

Elastic integrated electronics based on a stretchable n-type elastomer–semiconductor–elastomer stack

In the format provided by the
authors and unedited

Supplementary Notes

1. Calculation of field-effect mobility and threshold voltage

The μ_{FE} was calculated by fitting the plot of the linear regime in the curve of $\sqrt{I_{DS}}$ versus V_{GS} based on the following equation:

$$I_{DS} = \frac{WC_i\mu_{FE}}{2L}(V_{GS} - V_{TH})^2 \quad (S1)$$

$$\sqrt{I_{DS}} = \sqrt{\frac{WC_i\mu_{FE}}{2L}}(V_{GS} - V_{TH}) = \sqrt{\frac{WC_i\mu_{FE}}{2L}}V_{GS} - \sqrt{\frac{WC_i\mu_{FE}}{2L}}V_{TH} \quad (S2)$$

$$Slope = \sqrt{\frac{WC_i\mu_{FE}}{2L}} \quad (S3)$$

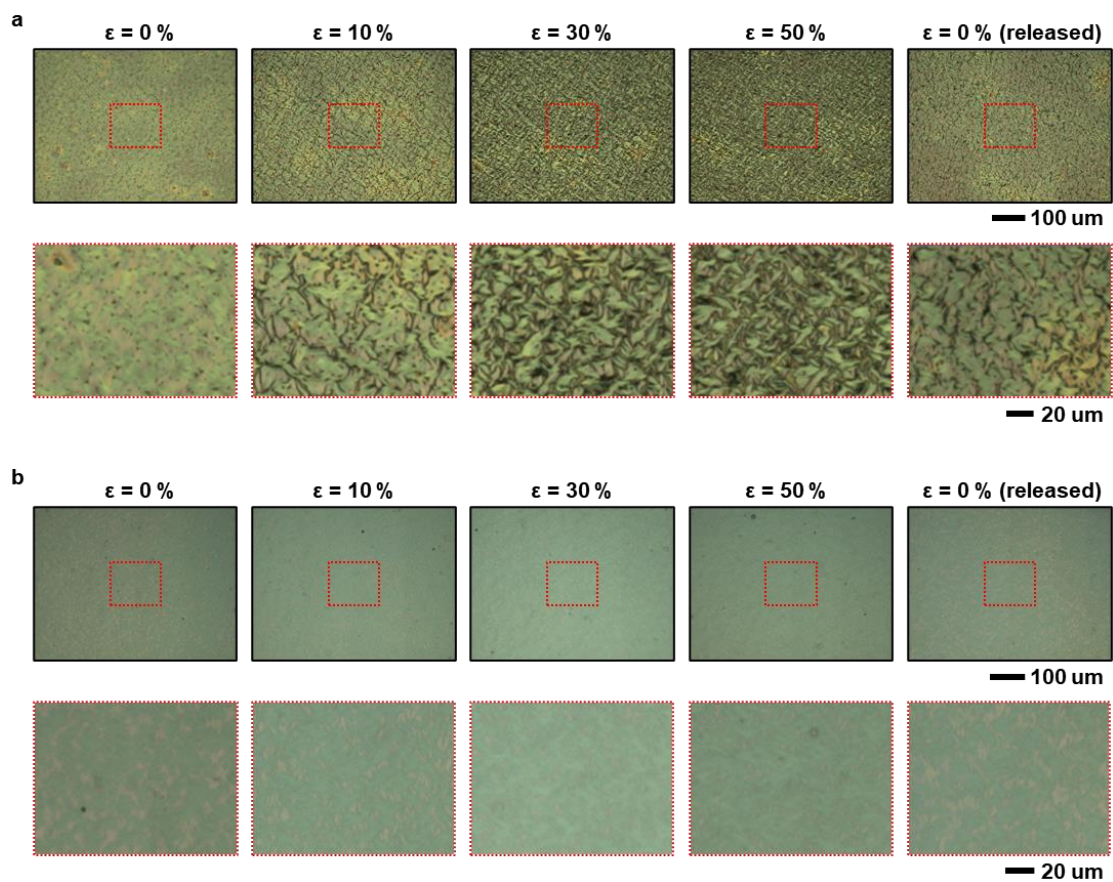
$$\mu_{FE} = \frac{2L}{WC_i}(Slope)^2 \quad (S4)$$

where L , W , and C_i are the channel length, the width, and the specific capacitance of the gate dielectrics, respectively. The threshold voltage (V_{TH}) is defined by the x-intercept of the extrapolation of the fitted curve.

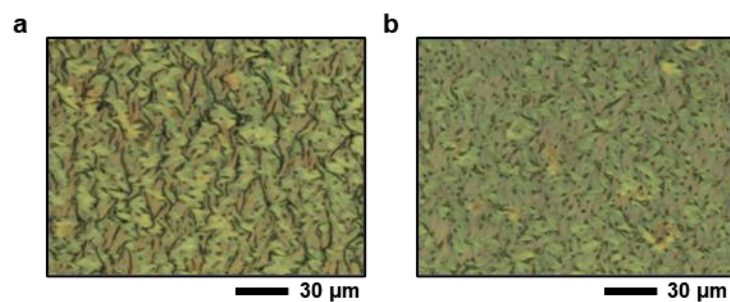
2. Data acquisition of the curvature-adjustable imager

The readout and voltage applying of a curvature-adjustable imager were achieved by a data acquisition system (National Instruments). The schematic circuit diagram of the active matrix and interface with the data acquisition is shown in Supplementary Fig. 26. To apply voltage in 8-word lines and V_{DD} , the devices were interfaced to the NI PXI-6723 (National Instruments) through a SCB-68 shielded I/O connector block. A NI PXI-6363 (National Instruments) was interfaced through another SCB-68 shielded I/O connector block for voltage readout from the bit line of the curvature-adjustable imager.

