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Fabrication of High-resolution Stencil for Liquid Alloy patterning based on Shrinkable Film

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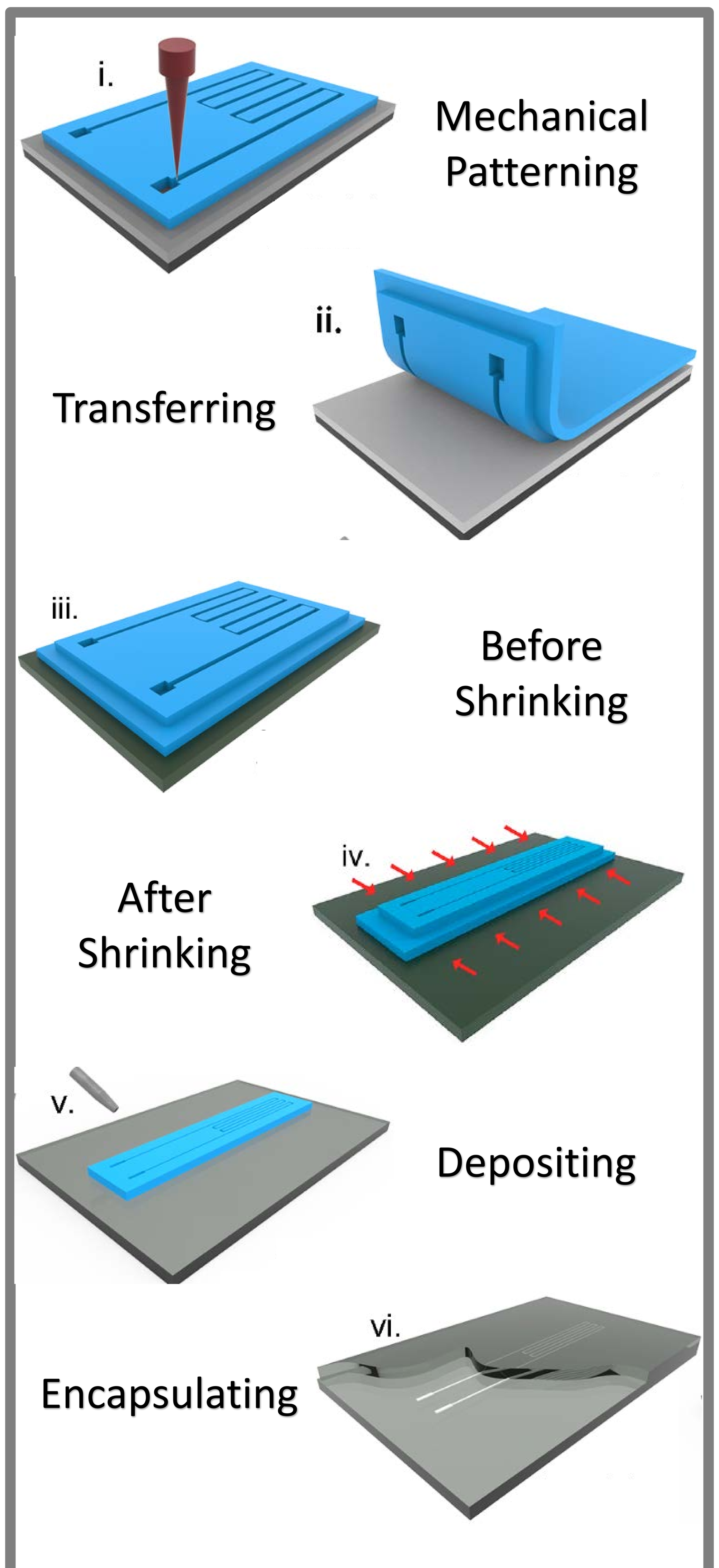
Introduction

