Electronic Supplementary Material (ESI) for RSC Advances

Rapid Prototyping of Microfluidic Modules with Water-Developable Dry Film Photoresist Bondable to PDMS

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Prepare the Photomask on the Vellum Sheet

To prepare the photomask on Vellum sheets, readers can either be referred to an education video clip,[1] or follow the steps below. First, print the desired patterns on a sheet of #17 Vellum paper with an office laser printer (Fig. s1a). Opacity of the printed pattern on the Vellum sheet can be enhanced by printing at a high-resolution setting (1200 dpi or higher is recommended), together with toner enhancement by applying a toner repair solution “Magic Dark” (Rayzist, Vista, CA). To apply the Magic Dark solution, spray it over the Vellum sheet. Ensure that the sheet is well wetted. Squeeze the extra solution out of the sheet with a roller (Fig. s1b) by applying one single stroke. (Repeated strokes will soften and disperse the toner.) Dry the wetted sheet in air or by a hair dryer. Once dried, the Vellum-paper photomask is ready to use.

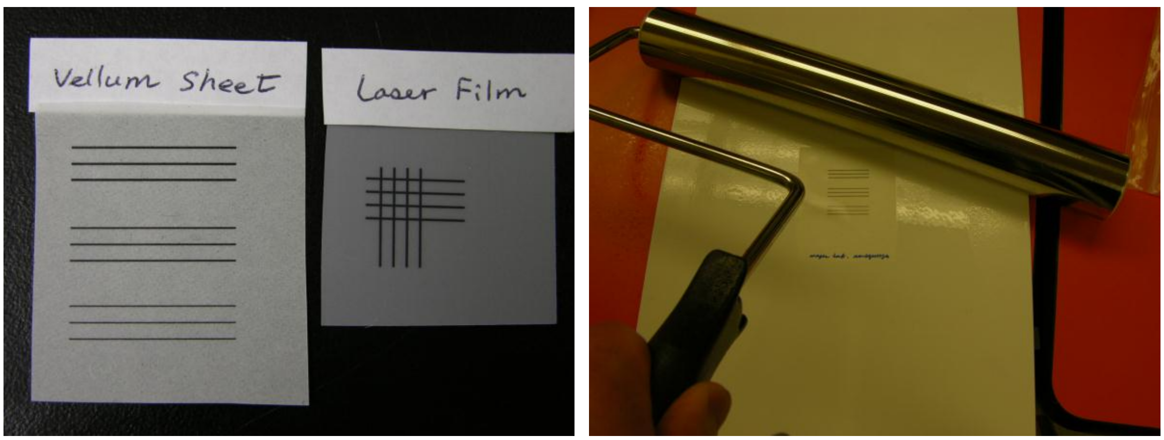


Fig. s1. Vellm-sheet photomask. (a) Prepare photomasks on the Vellum paper. (b) Enhance the toner opacity on the Vellum paper by spraying the toner repair solution on the vellum sheet, followed by one-stroke roller pressing to get rid of the extra solution from the sheet.

Characterization of Water Absorption and Hydrophilicity

SR-3000 is a dry-film negative photoresist which can absorb water regardless an exposure to UV. The water absorption is evidenced by the evolution of the contact angle of a de-ionized water droplet on the surface of an unexposed SR-3000 sheet shown in Fig. s2. The droplet is 30 μL.

The hydrophilicity on the SR-3000 surface can be modified by plasma treatment. Fig. s3 shows the contact angle under various plasma treatment parameters.

