

Supplementary Information

An integrated droplet-digital microfluidic system for on-demand droplet creation, mixing, incubation, and sorting

Fatemeh Ahmadi ^{1,2} Kenza Samlali ^{1,2} Philippe Q. N. Vo ^{1,2} Steve C.C. Shih*¹⁻³

¹Department of Electrical and Computer Engineering, Concordia University, Montréal, Québec, Canada

²Centre for Applied Synthetic Biology, Concordia University, Montréal, Québec, Canada

³Department of Biology, Concordia University, Montréal, Québec, Canada

*Corresponding author

Tel: +1-(514) 848-2424 x7579

Email: steve.shih@concordia.ca

***A Supplementary Video is included to show the operations on the ID2M device.**

ID2M automation system

Droplet manipulation was controlled by a GUI (Figure S8) generated in a MATLAB (Mathworks, Natlick, MA) which controlled an Arduino Uno that interfaced to a control board consisting of a network of high-voltage relays (AQW216 Panasonic, Digikey, Winnipeg, MB). The control board delivered AC signals from a high-voltage amplifier (PZD-700A, Trek Inc., Lockport, NY) paired with a function generator (33201A Agilent, Allied Electronics, Ottawa, ON) to initiate actuation sequences on the device (Figure S9). Additionally, the GUI controlled the neMESYS syringe pump and Flame spectrometer (Ocean Optics, Largo, FL). The ID2M microfluidic chip is mounted on a pogo pin-control board (104 pins) with a 3D printed base platform as previously reported^{1, 2} and was placed on the stage of an inverted IX-73 Olympus microscope (Olympus Canada, Mississauga, ON).

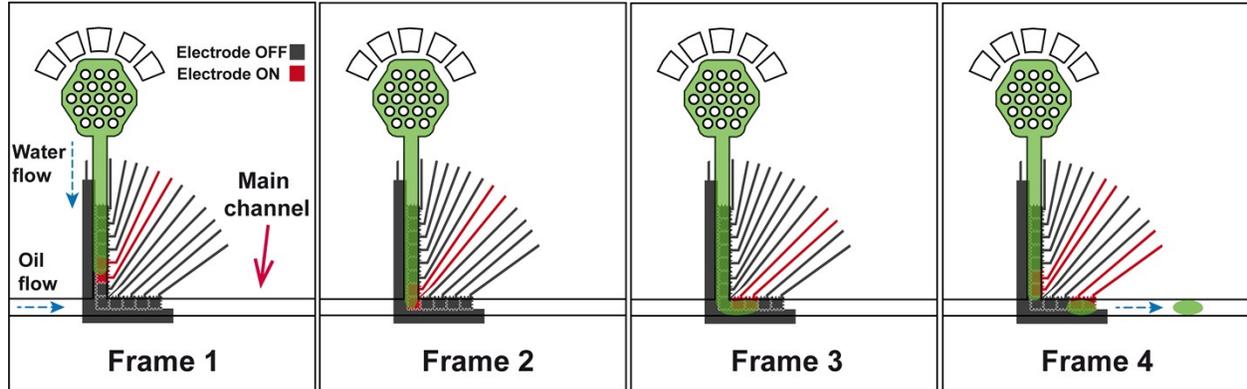


Figure S1. A series of images showing on-demand droplet generation with T-junction configuration. Frame 1 shows a water flow $0.0005 \text{ } [\mu\text{L/s}]$ with initialization of the electrodes. Frame 2-3 shows actuation sequences to drag the fluid to the main channel and Frame 4 shows the required sequence actuation to break-off a droplet. A constant oil flow rate of $0.01 \text{ } [\mu\text{L/s}]$ was maintained during this procedure.