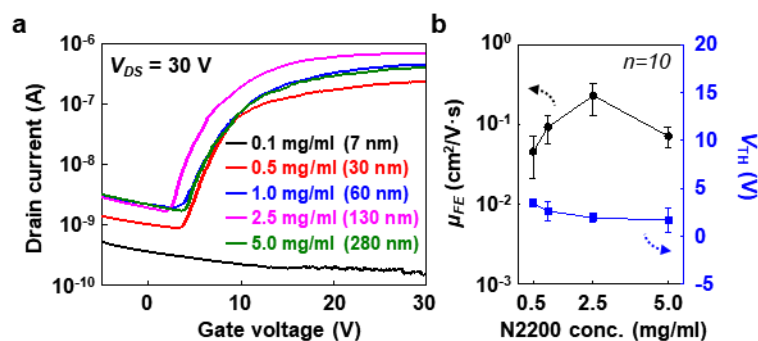
Supplementary Figures



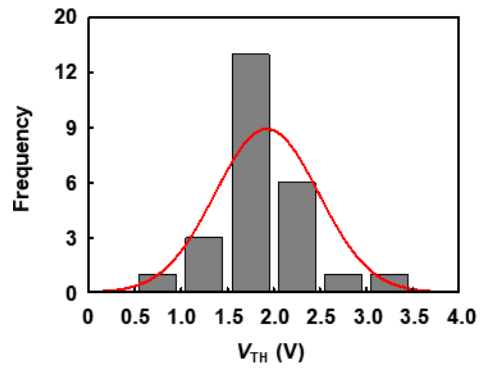
Supplementary Fig. 1. Detailed morphologies of the N2200 films without and with PU. a,b, Optical microscope images of N2200 on PDMS without (a) and with (b) PU encapsulation under different tensile strain.



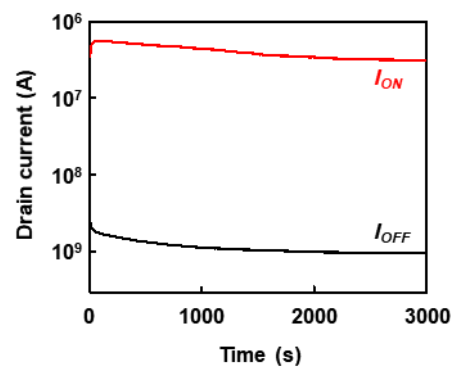
Supplementary Fig. 2. Optical microscope images of N2200 after stretching ($\varepsilon = 50\%$) and releasing ($\varepsilon = 0\%$). **a**, N2200 film on PDMS without PU encapsulation. **b**, N2200 film on PDMS with PU encapsulation after removing PU by DMF once the film was released after stretching.



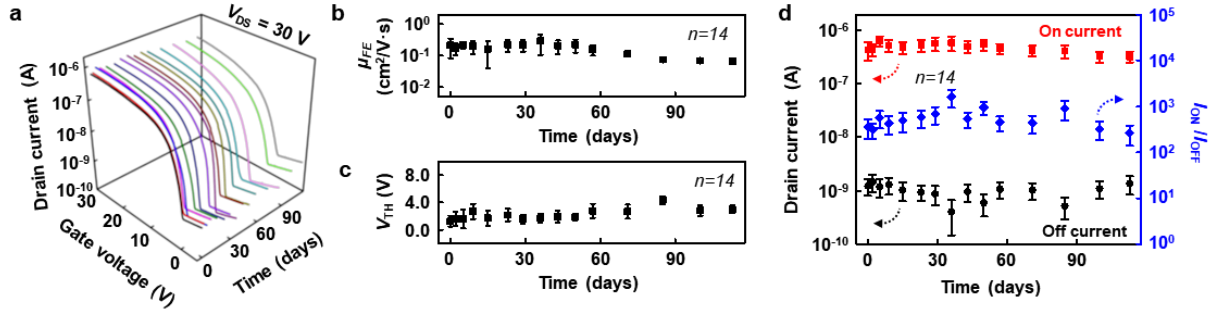
Supplementary Fig. 3. Electrical characterization of the stretchable n-type organic transistor with different concentrations of N2200. **a**, Transfer characteristics of the device at the different concentrations of N2200 solution. **b**, The μ_{FE} and V_{TH} of the transistor depending on the concentration of N2200. Data are presented as mean values $\pm$ one standard deviation based on measurements from ten devices.



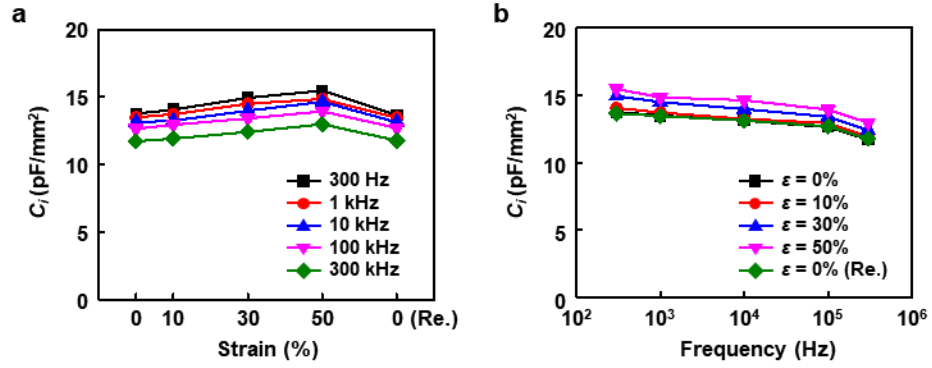
Supplementary Fig. 4. The statistical distribution of the V_{TH} in the stretchable n-type organic transistor array.



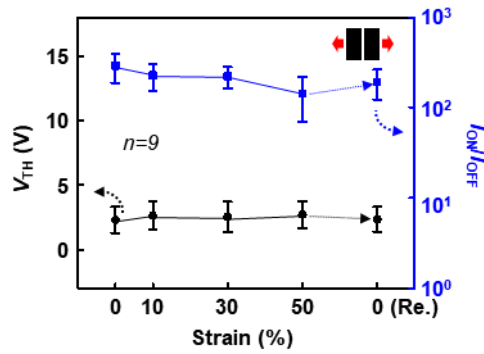
Supplementary Fig. 5. Electrical response of the stretchable n-type organic transistor under operation for 3000 s.