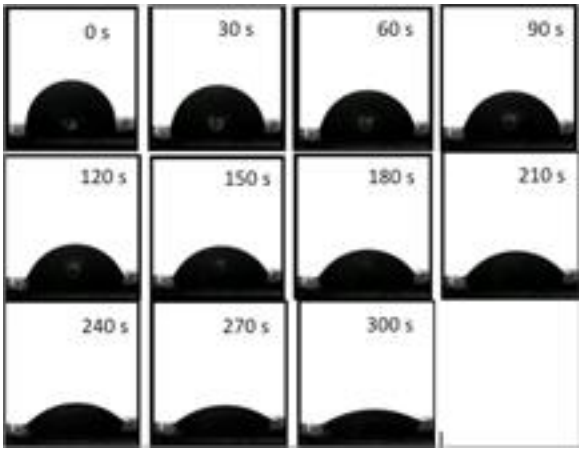


Fig. s2. Evolution of contact angle of DI water droplet on the SR-3000 surface that has not exposed to UV.

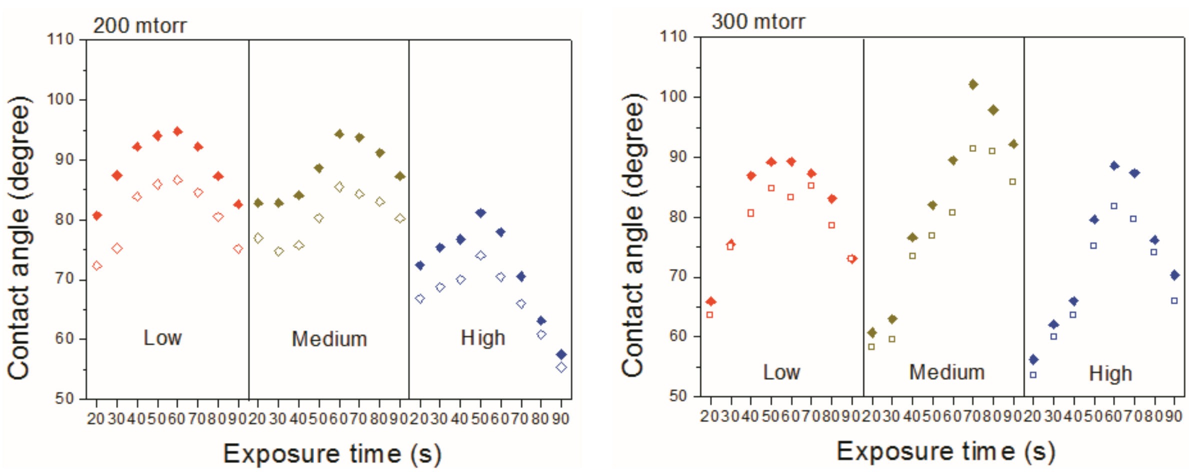


Fig. s3. The contact angle of DI water droplet on the plasma-treated surface of SR-3000 measured right after the plasma treatment (solid dots) and at 30 seconds after the plasma treatment (hollow dots). The plasma power setup: Low (6.8W), Medium (10.5W), High (18W).

XRF Analysis of the Surface Elemental Composition of SR-3000 Photoresist

The XRF analysis was conducted on both sides the SR-3000 photoresist sheet. Fig. s4 shows the results for the rough, matte side, which enriches silicon and oxygen on its surface. The XRF analysis generated ten different scans at various energy levels. The ten scans were compiled into the graph in Fig. s4.

