Supporting Information

Inkjet 3D-printing of stretchable silk membrane for strain measurements

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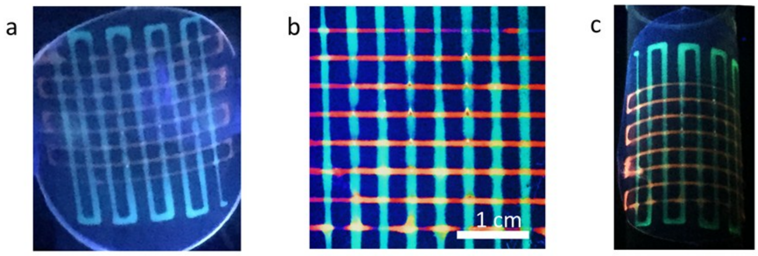


Fig. S1 Photographs of 3D-printed silk pattern on (a) polypropylene film (b and c) silk film under UV light irradiation. The red pattern was printed by rhodamie B-silk ink (red) and rhodamie 123-silk ink (green). a, c) the pattern was deformed with the substrate.

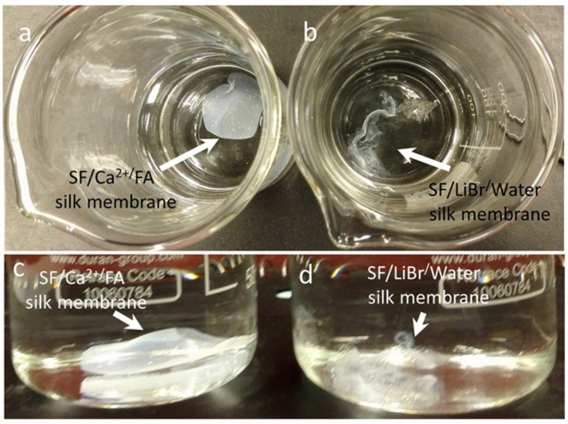


Fig. S2 Photographes of silk membranes immerged in water for 10 min at room temperatrue. a, c) The silk membrane was prepared by Formic Acid (FA)/$CaCl_2$ solvent; b, d) The silk membrane was prepared by LiBr/water solvent. The starting sizes of all membranes are same.

