Supporting Information

Adhesiveless Transfer Printing of Ultrathin Microscale Semiconductor Materials by Controlling the Bending Radius of an Elastomeric Stamp

Sungbum Cho[†], Namyun Kim[†], Kwangsun Song[†‡], Jongho Lee[†‡]*

[†]School of Mechanical Engineering, and [‡]Research Institute for Solar and Sustainable Energies (RISE), Gwangju Institute of Science and Technology (GIST), 123 Cheomdan-gwagiro, Buk-gu, Gwangju 61005, Republic of Korea

*E-mail: jong@gist.ac.kr

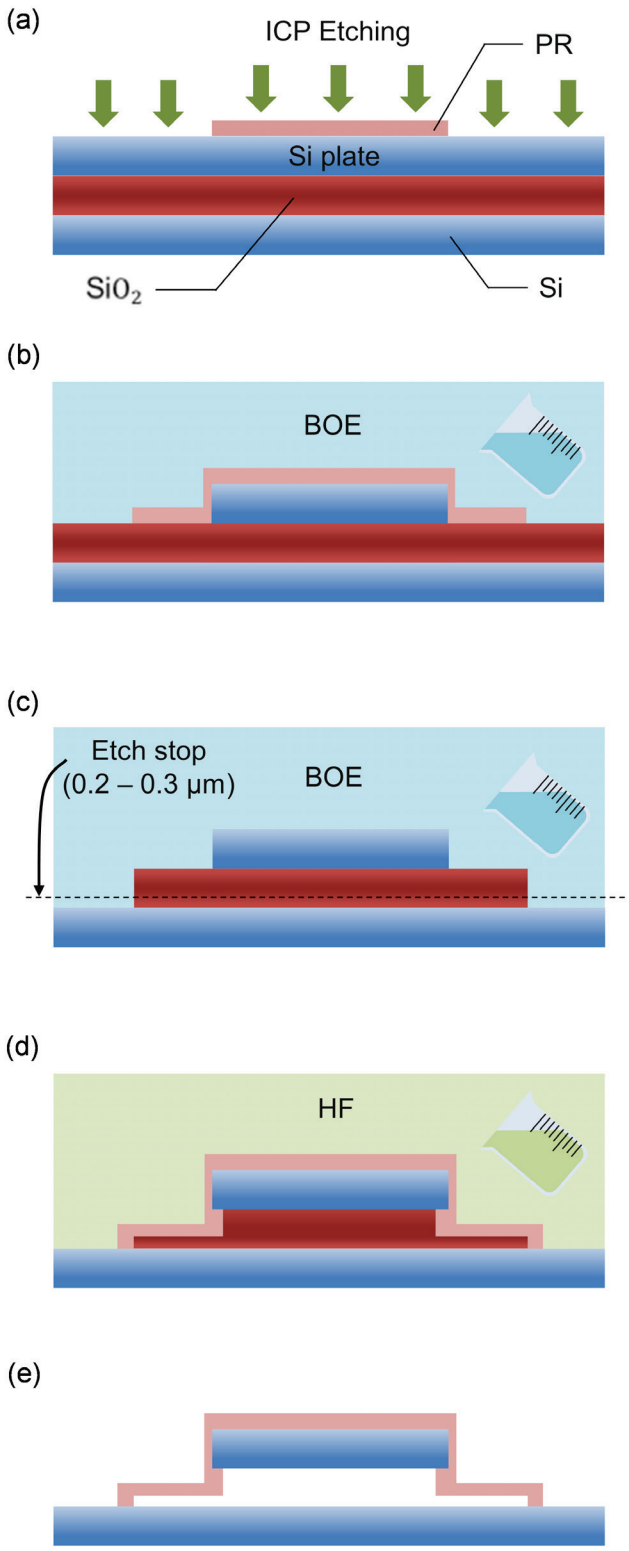

(a)
ICP Etching
PR
Si plate
SiO_2
Si
(b)
BOE
(c)
Etch stop
(0.2 – 0.3 μm)
BOE
(d)
HF
(e)

Figure S1. Schematic illustrations of steps of fabrication process for micro Si plates. (a) Dry etching (ICP-etching) a Si layer (thickness of ~7 μm) of a silicon on insulator (SOI) wafer except the area masked with patterned positive photoresist (PR). (b) Wet chemical etching the exposed oxide layer (thickness of ~1 μm) with buffered oxide etch (BOE) after the micro Si plates were completely covered with PR. (c) Wet etching the exposed oxide layer with BOE without patterned PR until the thickness of the sacrificial layer reaches the etch stop level ($0.2 - 0.3$ μm). (d) Anchoring with PR and removing the underlying oxide layer with hydrofluoric acid (HF). (e) Micro Si plate temporarily supported by the anchor.