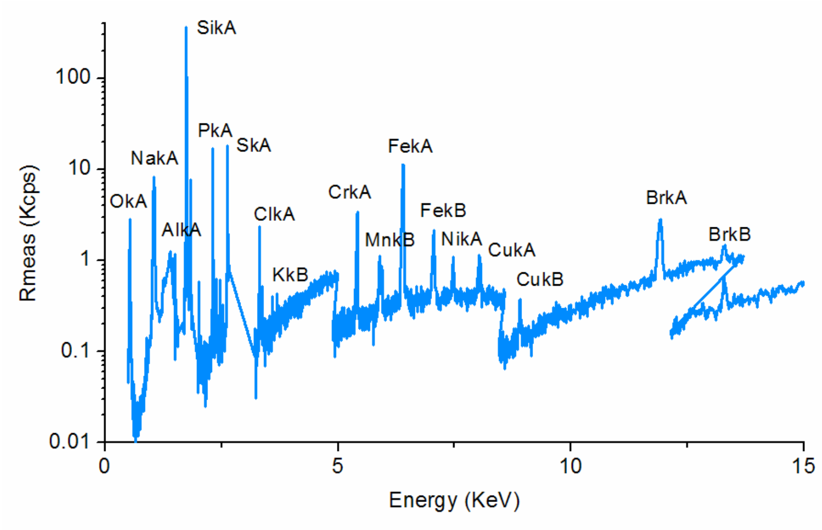


Fig. s4. XRF scanning results show that SR-3000 is Si-enriched.

Fidelity of Line Patterns Developed in SR-3000

Line patterns at the width 0.5, 0.75, and 1 pt (1 pt = 352 μm) were individually printed onto the laser-film transparency (c.f. Fig. 1b in the paper) by a laser printer at 1200 dpi to form the photomask. Each line pattern was transferred to the SR-3000 photoresist sheet for development per the procedure addressed in the paper. For each width, the images of four developed lines were taken at one end, in the middle, and at the cross of the line. In Fig. s5 - Fig. s7, these images are placed in the same column with the printed pattern for comparison.

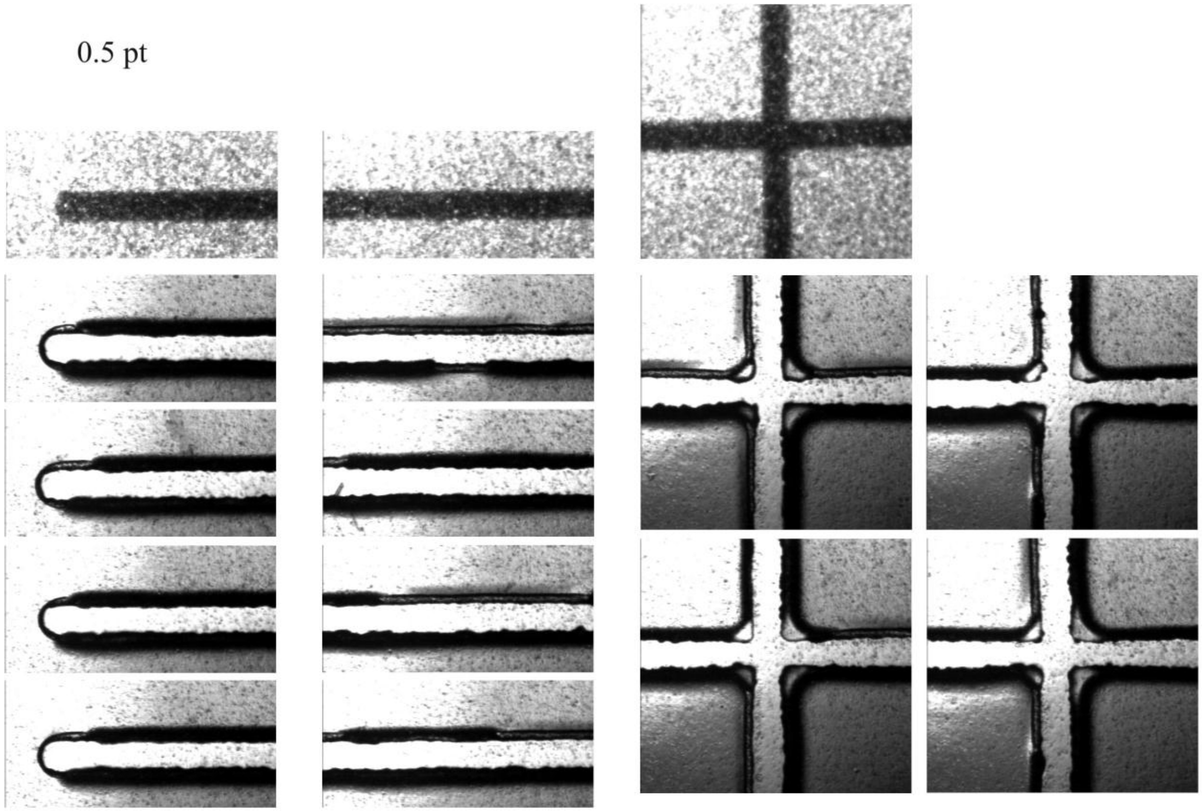


Fig. s5. 0.5-pt line patterns (shown on the top row) developed on the SR-3000 photoresist sheet. (1 pt = 352 μm)