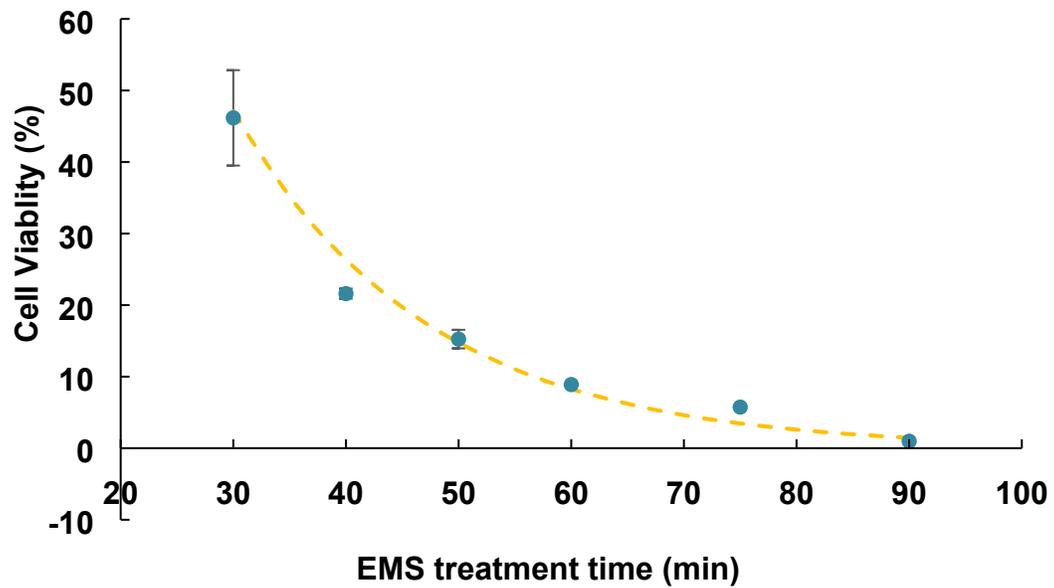


Figure S2. Cell viability of yeast BY4741 strain as a function of different EMS treatment time. Cell viability was calculated by counting colonies growing on SD media plates after 48 h incubation at 30 °C.

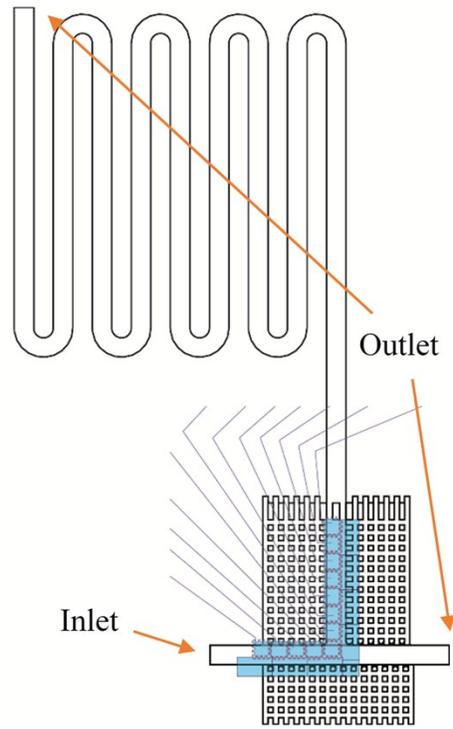


Figure S3. The CAD model design for simulating the sink channel in COMSOL Multiphysics V5.2. For simplification, we only modeled the mixing and sinking channels with the following inlet and outlets of the system.

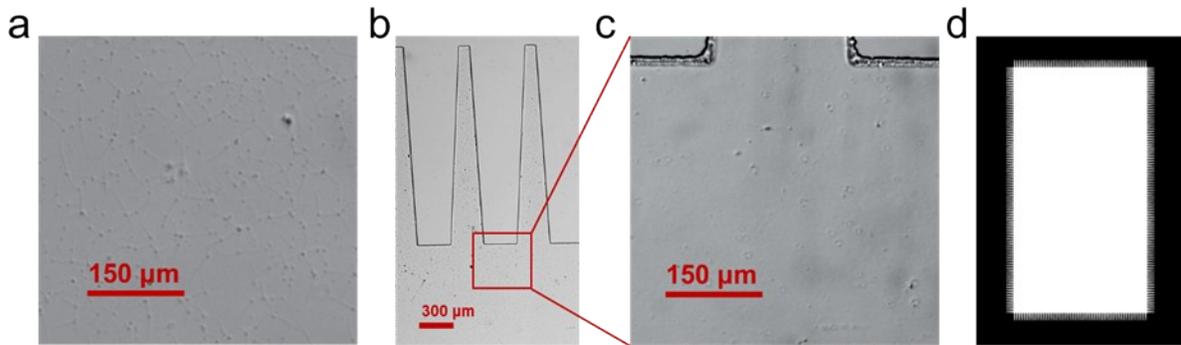


Figure S4. Finger-like structures on the boundary of the SU-8 5 negative photoresist layer. (a) Cracks distributed in the resist layer fabricated with a straight edge mask, (b) and (c) show 10X and 20X images of the same layer fabricated with mask design with fingers, and d) the final mask design with finger-like boundaries.