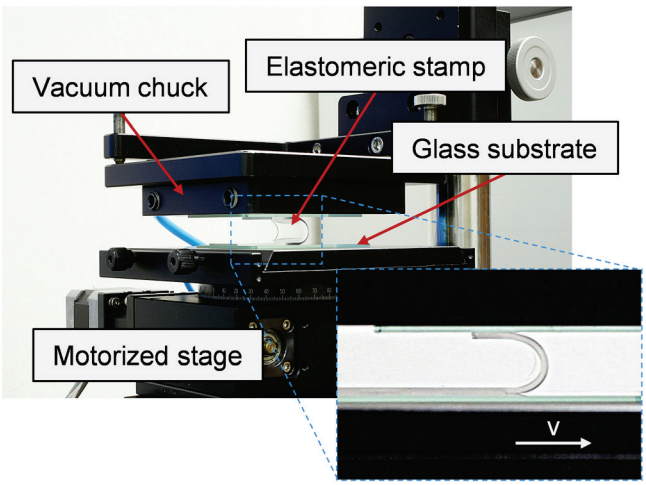


Figure S2. Images of multi-axis transfer printing system consisting of a vacuum chuck, custom-built motorized stage. Flat stamp is bent on glass substrates mounted on the vacuum chuck and the stage, then the stage translates at predetermined velocity.

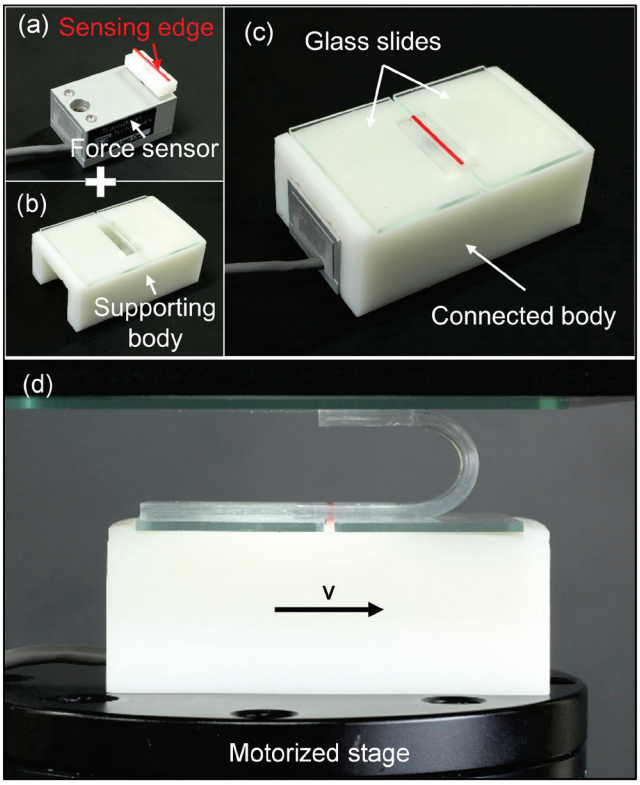


Figure S3. The pressure measurement system. (a) Sensing edge combined with a force sensor (GSO-1k, Transducer Techniques), (b) custom supporting body with glass slides, and (c) a connected body of two parts. (d) Assembled pressure measurement system of the motorized stage and the combined body.