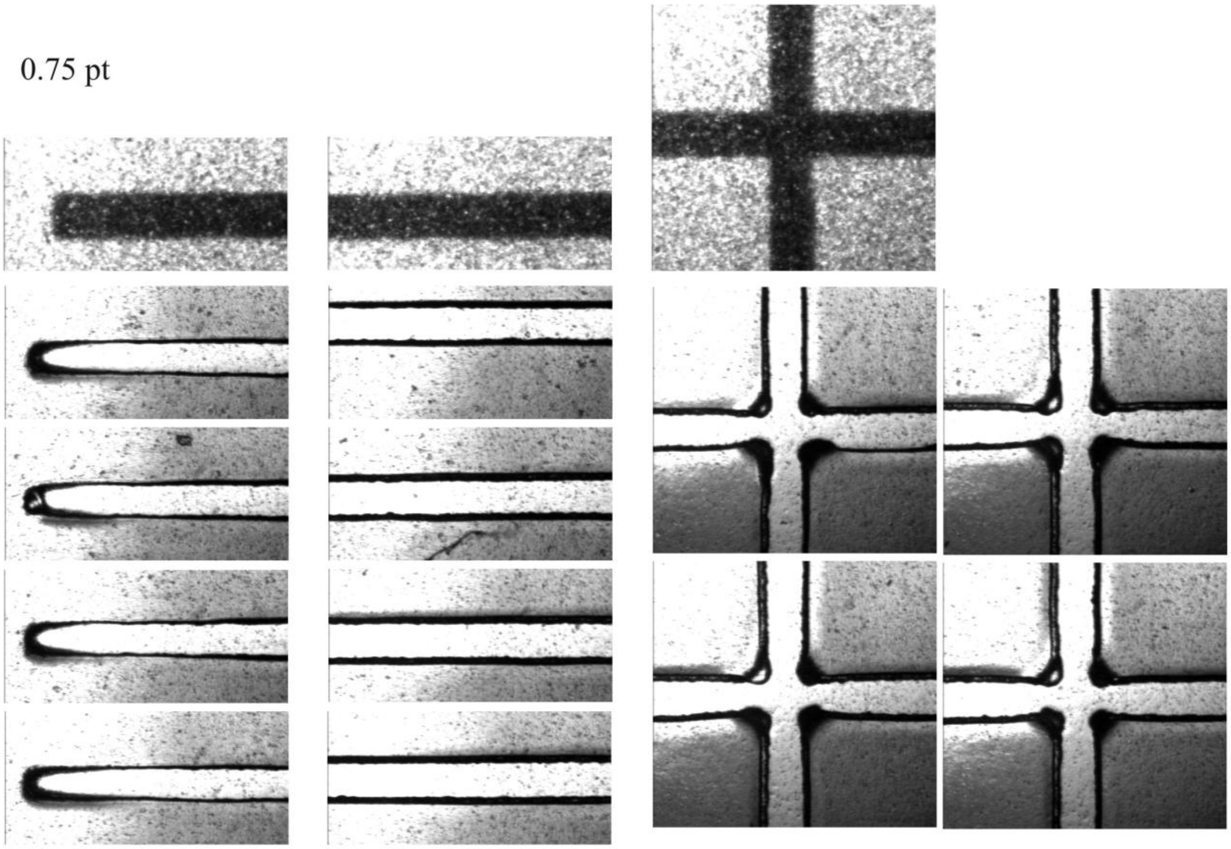


Fig. s6. 0.75-pt line patterns (shown on the top row) developed on the SR-3000 photoresist sheet.

