FABRICATION OF POLYMERIC MICRO STRUCTURES BY CONTROLLED DROP ON DEMAND INKJET PRINTING

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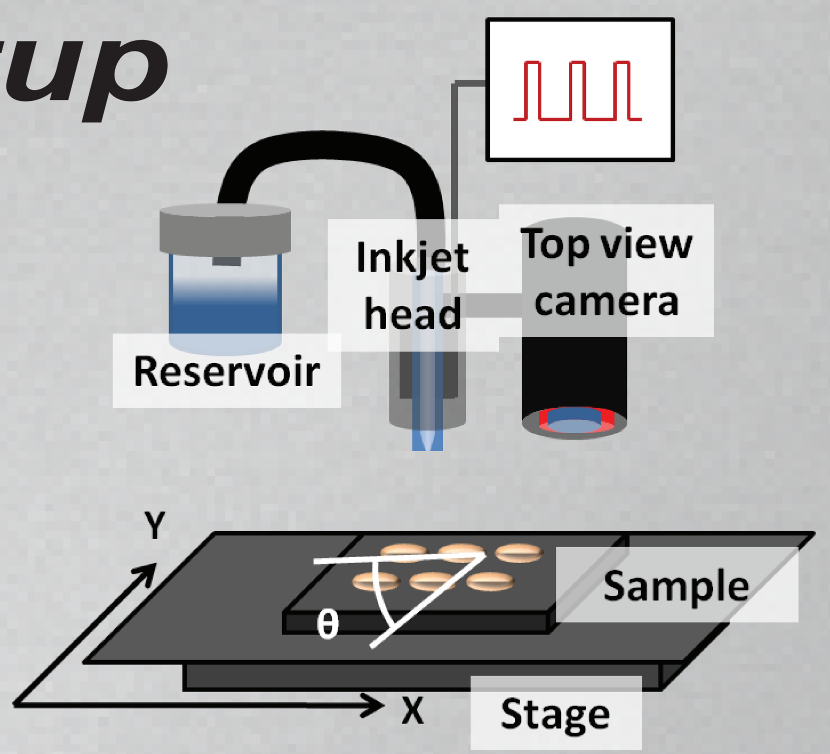
Abstract

The control of spherical micro structure shapes is difficult to achieve with conventional planar microfabrication processes [Z. Xuefeng, 2008], but could enable several novel MEMS devices. In the work described here, a method allowing a precise control of micro spherical shape is presented. Drops in the range of hundreds of picoliters of a SU-8 based polymeric solution [A. Voigt, 2011], are accurately inkjet printed on rounded platforms. The inkjetted volume is confined by the platform allowing a fine control of the spherical cap edge angle and thus of the radius of curvature. The process proposed here permitted to fabricate large arrays of micro spherical shapes, with a controlled edge angle between 25° and 110°. We give an example of a 30 by 30 hemisphere array with a yield higher than 98%.

Setup

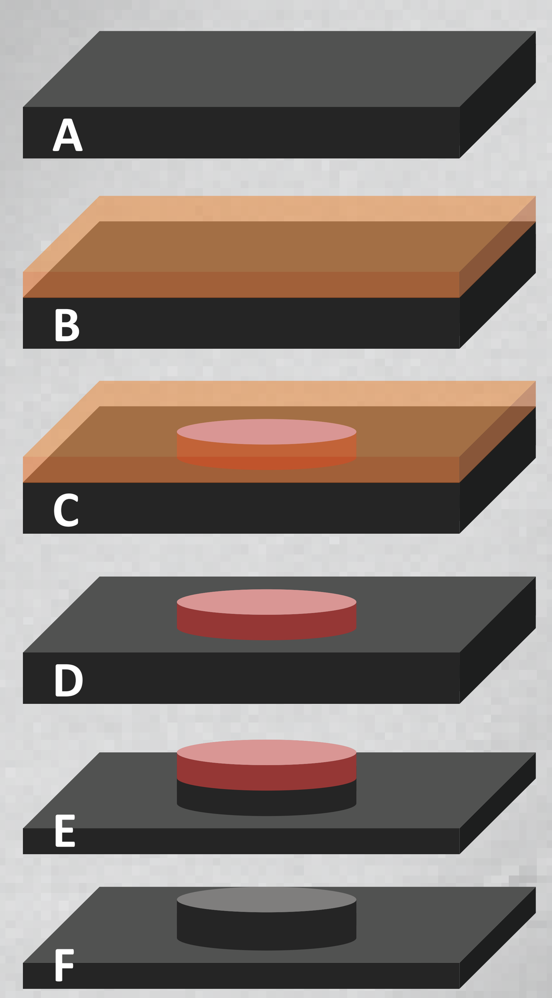
The setup used, from Microdrop Technologies GmbH, is mainly composed of an inkjet printing head, a reservoir, a top view camera and the control units.