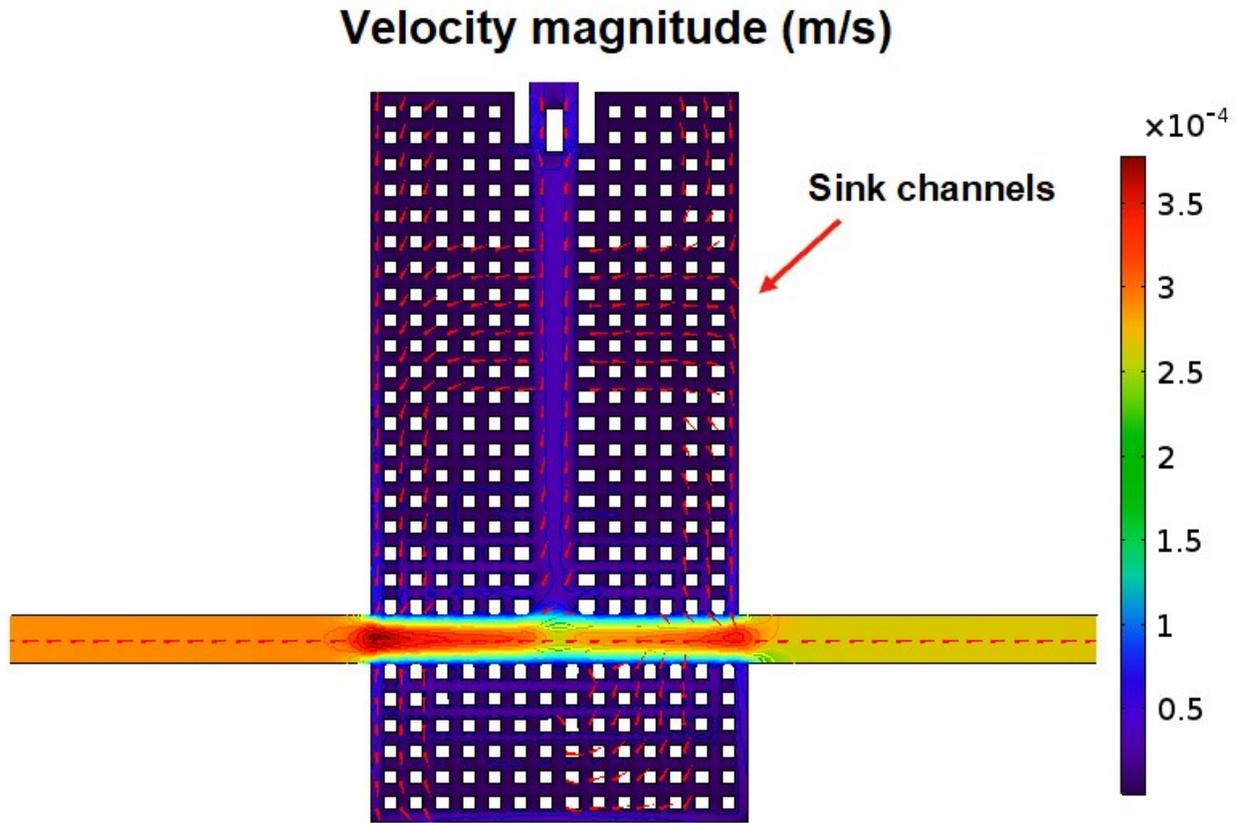


Figure S5. COMSOL simulation of the oil flow velocity in the mixing area, indicating a visible decrease in its velocity. Red arrows indicate the flow direction of the velocity field.