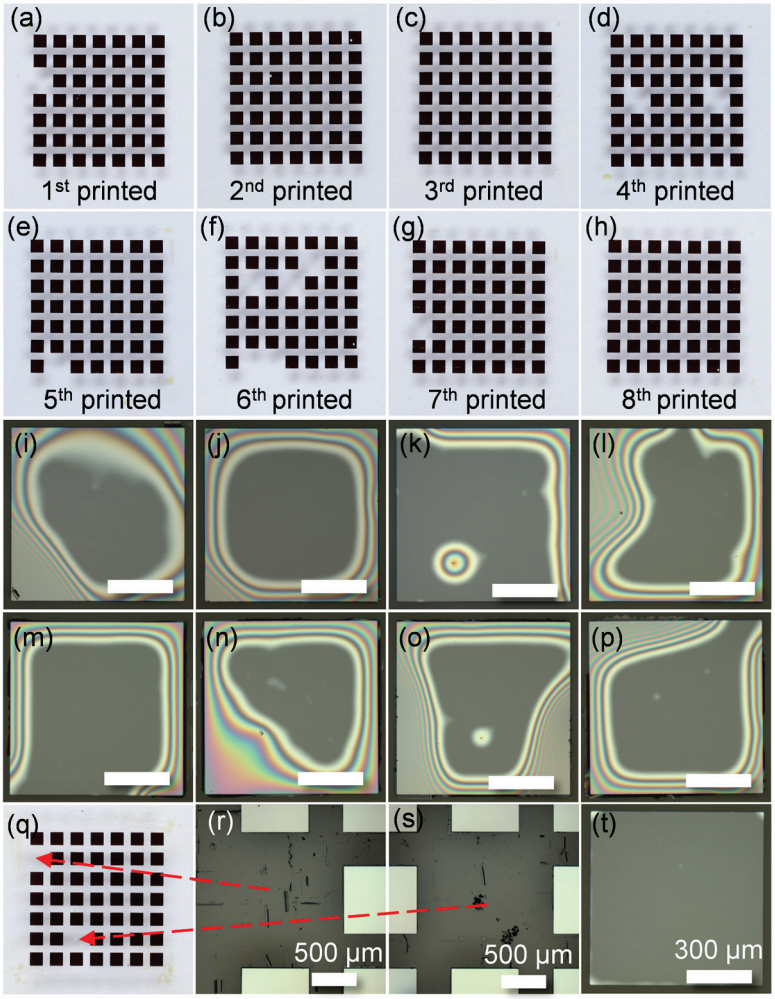


Figure S4. Results of transfer printing the eight sets of micro Si plate arrays (size, 760 × 760 μm) without cleaning the PDMS stamp and bottom surfaces of the micro Si plates. (a−h) Eight sets of the micro Si plate arrays transfer printed on glass substrates. The printing yield is about 97.4 %. (i−p) Bottom surfaces of the printed micro Si plates without cleaning process. The dark areas indicate contact region. Scale bars are 300 μm. (q) Micro Si plate array picked up at 9th trial with the PDMS stamp. (r and s) There are PR residues around the regions where the micro Si plates are not picked up. (t) Micro Si plate transfer printed on a glass substrate after the bottom surface was cleaned. The micro Si plate makes a full contact with the substrate.

