3D Printed Integrated Nanoporous Membranes for Electroextraction of DNA

Hari Kalathil Balakrishnan [a, b], *Soo Min Lee* [a], *Ludovic F. Dumée* [c, d], *Egan H. Doeven* [e], *Richard Alexander* [a], *Dan Yuan* [a, f*], *Rosanne M. Guijt* [a*]

[a] Deakin University, Centre for Rural and Regional Futures, Locked Bag 20000, Geelong, VIC 3320, Australia

[b] Deakin University, Institute for Frontier Materials, Locked Bag 20000, Geelong, VIC 3320, Australia

[c] Khalifa University, Department of Chemical Engineering, Abu Dhabi, United Arab Emirates

[d] Research and Innovation Centre on CO_2 and Hydrogen, Khalifa University, Abu Dhabi, United Arab Emirates

[e] Deakin University, School of Life and Environmental Sciences, Locked Bag 20000, Geelong, VIC 3320, Australia

[f] The University of Queensland, School of Mechanical and Mining Engineering, Brisbane, QLD 4072, Australia

*Corresponding authors: rosanne.guijt@deakin.edu.au; d.yuan@uq.edu.au.

3D Printing of Membrane Integrated Device

The size/mobility-based DNA extraction device consisted of three chambers separated by two membranes printed into the device in a semi-automated manner, adopting a print-pause-print strategy [1] employing resin exchange to swap from the standard resin to the purpose-developed resin to form nanoporous membranes. This process schematically illustrated in Figure 2 in the manuscript. Initially, the standard resin was used for the 3D printing of the lysate chamber (chamber 1), after which the printing was paused, and the resin in the vat was replaced with the custom resin. Next, the print was resumed to 3D print porous membrane into the device, after which the resin in the vat was replaced with regular resin to continue 3D printing the body. This was repeated for the second membrane. The porous properties of the 3D-printed membrane depend on the resin formulation and exposure settings (which were not varied in this work). No additional post-processing was required for the membrane-integrated devices, which were rinsed with and sonicated in isopropanol. There was no debonding, delamination, or leakage around the membranes, suggesting good adhesion between the resins. Printing the membranes into the device circumvents many challenges involved in manual membrane integration, including inaccuracies in positioning, dislocation before bonding, and bending and wrinkling of the membrane, especially in miniaturized devices. A print batch of 9 devices consumed 31 mL of resin worth ~USD 1 per device and took 50 min; no defects were found after printing 3 batches (27 devices), demonstrating the potential for small-scale manufacturing (Figure S1).

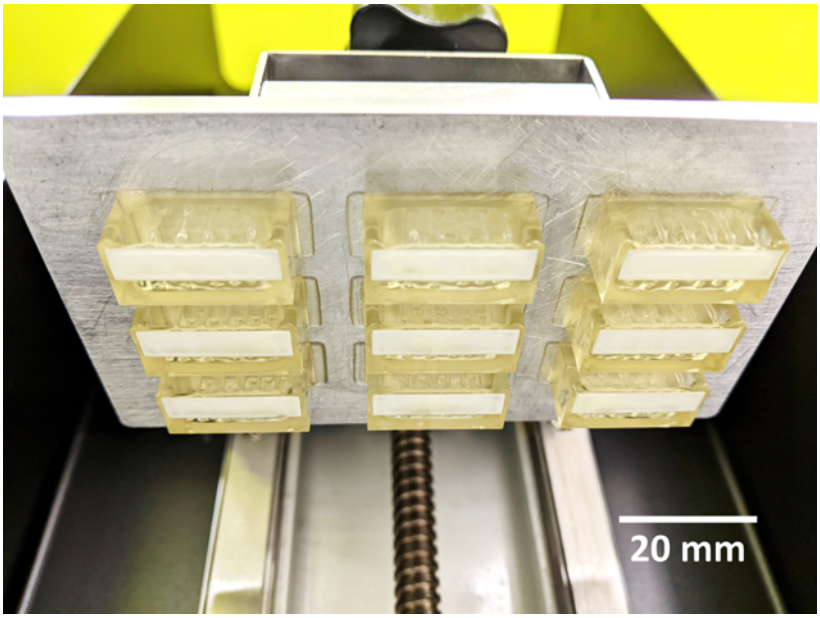

Figure S 1: Photograph during the paused stage showing the printed membranes.

Electrical resistance of the membranes

The electrical resistance of the printed membranes was determined by chronoamperometry using a potentiostat (PGSTAT128N, Metrohm Autolab B.V.), applying 2 V to 1 mm glassy carbon electrodes mounted at a fixed distance (5 mm). The resistance was measured in absence on a membrane, and with electrodes placed at either side of the 70 % porogen and 50% porogen membranes, An increase in resistance from just solution (no membrane) to the large pore size membrane was 485 kOhm and the increase in resistance for the small pore size was 940 kOhm. These values are 4 orders of magnitude larger than those reported for 200 nm pores in a 200 nm thin silicon nitride membrane[2] . The difference may be due to the significantly thicker 300 µm thick membranes used here. When comparing the resistance per mm for the KCl and membranes, the respective 1.7 and 3.2 fold increase in resistance agree with the increase in void volume based on the porosity data, confirming the polymer is non-conducting.