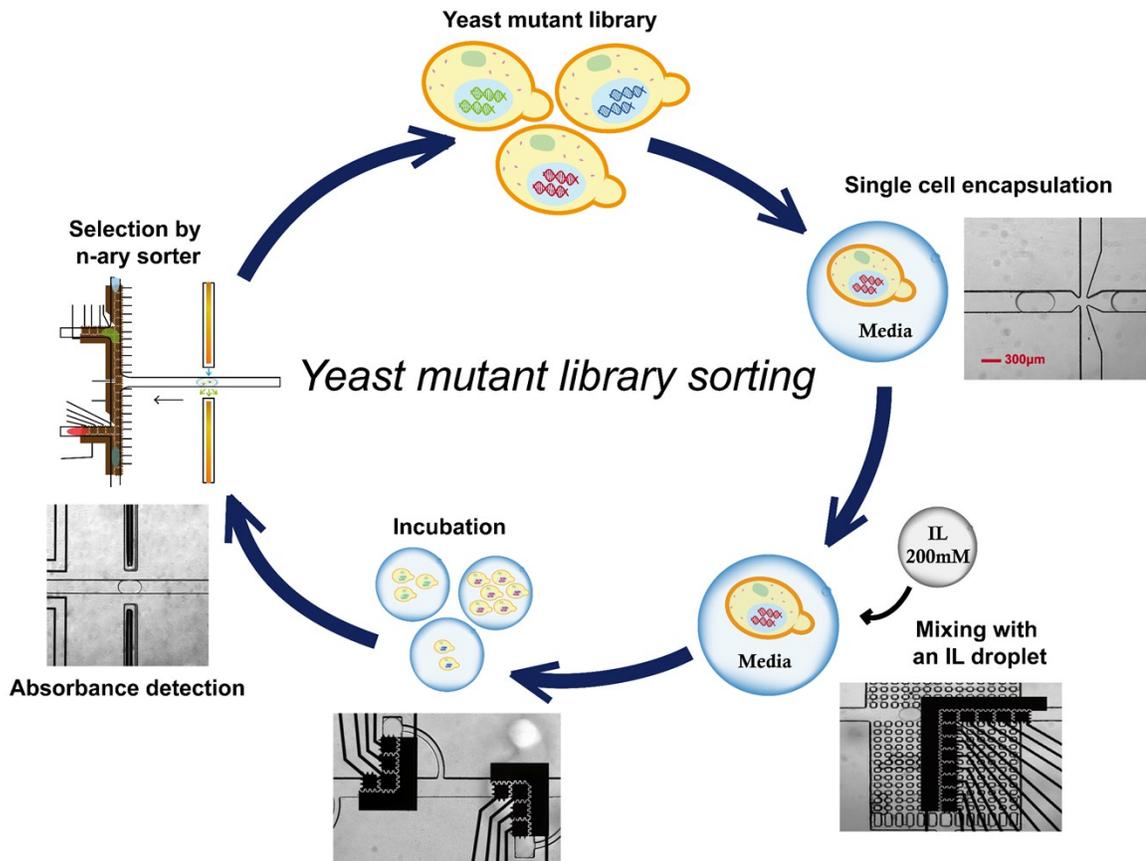


Figure S6. Schematic of the ID2M work flow for screening of a yeast mutant library for ionic liquid resistance based on growth (i.e. absorbance). All steps (except generating the mutant library) was conducted on the ID2M system.

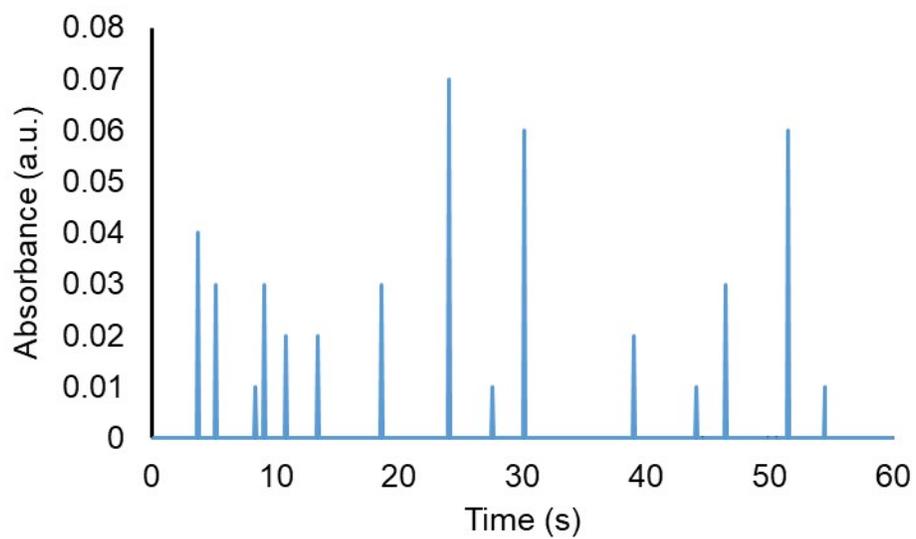


Figure S7. The time course (absorbance vs. time) plot for only oil phase (i.e. no droplets).