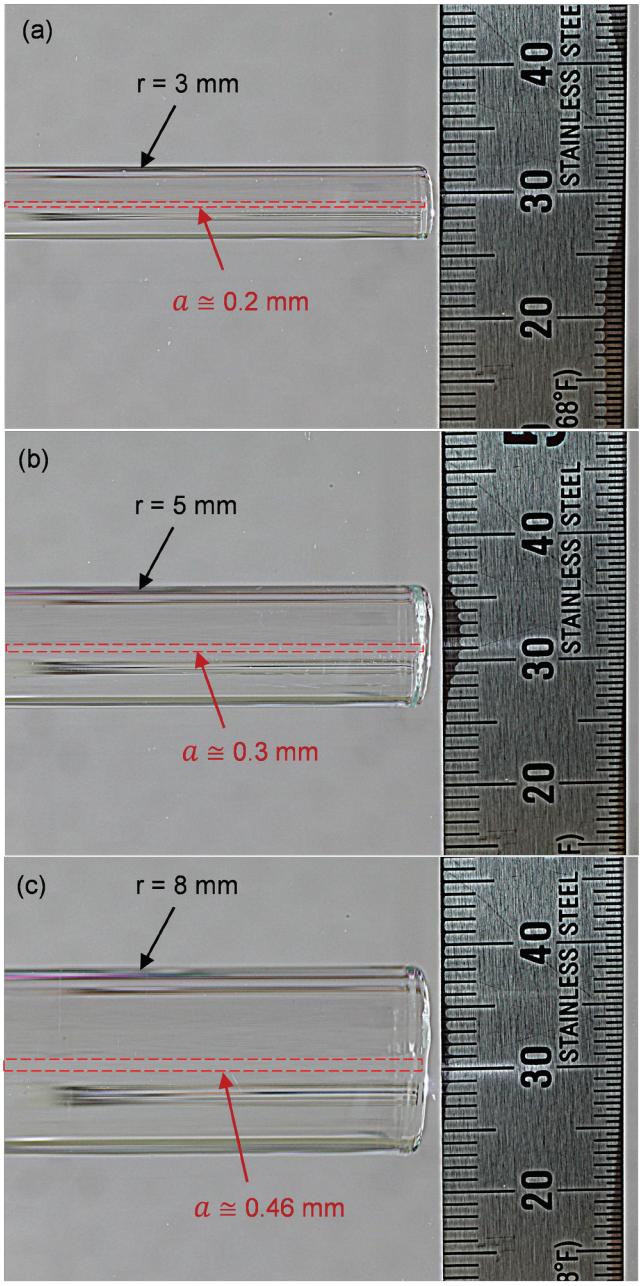


Figure S5. Contact widths of the glass rods in contact with the PDMS layer (thickness of ~7 mm). The images were taken from the bottom of the PDMS layer mounted on a transparent glass slide. For (a) r = 3 mm, (b) 5 mm, and (c) 8 mm, the contact widths are 0.2, 0.3, and 0.46 mm, respectively.

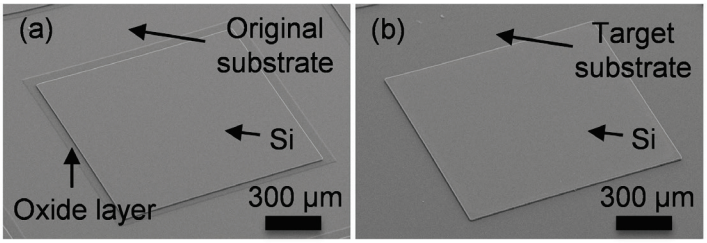


Figure S6. Scanning electron microscopy (SEM) images (a) before and (b) after transfer printing. There is no apparent difference on the surfaces of the micro Si plate.

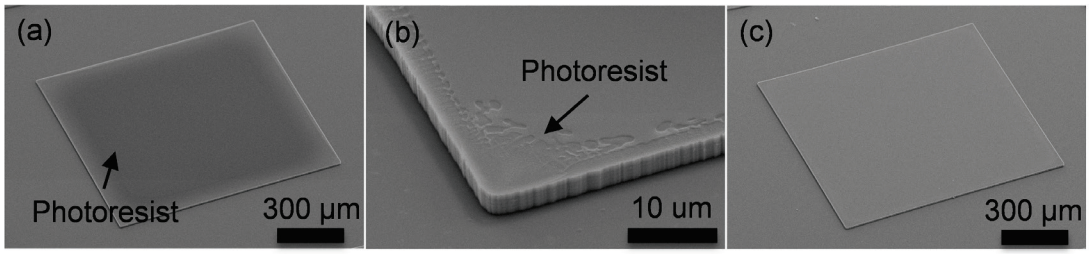
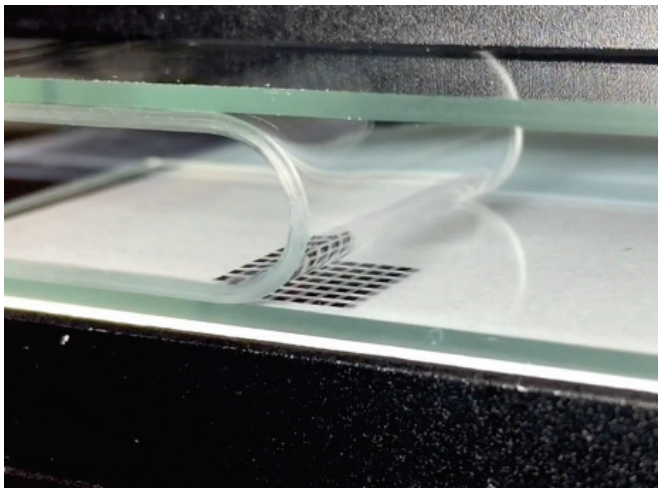


Figure S7. SEM images of the transfer printed micro Si plate before and after cleaning with acetone. (a) Micro Si plate covered with the PR layer on the top surface. (b) Magnified SEM image of the micro Si plate covered with the PR layer. Some parts of the PR layer were left on the PDMS stamp while peeling. (c) Top surface of the micro Si plate after cleaning the PR layer with acetone.



Move S1. Video clip of the micro Si plate array being printed on the glass substrate by bending and peeling the PDMS stamp (stamp thickness, 1 mm; bending radius, 5 mm).