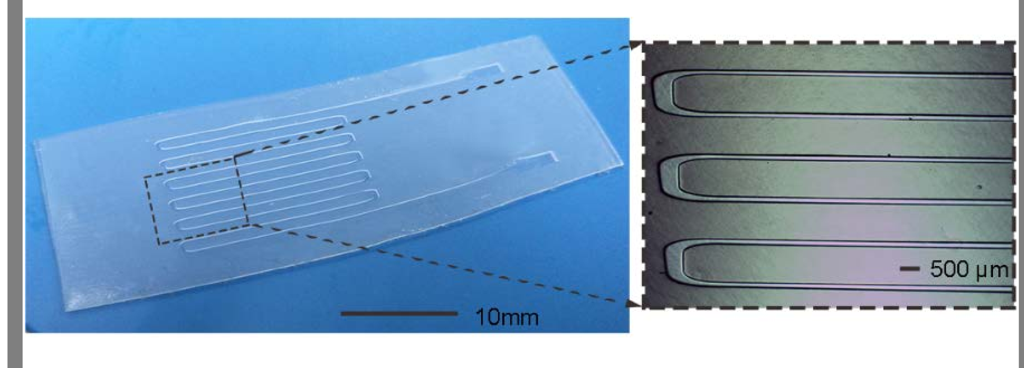
For any other mask-based process, its resolution is often constrained by the quality of the mask, and the fabrication cost increases drastically with increased resolution. In this work, we introduced a sandwiched thermal shrink polymer film masking technique for fine liquid alloy patterns, which were demonstrated by only using a mechanical cutting plotter together with a common oven.

With the relaxing of the polymer chain, shrink polymer film can shrink to a certain ratio after heating. By introducing shrink polymer film masking, the mask resolution could be tuned in some range towards higher resolution so that it becomes sufficient for more applications in stretchable electronics. Also, with different pre-stretched methods and parameters in manufacturing, the shrink polymer film could shrink uniaxially or biaxially with different shrink ratios. Here, we have found means to control the shrink ratio precisely and developed it into three-dimensional (3D) applications.