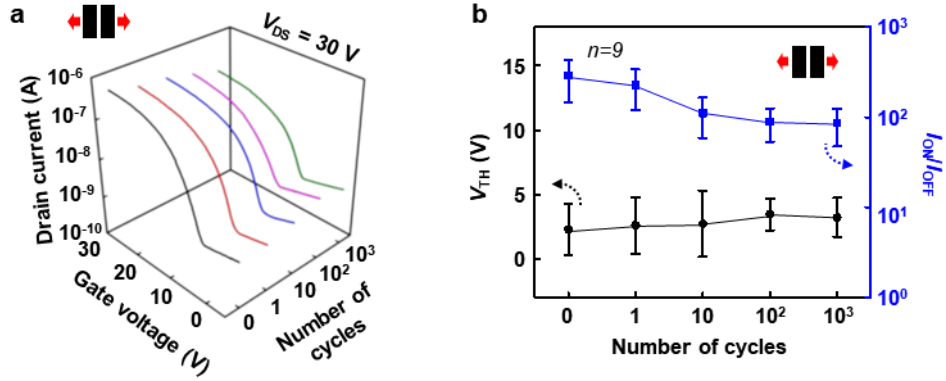
Supplementary Fig. 6. The long-term stability of the stretchable n-type organic transistor. a-d, Transfer characteristics (a), μ_{FE} (b), V_{TH} (c), drain current (d, red and black), and I_{ON}/I_{OFF} (d, blue) of the transistor for 113 days at an ambient environment. Data are presented as mean values $\pm$ one standard deviation based on measurements from fourteen devices.



Supplementary Fig. 7. The specific capacitance of PU. **a**, The specific capacitance of PU at different frequencies under different tensile strain. **b**, The specific capacitance of PU at different tensile strain depending on frequency.

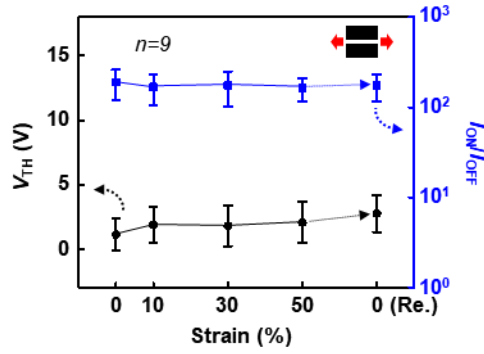


Supplementary Fig. 8. V_{TH} and I_{ON}/I_{OFF} of the stretchable n-type organic transistor under the tensile strain of 0%, 10%, 30%, 50%, and 0% (released) along with the channel length direction. Data are presented as mean values $\pm$ one standard deviation based on measurements from nine devices.

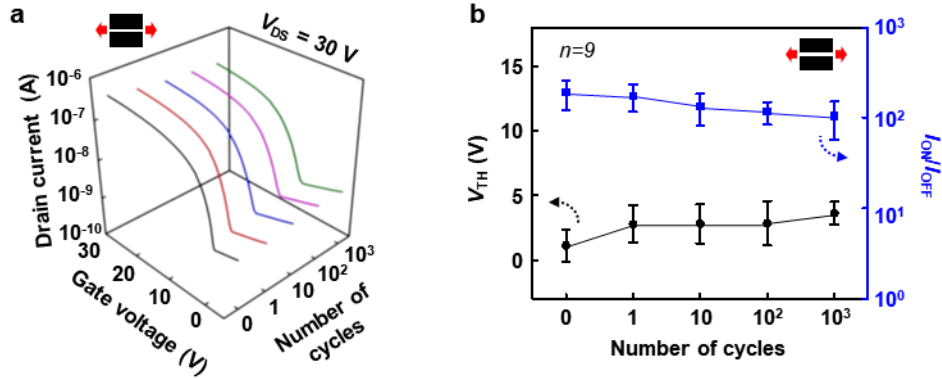


Supplementary Fig. 9. Electrical performance of the stretchable n-type organic transistor depending on the number of stretching cycles ($\varepsilon = 50\%$) along the channel length direction.

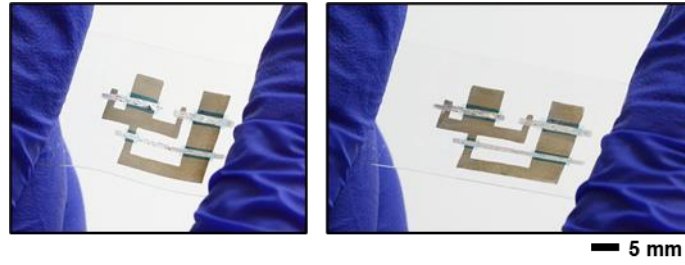
a, Transfer characteristics of the stretchable n-type organic transistor at the number of stretching cycles. **b**, V_{TH} and I_{ON}/I_{OFF} of the stretchable n-type organic transistor depending on the number of stretching cycles. Data are presented as mean values $\pm$ one standard deviation based on measurements from nine devices.



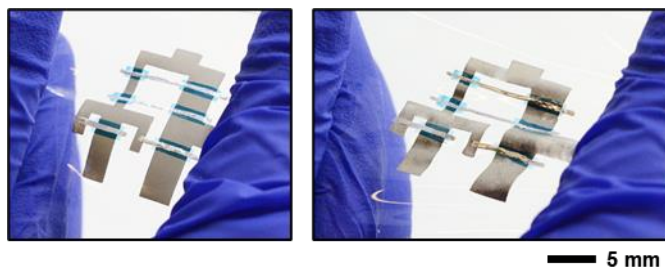
Supplementary Fig. 10. V_{TH} and I_{ON}/I_{OFF} of the stretchable n-type organic transistor under tensile strain of 0%, 10%, 30%, 50%, and 0% (released) perpendicular to the channel length direction. Data are presented as mean values $\pm$ one standard deviation based on measurements from nine devices.