The inkjet printing setup is synchronized with a stage, from Newport, through a Labview based software.

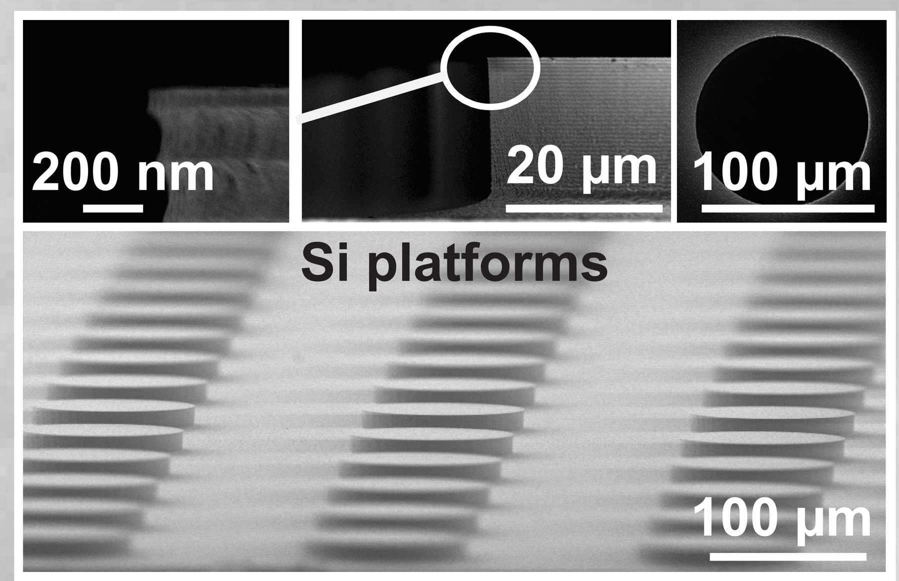


Substrate

Process flow



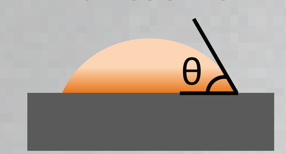
A. Silicon (Si) wafer
B. Photoresist spin-coating
C. Shadow mask UV exposure
D. Development in PGMEA
E. Si anisotropic etching
F. Photoresist remove and silanization



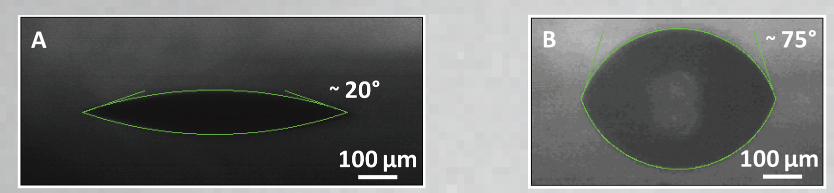
Spherical Micro Shape

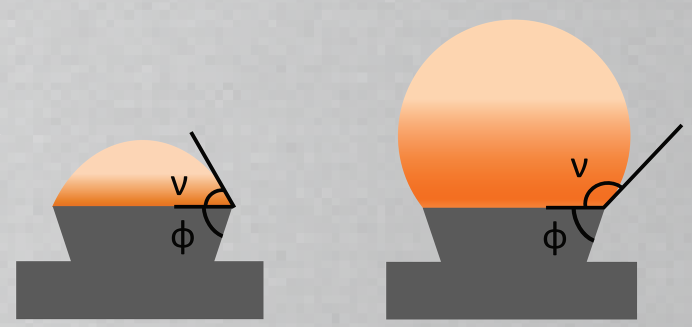
Under the capillary lenght (λ), the surface tension (γ) dominates versus the gravity (g), giving a drop a shape of a spherical cap.

