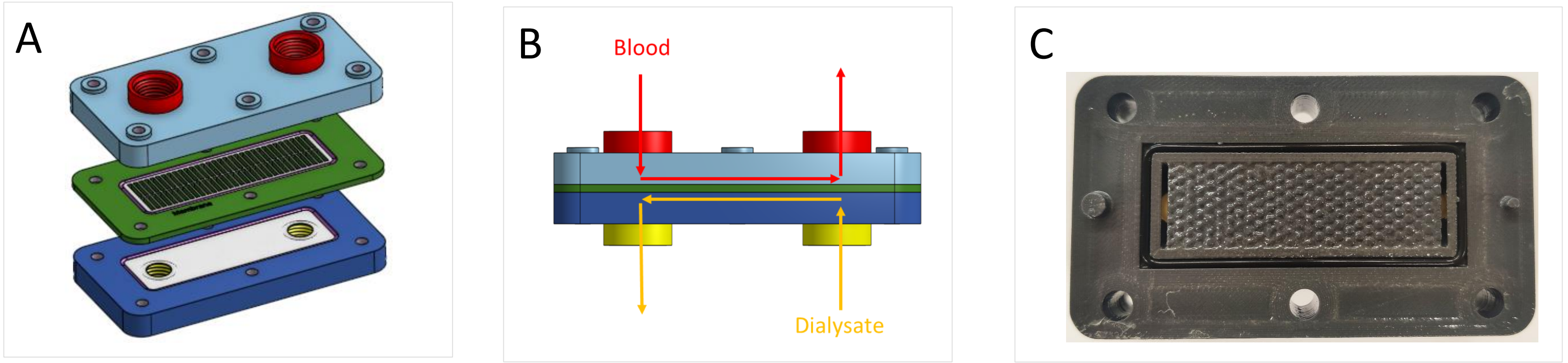

Figure 3 – (A) Illustration of the semi-assembled MFMD; (B) Illustration of assembled MDFD and the representation of the fluid pathway. (C) Prototype of MFMD.

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