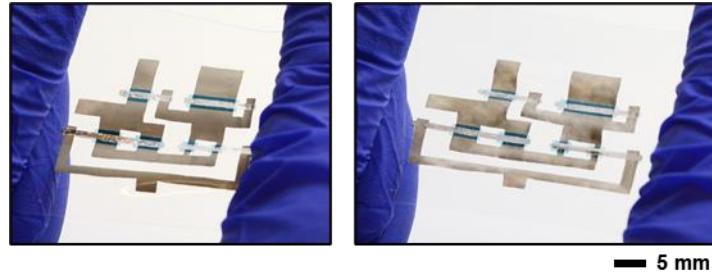
Supplementary Fig. 11. Electrical performance of the stretchable n-type organic transistor depending on the number of stretching cycles ($\varepsilon = 50\%$) perpendicular to the channel length direction. **a, Transfer characteristics of the stretchable n-type organic transistor depending on the number of stretching cycles. **b**, V_{TH} and I_{ON}/I_{OFF} of the stretchable n-type organic transistor depending on the number of stretching cycles. Data are presented as mean values $\pm$ one standard deviation based on measurements from nine devices.**



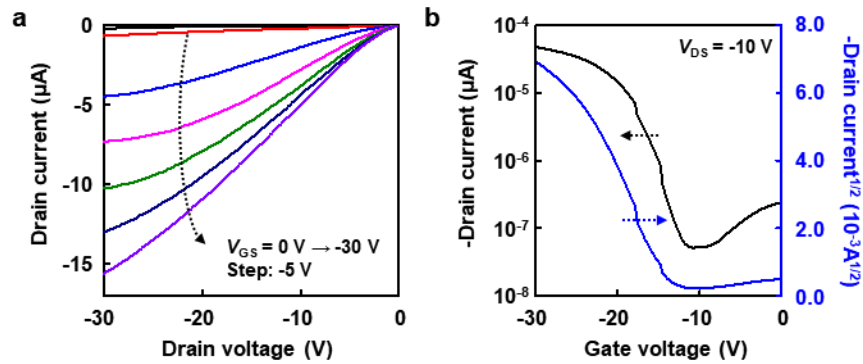
Supplementary Fig. 12. Optical images of the stretchable pseudo-complementary inverter without and with the tensile strain perpendicular to the channel length direction.



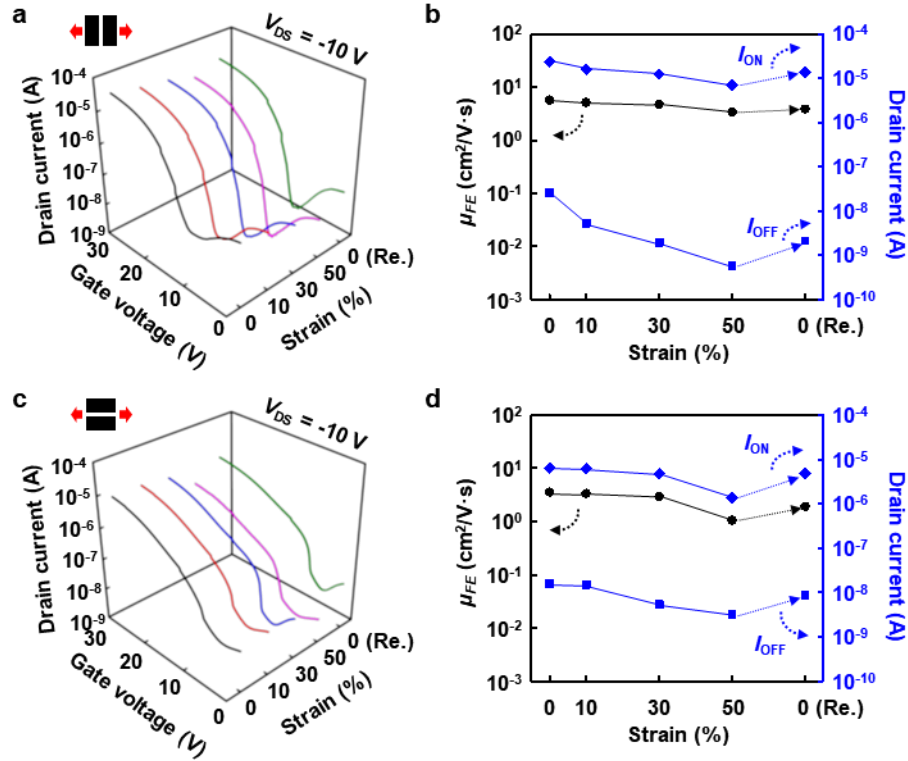
Supplementary Fig. 13. Optical images of the stretchable NAND gate without and with the tensile strain perpendicular to the channel length direction.



Supplementary Fig. 14. Optical images of the stretchable NOR gate without and with the tensile strain perpendicular to the channel length direction.

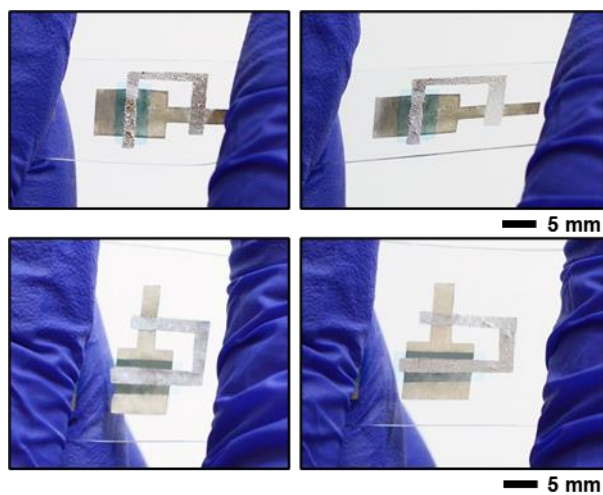


Supplementary Fig. 15. Electrical performance of the stretchable p-type transistor based on s-CNT networks. a,b, Representative output (a) and transfer (b) characteristics of the stretchable p-type transistor.