$$\lambda = \sqrt{\frac{\gamma}{\rho g}}$$



Contact angle (θ) depending on surface energies (chemical treatment). Below, optical images of SU-8 based solution on (A) bare Si and (B) silanized Si .

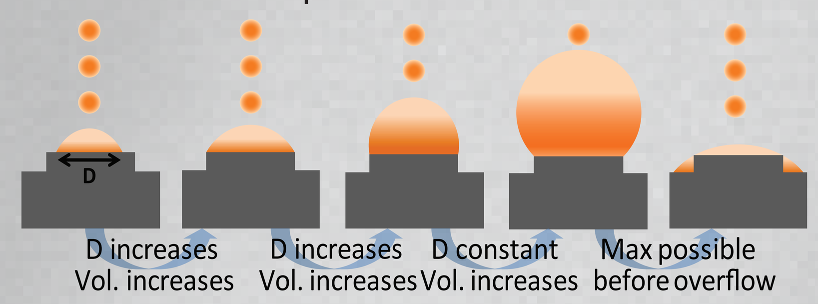




$$\nu = \theta \qquad \nu = \theta + \pi - \phi$$

Confinement leads to an edge angle (ν); between θ and θ + Φ.

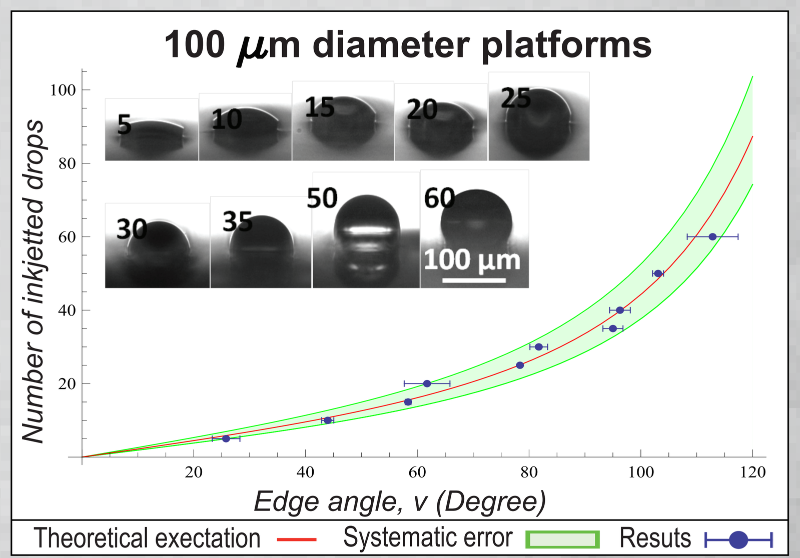
The platform filling process is shown below (left) and the number of drops to deposit, N_{drops}, for an expected edge angle is given by equation below.