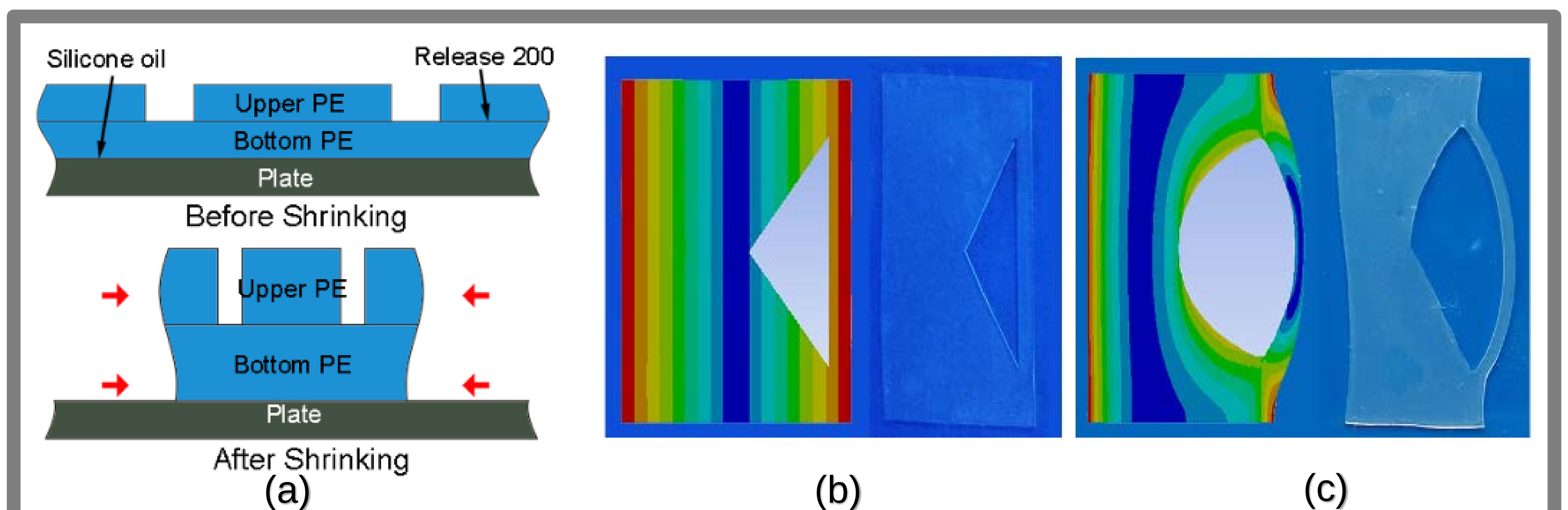
Methods



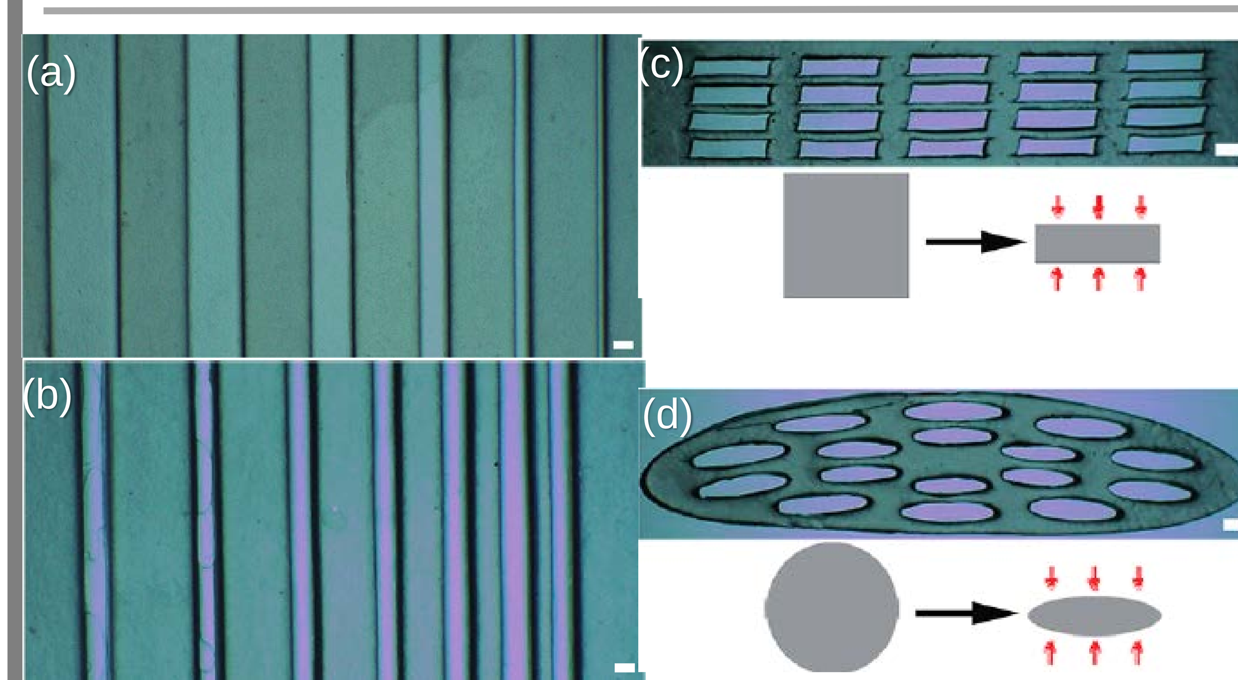
(Upper) Schematic of the fabrication process of a strain sensor using sandwiched polyethylene shrink film structure (Below) Photo of a shrunk mask film and pattern in details