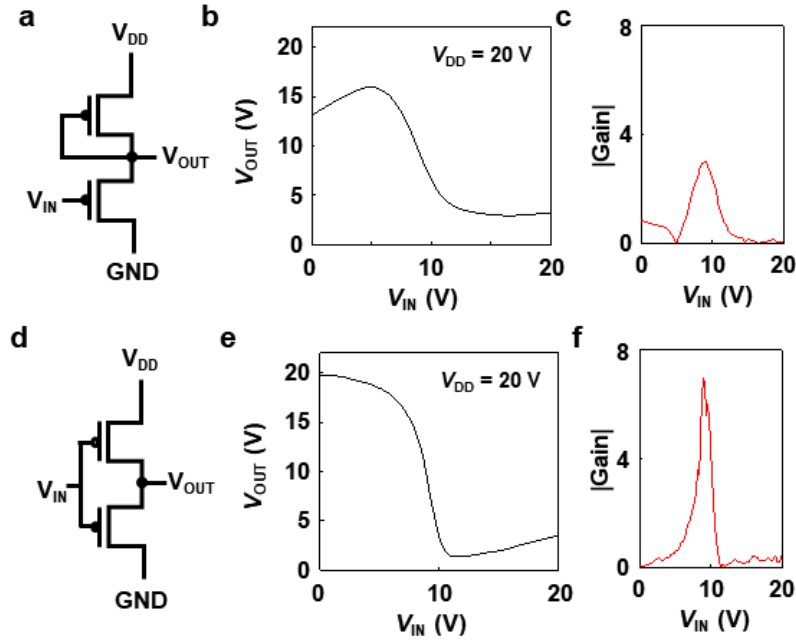


Supplementary Fig. 16. Electrical performance of the stretchable p-type transistor based on s-CNT networks depending on the tensile strain (0%, 10%, 30%, 50% and, 0% (released)).

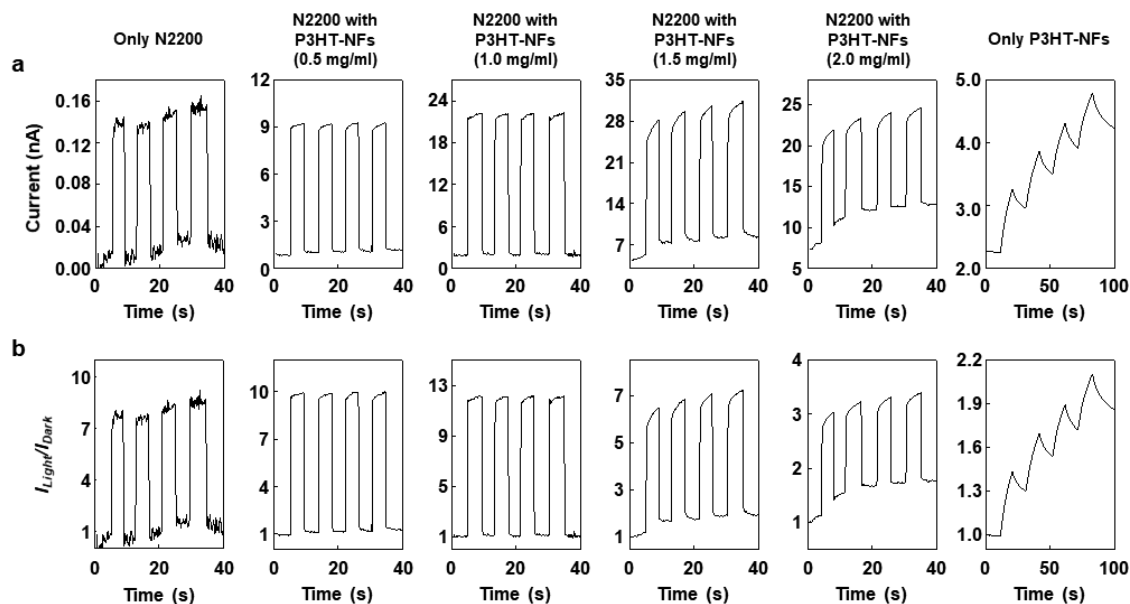
a, Transfer characteristics of the stretchable p-type transistor at different tensile strain along the channel length direction. **b**, The field-effect mobility and drain current of the stretchable p-type transistor depending on the tensile strain along the channel length direction. **c**, Transfer characteristics of the stretchable p-type transistor at different tensile strain perpendicular to the channel length direction. **d**, The field-effect mobility and drain current of the stretchable p-type transistor depending on the tensile strain perpendicular to the channel length direction.



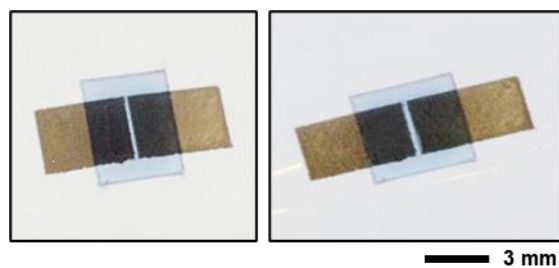
Supplementary Fig. 17. Optical images of the stretchable complementary inverter under the tensile strain along (upper) and perpendicular (lower) to the channel length direction.



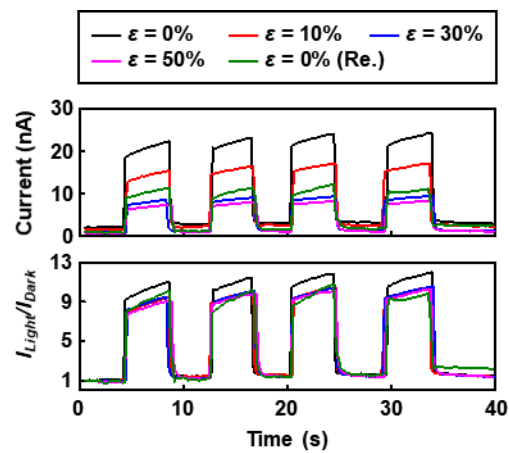
Supplementary Fig. 18. Comparison between zero- V_{GS} inverter based on only n-type transistor and complementary inverter. a-c, The circuit diagram (a), VTC (b), and gain (c) of the zero- V_{GS} inverter based on only n-type transistor. **d-f,** The circuit diagram (d), VTC (e), and gain (f) of the complementary inverter based on n-type and p-type transistors.