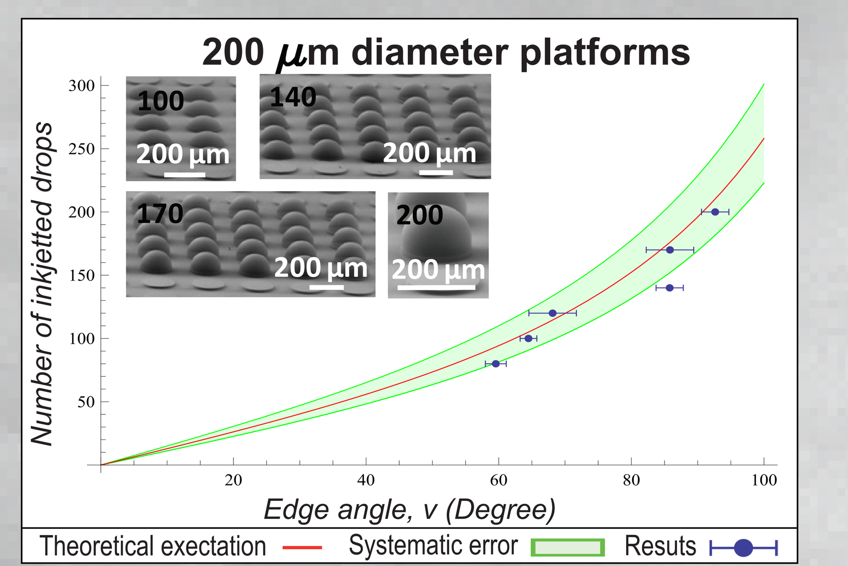


$$N_{drops}(D,R,\nu) = \left(\frac{3}{4\pi R^3}\right) E_V \frac{\pi}{3}\left(\frac{D}{2}\right)^3 \frac{(2+\cos\nu)((1-\cos\nu))^2}{(\sin\nu)^3}$$

Number of drops to depsit for a desired edge angle, where D is the platform diameter, R the in flight drop radius and Ev evaporation coefficient,adapted from [D. Quere, 2005]

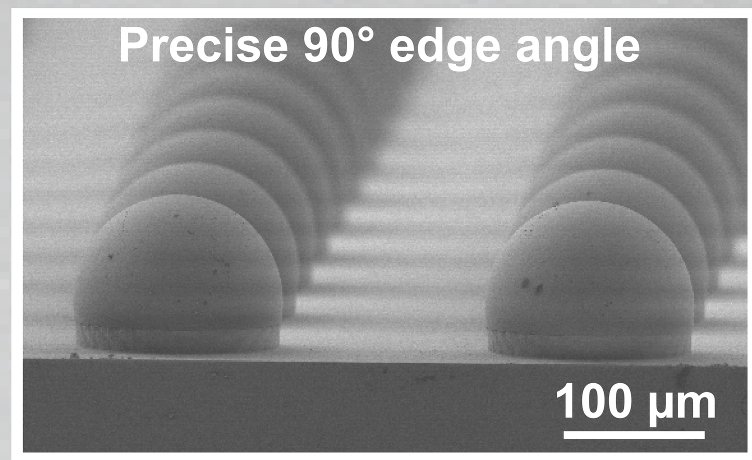
Below, comparison between theory and experiment of the number of drops to be deposited on 100 µm and 200 µm platforms for desired edge angle.

