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MICROMACHINE CENTER
No. 16
Research on Micromolding and Microactuation
Using Surface Tension

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Micromolding

In this part we investigated the use of surface tension in reshaping meltable microstructures. Previous applications for this technique include the formation of channel waveguides and micro lenses, where the requirement is for smooth cylindrical or spherical surfaces. Here, we considered the use of reflo to transform a structure with uniform height, made up of rectangular strips or dies, into portions of cylinders or spheres with height variations. The shape transformation can be analysed using minimisation of surface area and conservation of volume, from which we find that, for appropriate initial hard dimensions, a uniformly etched structure can be reshaped into one in which the height of refloed spherical droplets considerably exceeds that of cylindrical droplets. A connected structure containing both types may then be planarised by an encapsulant, which is etched back to expose the tops of the spherical droplets. Using these access points, the meltable material may be etched away to leave a network of buried cylindrical pipes suitable for microchemical analysis systems (Fig. 1). Fig. 2 shows a verification of this principle, in structures formed by reactive ion etching and melting 15 μm thick layers of beryllium phosphate glass on Si.

Microactuation

The effects of capillary forces in micromechanisms are well known; often the results are unwanted, such as the stick-down of structures freed by wet etching, but useful effects have been shown, such as in flip-chip bonding or in 3-D micro-assembly (1). Here we have examined the use of surface tension to achieve reversible, electrically controlled actuation. The effect exploited is electro-wetting, in which the contact angle between a liquid electrolyte and a conducting surface is altered by an applied voltage. This results from the increase in the liquid-solid interfacial energy \( \gamma_{ls} \) due to the introduction of surface charges; the contact angle is dependent on \( \gamma_{ls} \) according to Young's equation. Surface tension actuation scales very favourably into micro-dimensions, with enormous forces being achievable. We have obtained resonant excitation of a simple beam structure using an electrolyte between Au and Pt surfaces, and have fabricated micro-mechanical actuators in Si for more detailed and precise investigation, as shown in Fig. 3. An advantage of the technique is that only low voltages (< 1 V) are necessary. However, there are difficulties with degradation of surfaces, and control of liquid volumes, which we are seeking to overcome. A longer term aim is to implement the mechanism in a conductive porous medium to form an 'artificial muscle' material.

Fig. 1 Process for micro-channel fabrication

Fig. 2 Etched and refloed glass structures

Fig. 3 Electro-wetting Si actuators with transparent counter-electrode