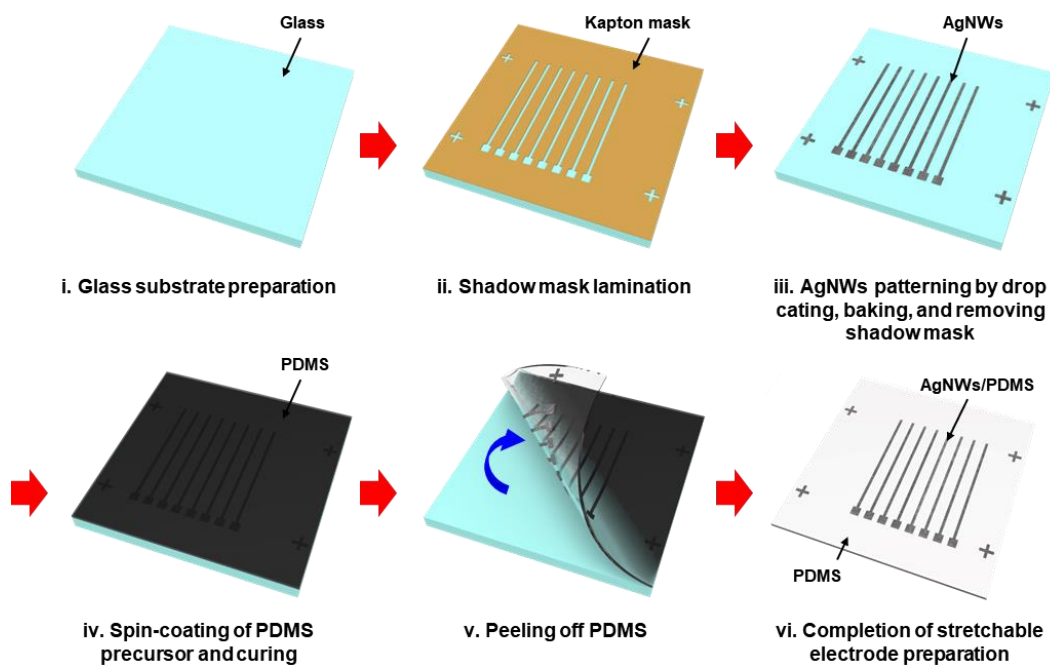
Supplementary Fig. 19. Dynamic photoresponse of photodetector using different concentrations of P3HT-NFs. a,b, Measured current (a) and calculated I_{Light}/I_{Dark} (b) at different concentrations of P3HT-NFs (0, 0.35, 1.0, 1.5, and 2.5 mg/ml) and constant concentration of N2200 (2.5 mg/ml).



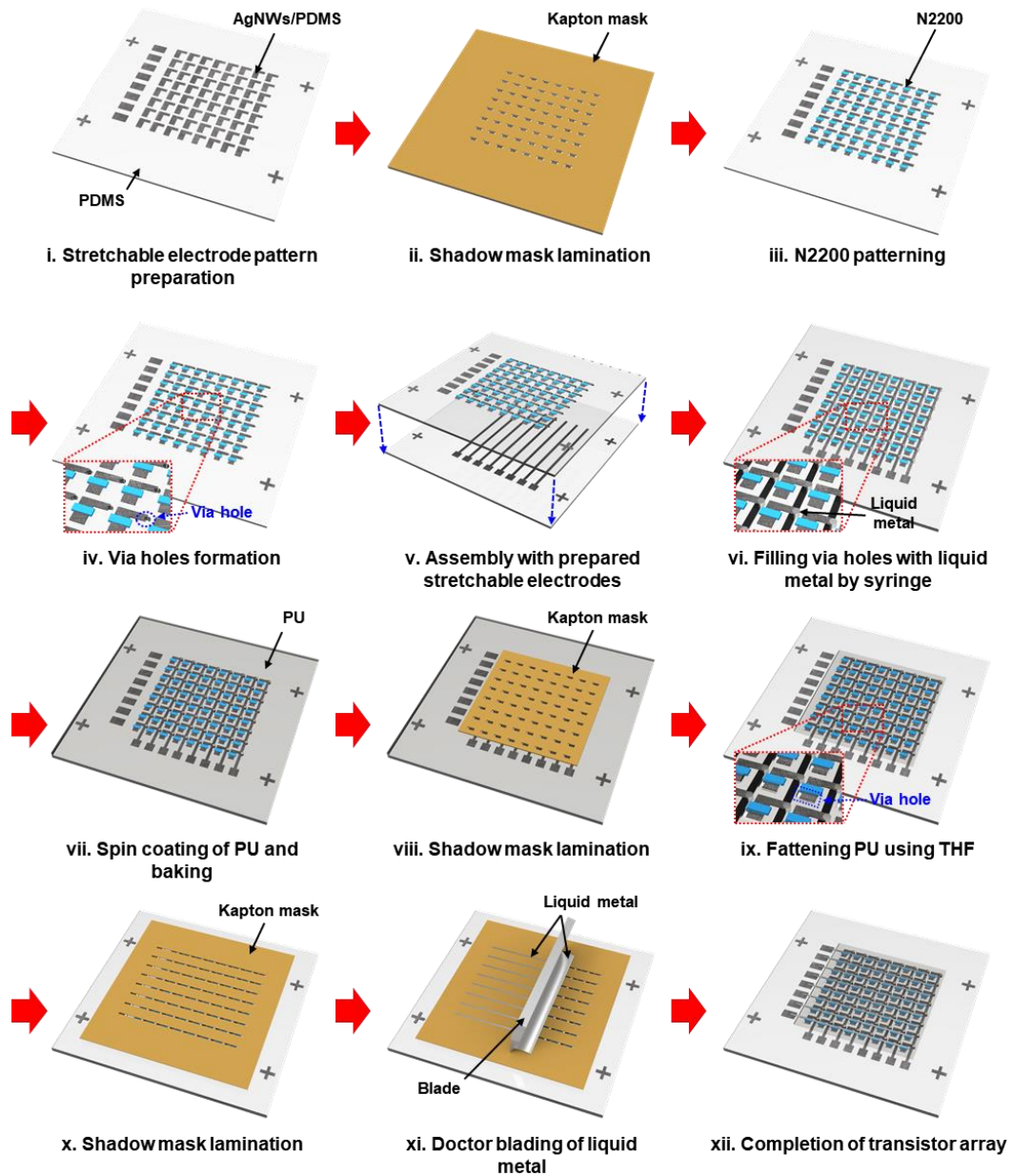
Supplementary Fig. 20. Optical images of the stretchable photodetector without and with tensile strain.