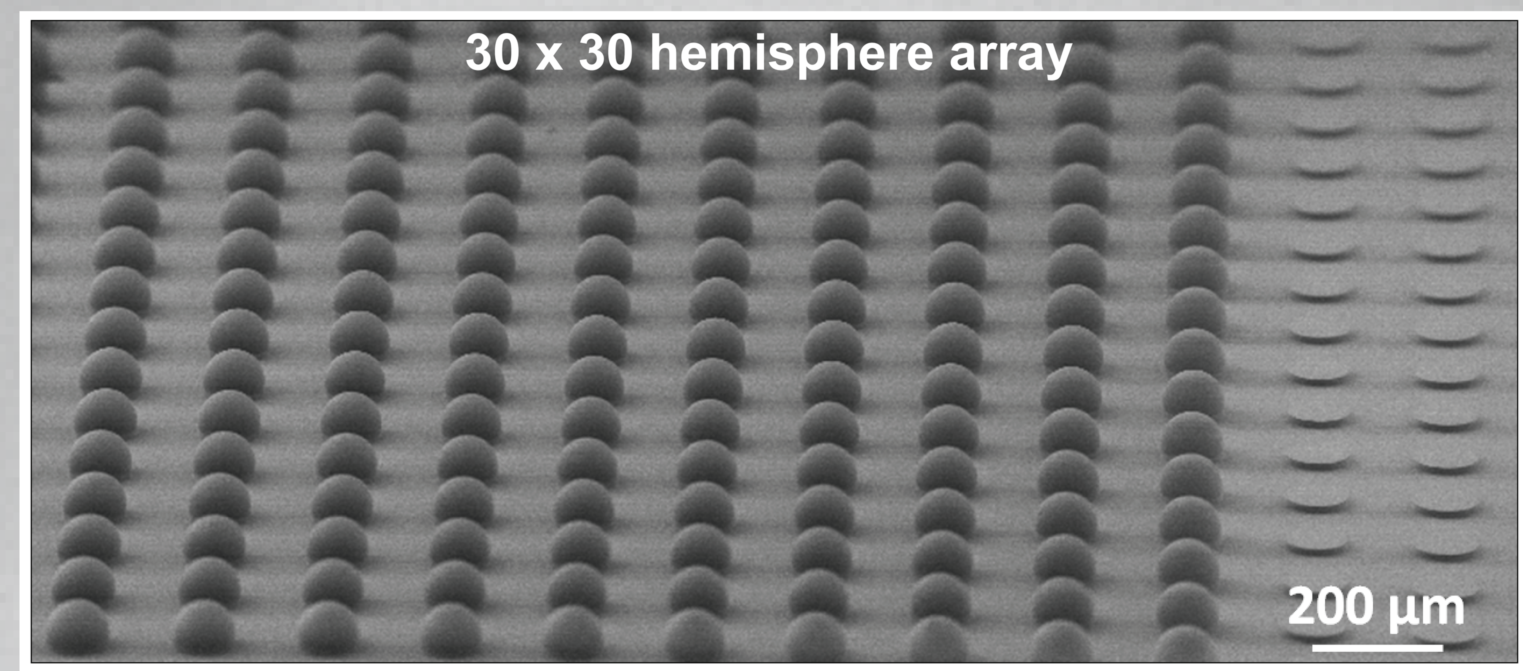




Micro Lens Arrays

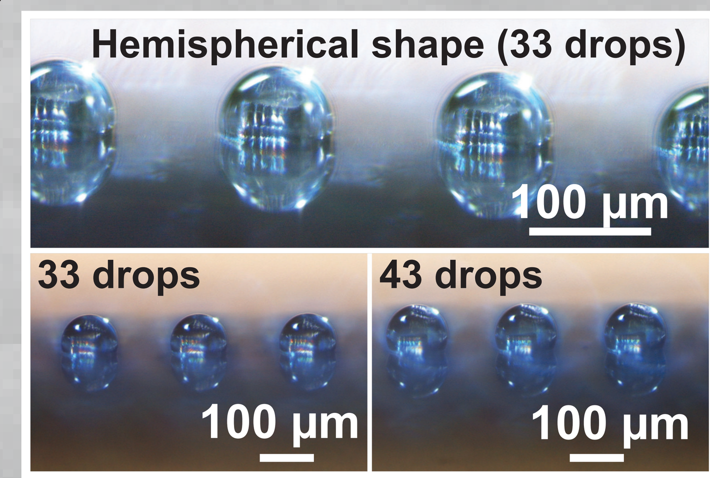
The proposed method allowed us to inkjet print 35 SU-8 drops on 900 Si platforms. The obtained hemisphere arrays showed high reproducibility. Below, example of an array with a yield above 98% (14 over 900 overflowed)





Micro Encapsulation

The proposed method also allows embedding microstructures with a controlled spherical shape. We show here an example of SU-8 structures fabricated by inkjet printing on top of platforms supporting pillars.



Conclusion

We demonstrated the ability to obtain SU-8 epoxy based micro spherical caps with controlled edge angles between 25° and 110° and between 60° and 90° on top of 100 µm and 200 µm platforms, respectively. Using inkjet printing technology, we deposited a precisely controlled number of drops on Si platforms achieving a specific edge angle, due to platform rim confinement. Experimental results showed good agreement with preliminary studied theoretical evolution. Furthermore, we could to produce large arrays of precise micro hemispheres on pre-patterned substrates with a yield above 98%. The proposed method is shown as an interesting candidate for the development of spherical structures for various applications, such as micro structures embedding and micro-optical elements, such as lenses and mirrors with a well controlled curvature.

Acknowledgements

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