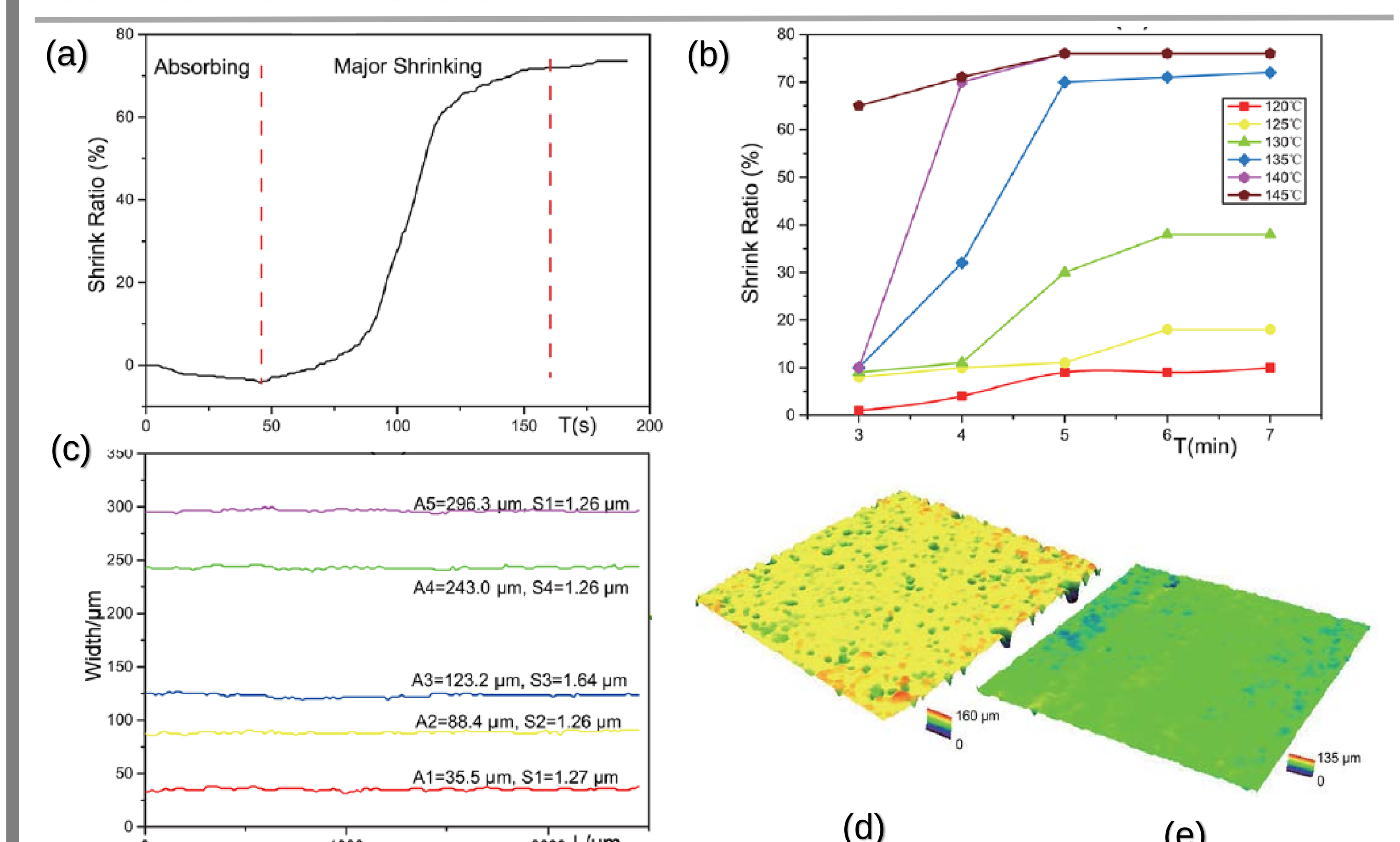
Result



(a) The cross section schematic of sandwiched polyethylene shrink film structure before / after shrinking (b) (c) Comparison of simulation and experiment result with (b) or without (c) sandwiched structure