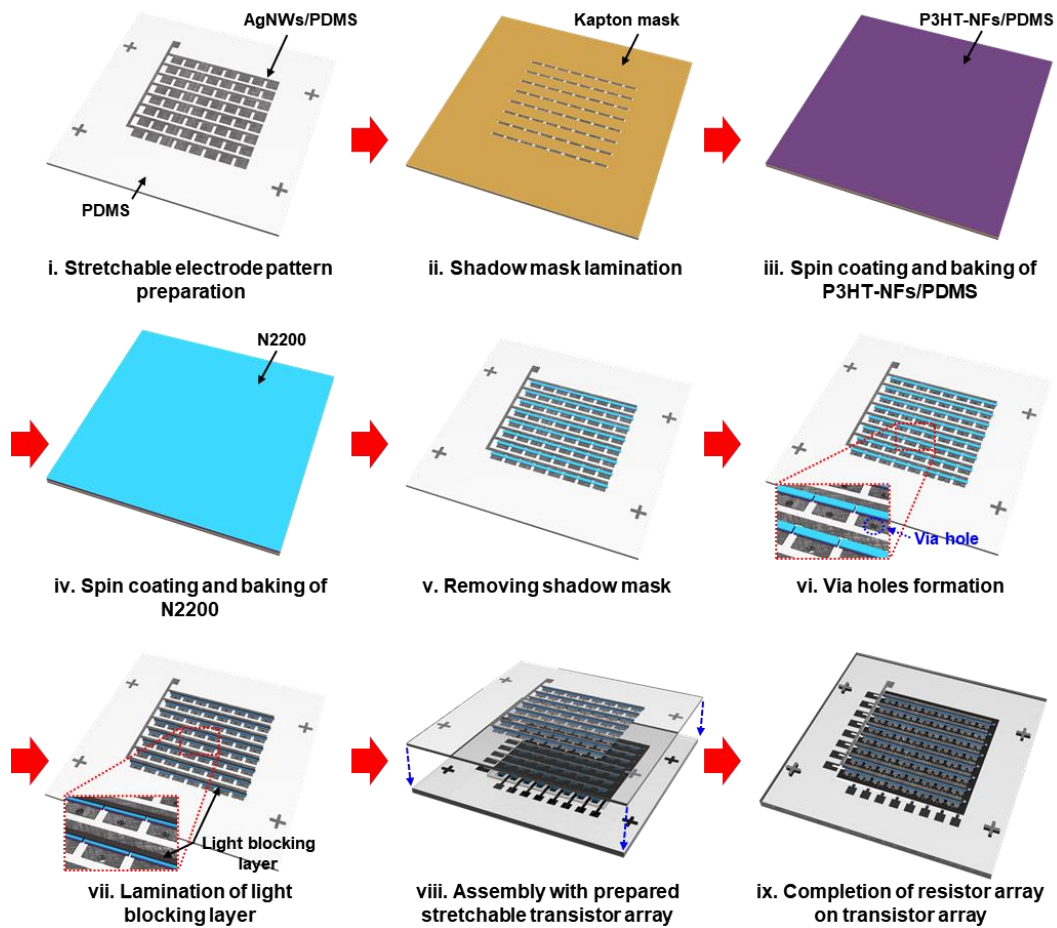
Supplementary Fig. 21. Photoresponse property of the stretchable photodetector at the different tensile strain of 0%, 10%, 30%, 50%, and 0% (released).



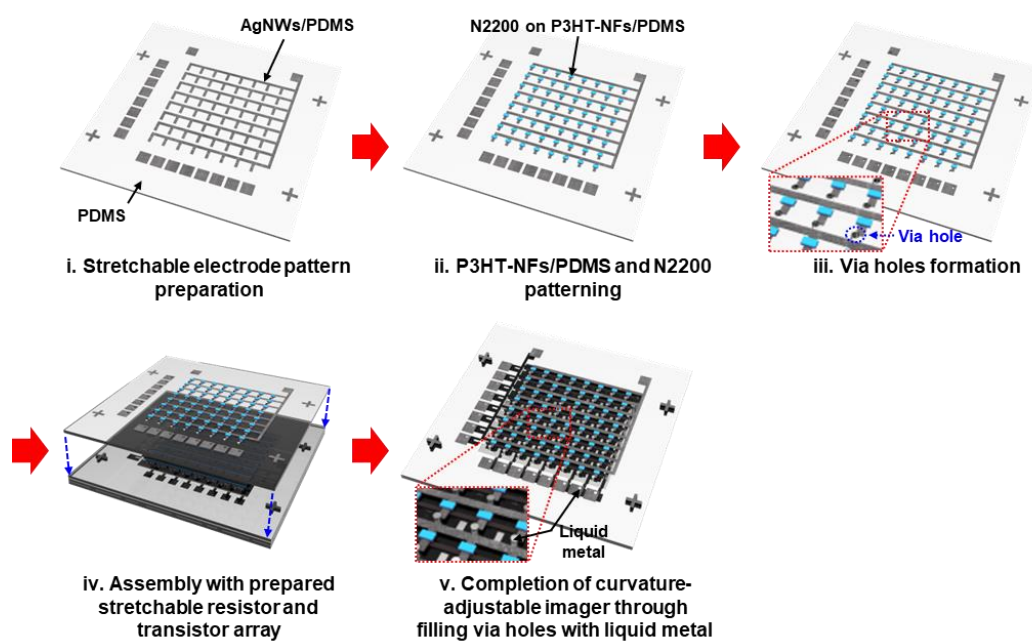
Supplementary Fig. 22. The schematic fabrication process of the electrode array for the curvature-adjustable imager.