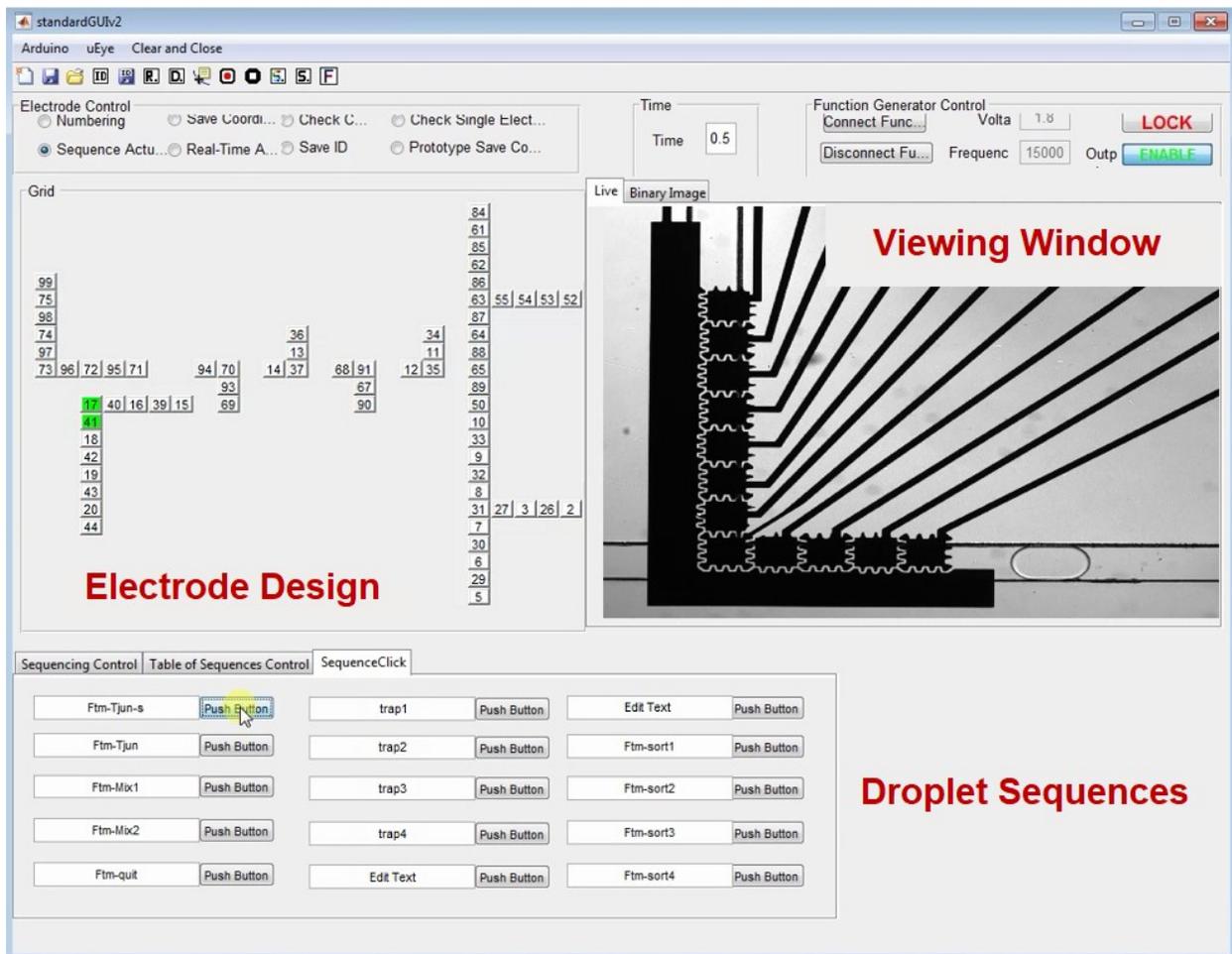


Figure S8. MATLAB GUI. This is the interfaced used to automate our droplet operations which contains a region showing the electrode design (1), the real-time view of the device (2), the voltage and frequency control for the droplet actuations (3), the creation of user-defined droplet sequences that are preprogrammed (4).