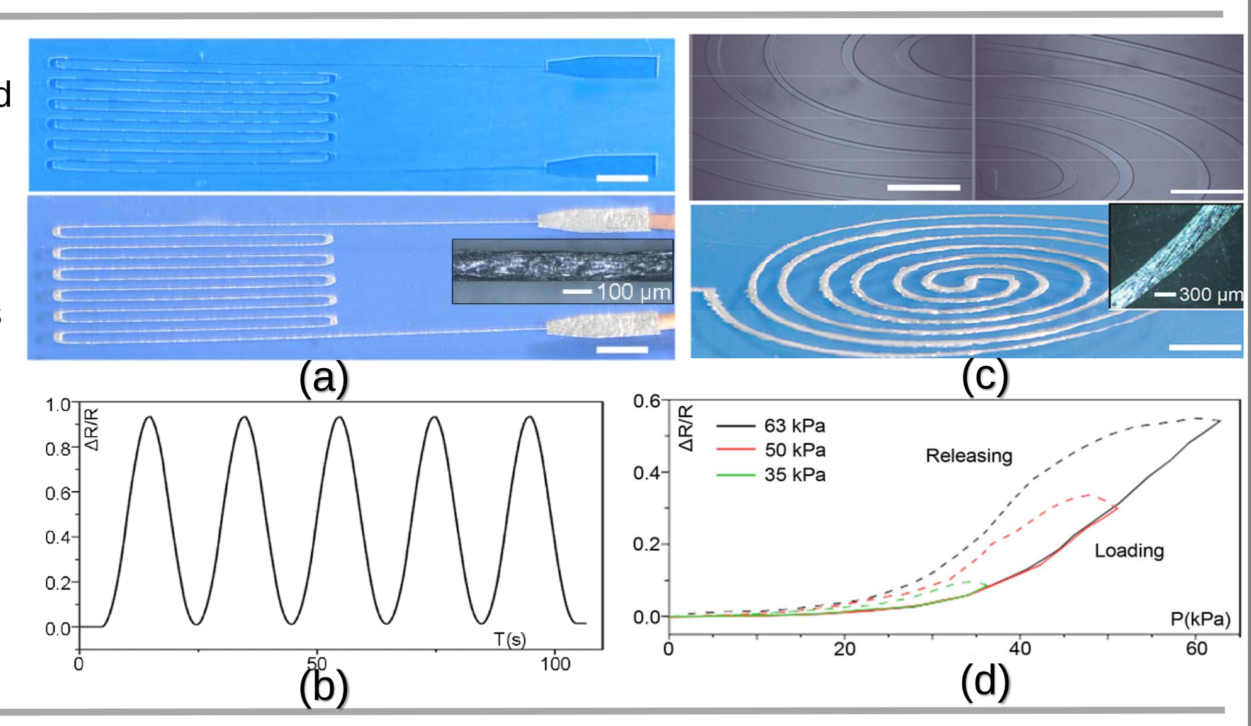


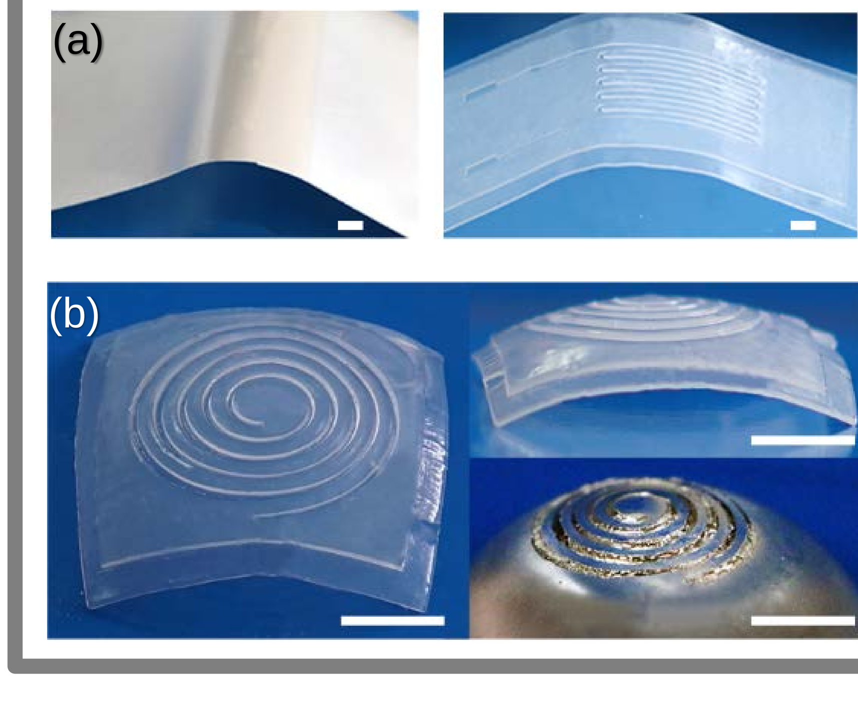
(a) The widths of channel are 34, 68, 136, 221, 284, and 358 μm, shrunk from the original 100, 200, 400, 600, 800, and 1000 μm, respectively. (b) The spaces are 60, 113, 173, 240, 298, and 349 μm, shrunk from the original 200, 400, 600, 800, 1000, and 1200 μm, respectively. Examples of the formation of matrix with rectangles (c) and ellipses (d) are shown right side.