Protein Migration

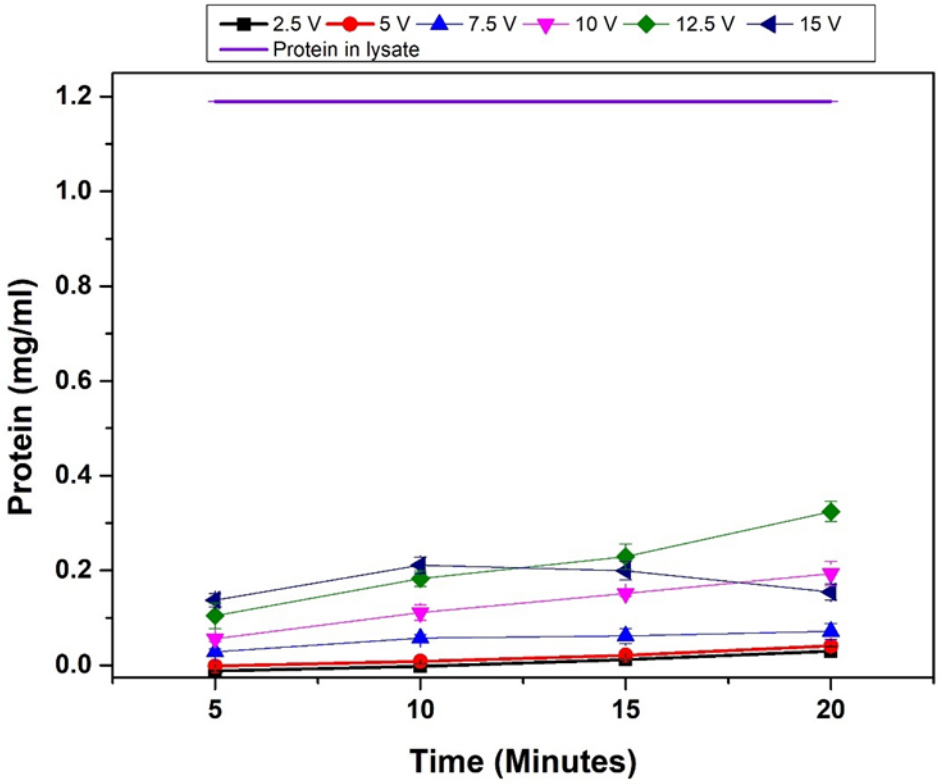

Figure S 2: Migration of protein across the membrane for increasing extraction times and voltage. The protein amount was measured from the samples collected from the extraction chamber.

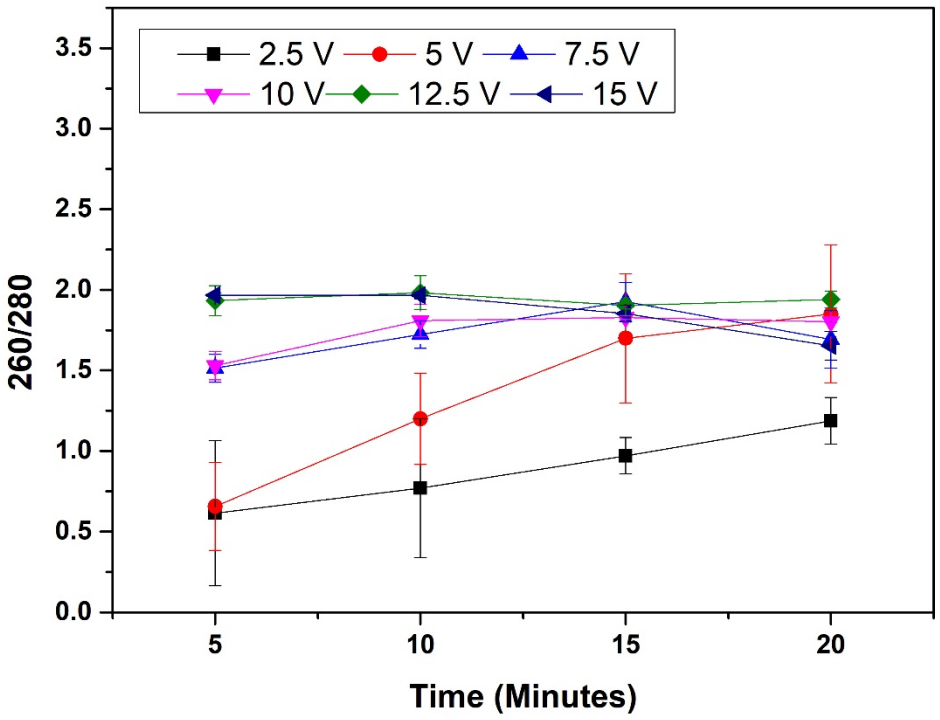

Figure S 3: Variation of A_{260}/A_{280} ratio of the extract over time for different extraction voltage.

1. H. K. Balakrishnan, E. H. Doeven, A. Merenda, L. F. Dumée and R. M. Guijt, *Anal. Chim. Acta*, 2021, **1185**, 338796.
2. K. Lee, J.-H. Kang, H.-M. Kim, J. Ahn, H. Lim, J. Lee, W.-J. Jeon, J.-H. Lee and K.-B. Kim, *Nano Convergence*, 2020, **7**, 1.