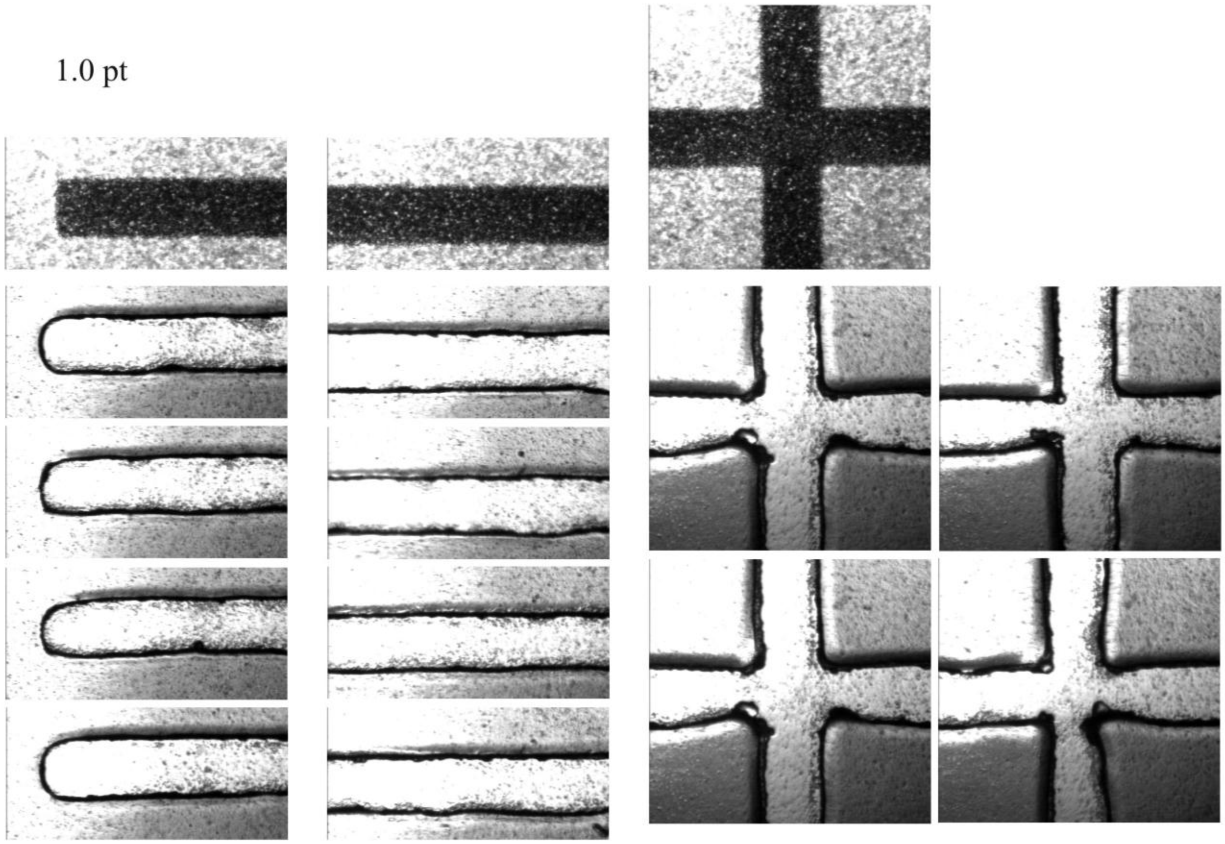
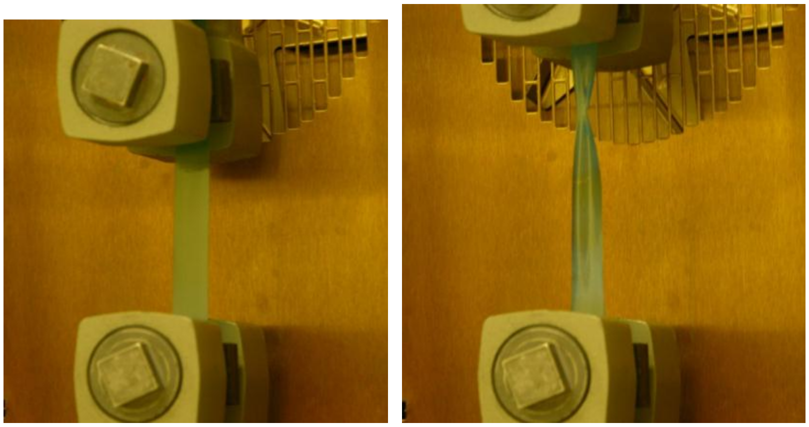