(a) Shrink ratio versus time. (b) Shrink ratio versus time and temperature. (c) Width variation of the channel (A for average and S for standard deviation). The roughness of original (d) and shrunken (e) surface of PE film.

(a) Shrunken PE mask and deposited strain sensor, the inset is the partial micrograph of the circuit. (b) The resistance change of the strain sensor versus time. (c) A spiral tactile sensor (middle) deposited by a mask (top) shrunk from native circular-spiral and (d) its response to different maximum pressures





(a)To further explore the potential of this technique in masking, a cylindrical conformal mask was fabricated from an original planar pattern on PE film. It was then conformally shaped by pressurizing with a cylindrical steel sheet(left).
(b) the spatial mask was fabricated with a slightly modified process. The whole structure was entirely wrapped by another layer of PE film, which generated an even force to push the mask shrinking toward the surface of the steel hemisphere. Along with this spatial mask, a spiral circuit was deposited on a PDMS hemisphere.(below)

Conclusion

1.By introducing a thermal shrink polymer film, this technique provides a facile way to fabricate a mask with tunable resolution and shape.
2.With proper tuning, it can achieve a relatively high-resolution of mask from an initial mechanically produced low-resolution, which is a universal tool in micro-patterning.
3.The sandwiched structure, consisting of a double layer films and interface design, that enables a final high-quality mask, has been studied experimentally and numerically.
4.Moreover, with the characteristic of shrink polymer material, adjustable parameters like shrink ratio and anisotropy, and heating time and temperature, have been analyzed to better tune the resolution and shape of a mask.
5. A few sensors, like a strain sensor and a tactile sensor have been fabricated to demonstrate the capability of this technique.
6. Such technique can be developed into three-dimensional(3D) mask fabricating, which creates a new method to manufacture liquid alloy pattern or circuit on a spatial curved surface. A cylindrical-shape mask, a hemisphere-mask and a helix liquid alloy circuit on a PDMS hemisphere has been made to demonstrate the possibility respectively.

Acknowledgements

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Reference

(1) Rogers, J. A.; Someya, T.; Huang, Y. Materials and Mechanics for Stretchable Electronics. Science 2010, 327, 1603−1607.
(2) Kim, S.; Laschi, C.; Trimmer, B. Soft robotics: a Bioinspired Evolution in Robotics. Trends Biotechnol. 2013, 31, 287−294.
(3) Park, S. I.; Xiong, Y.; Kim, R. H.; Elvikis, P.; Meitl, M.; Kim, D. H.; Wu, J.; Yoon, J.; Yu, C. J.; Liu, Z.; Huang, Y.; Hwang, K.; Ferreira, P.; Li, X.; Choquette, K.; Rogers, J. A. Printed Assemblies of Inorganic Light-emitting Diodes for Deformable and Semitransparent Displays. Science 2009, 325, 977−981.
(4) Zhou, Y. X.; Hone, J.; Smith, W. F.; Johnson, A. T. Simple Fabrication of Molecular Circuits by Shadow Mask Evaporation. Nano Lett. 2003, 3, 1371−1374.
(5) Brambley, D.; Martin, B.; Prewett, P. D. Microlithography: an overview. Adv. Mater. Opt. Electron. 1994, 4, 55−74.
(6) Hidber, P. C.; Helbig, W.; Kim, E.; Whitesides, G. M. New Strategy for Controlling the Size and Shape of Metallic Features Formed by Electroless Deposition of Copper: Microcontact Printing of Catalysts on Oriented Polymers, Followed by Thermal Shrinkage. Langmuir 1996, 12, 5209−5215.