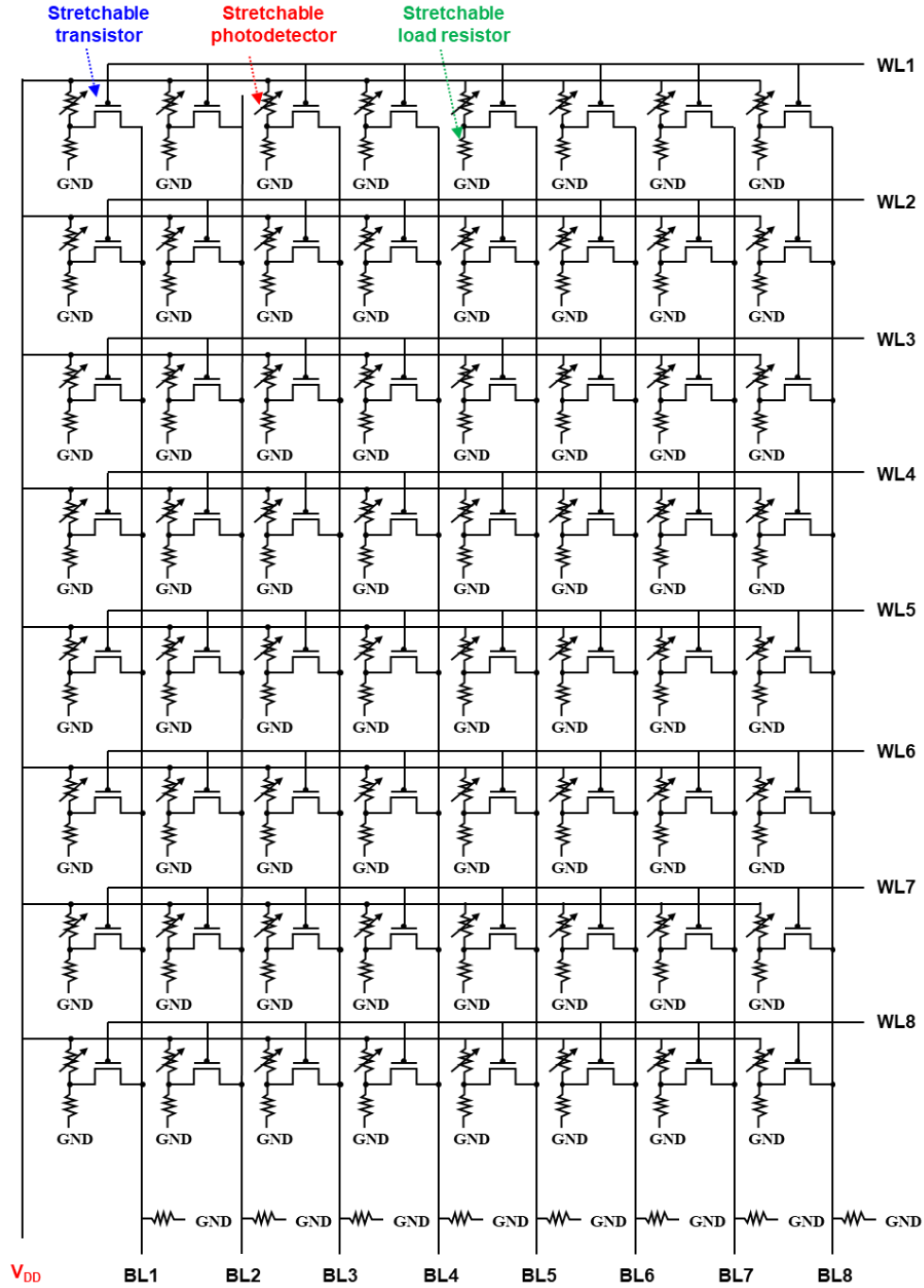
Supplementary Fig. 23. The schematic fabrication process of the transistor array for the curvature-adjustable imager.



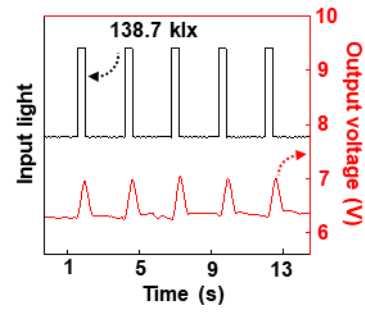
Supplementary Fig. 24. The schematic fabrication process of the load resistor array for the curvature-adjustable imager.



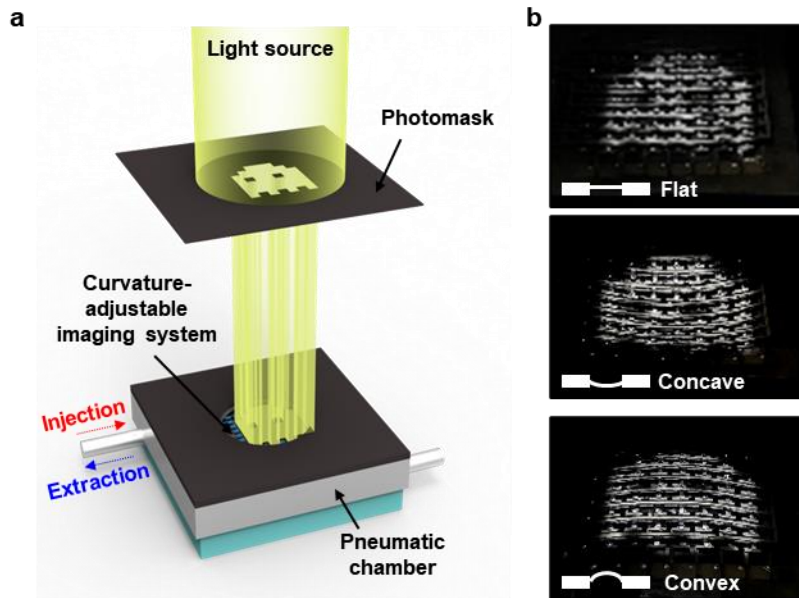
Supplementary Fig. 25. The schematic fabrication process of the photodetector array and completion of the curvature-adjustable imager.



Supplementary Fig. 26. Circuit diagram of the 8×8 active matrix-based curvature-adjustable imager.



Supplementary Fig. 27. The voltage output result of the single sensing pixel of the imager corresponding to light projection.



Supplementary Fig. 28. The schematic illustration of the test setup for the curvature-adjustable imager (a) and optical image of the device during the deformation test (b).