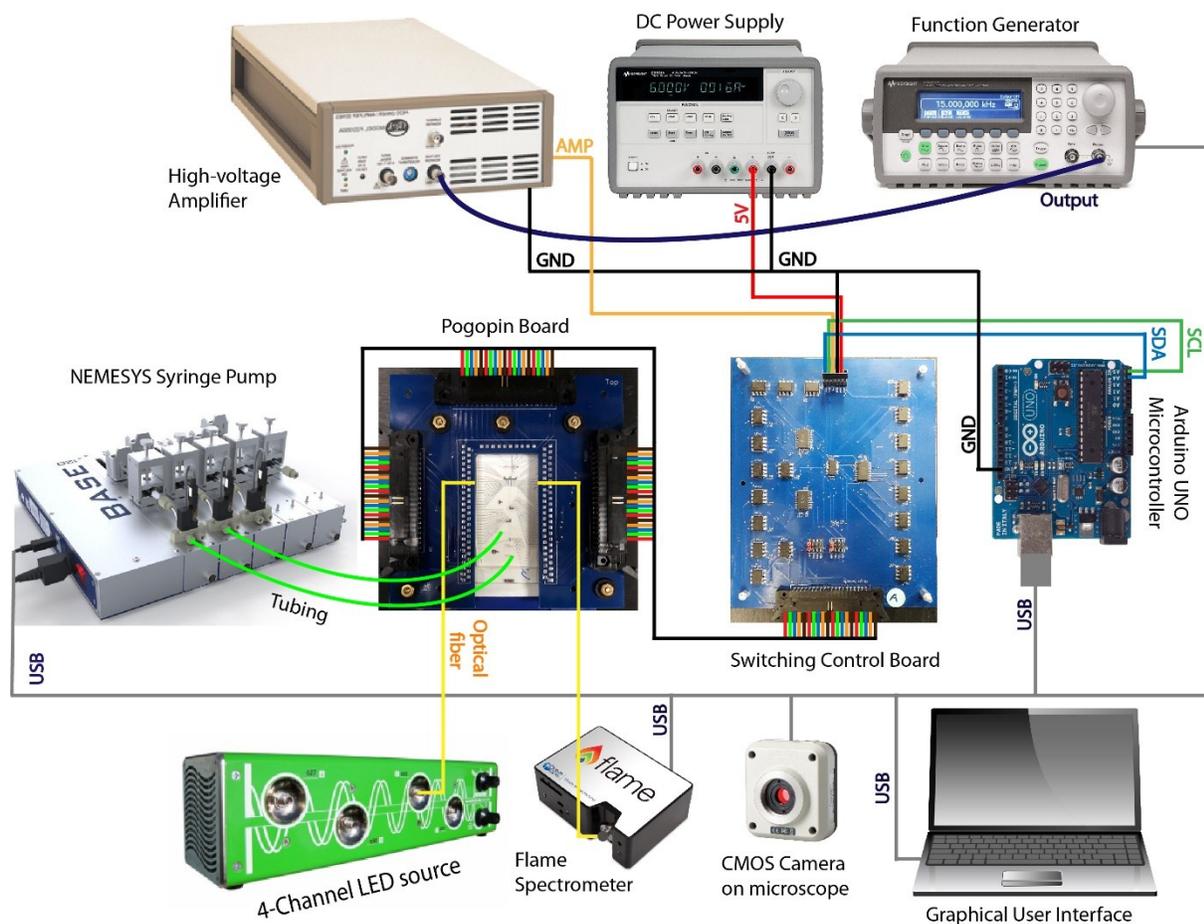


Figure S9. The ID2M automation setup. An image showing the connectivity of all the different components used in this system.

References

1. M. C. Husser, P. Q. N. Vo, H. Sinha, F. Ahmadi and S. C. C. Shih, *ACS Synthetic Biology*, 2018, 7, 933-944.
2. P. Q. N. Vo, M. C. Husser, F. Ahmadi, H. Sinha and S. C. C. Shih, *Lab on a Chip*, 2017, 17, 3437-3446.