Fig. s7. 1-pt line patterns (shown on the top row) developed on the SR-3000 photoresist sheet.

Tensile Test on SR-3000

Eight strips of the SR-3000 photoresist, each 7 mm × 90 mm, are cut for the tensile tests. Unlike the traditional dog-bone shape commonly seen in metallic specimens, the polymeric SR3000 specimens are prepared in rectangle. It is to eliminate the non-uniform strain distribution in the shoulder area which will need extra correlation on the data measured.[2]

The mechanical properties for polymeric materials are strain-rate dependent because of their viscoelastic nature. At the strain rate $1/300\, s^{-1}$, the measured Young's modulus and yielding strength are 55.45±1.20 MPa (at one standard deviation) and 0.49±0.08 MPa, respectively. At the strain rate $1/150\, s^{-1}$, the measured Young's modulus and yielding strength are 72.65±8.81 MPa and 0.57±0.03 MPa, respectively. The tensile test setup is shown in Fig. s8, which shows the initial configuration and necking of one specimen under testing. The images are corresponding to the strain rate at $1/300\, s^{-1}$. The yielding progress toward failure is similar for the strain rate $1/150\, s^{-1}$.

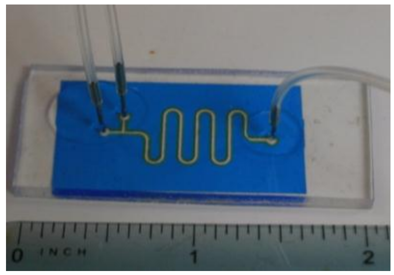


(a) (b)

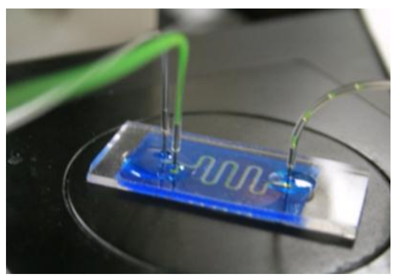
Fig. s8. Tensile test of SR-3000 photoresist. (a) Initial setup. (b) Necking.

Production of Aqueous Droplets in Air

As opposed to the production of aqueous droplets in oil in Fig.8(c) of the paper, aqueous droplets can also be produced at a T- or Y-junction of microchannels by air. In Fig. s9 we demonstrate a primitive prototype for this purpose. To simply prove the feasibility of producing droplets in air, here we set the fluorescent flow rate at 8 μL/min and the air flow rate between 30 and 50 μL/min. The larger the air flow rate, the smaller the aqueous droplets (Fig. s9b), and vice versa (Fig. s9c). More quantitative work is ongoing for better production of uniform droplets.



(a)



(b)

(c)

Fig. s9. Production of fluorescent droplets by shearing of the fluorescent solution flow by the air flow at a T-junction.

References

[1] http://www.rayzist.com/Education/Education-MaskVideo.php Making a Photomask, Rayzist. 5/2/2013.

[2] F. Schneider, T. Fellner, J. Wilde and U. Wallrabe, *J. Micromechanics and Microengineering,* 2008, **18**, 065008 (9pp).