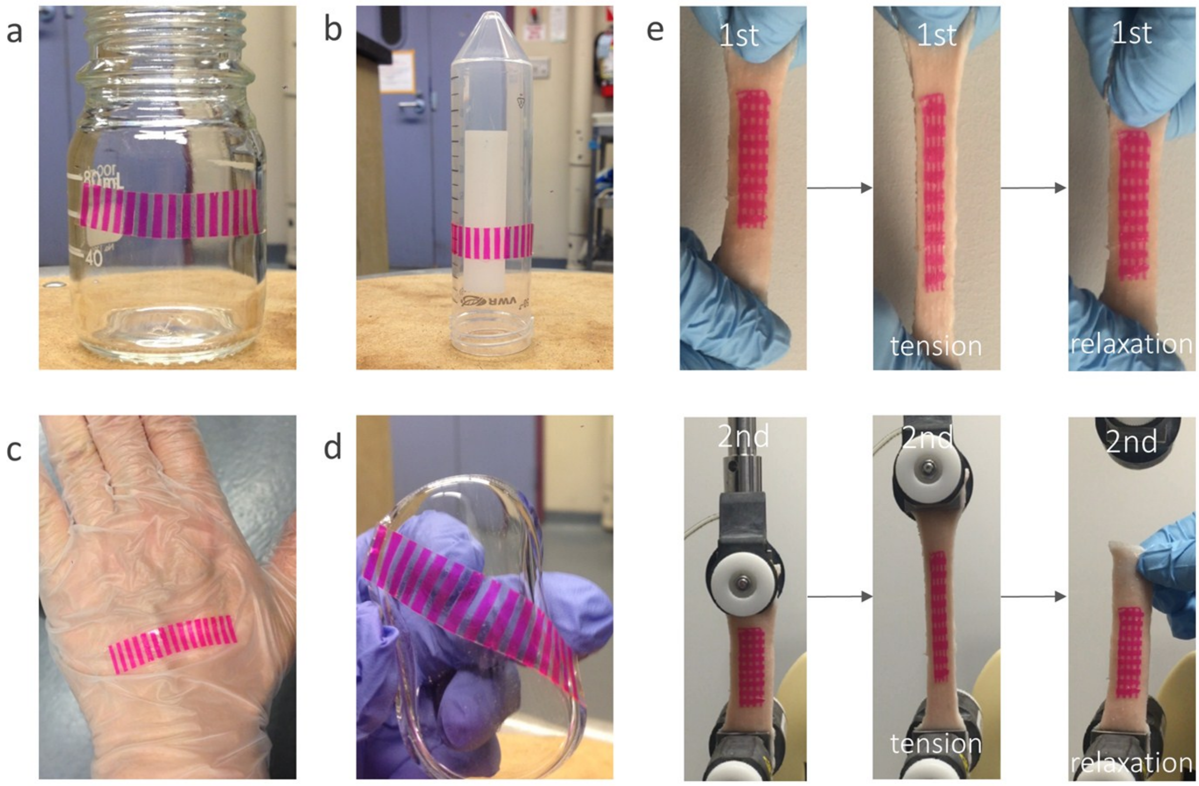


Fig. S3 Transfering and reusing of silk strain gauges. a-d) A silk strain gauge was transfered to different substrate. a) glass bottle; b) polypropylene tube; c) rubber glove; d) polydimethylsiloxane film. e) a silk strain was reused in twice tensions.

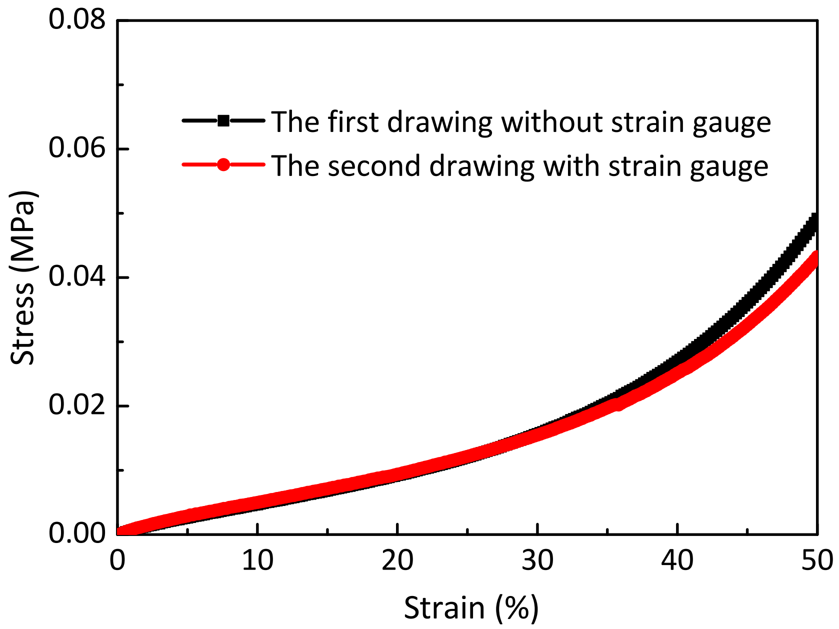
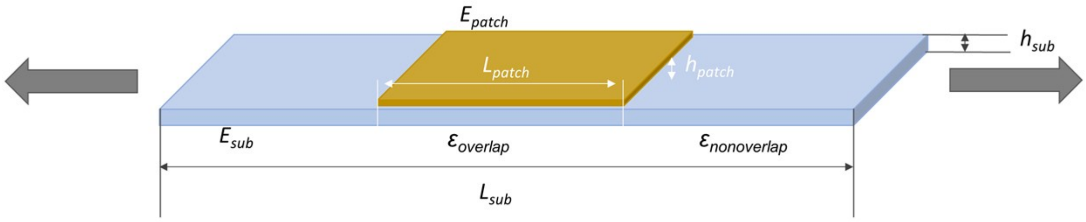


Fig. S4 Stress-strain plots of pig skin in twice stretching. The black curve is the first round of tensile test, the pig skin without strain gauge was stretched. The red curve is the second round of tensile test by using same skin sample, a strain gauge was attached on the skin surface.

a



$$E_{sub}*\varepsilon_{nonoverlap}*h_{sub} = E_{sub}*\varepsilon_{overlap}*h_{sub} + E_{patch}*\varepsilon_{overlap}*h_{patch}$$

$$\varepsilon_{overlap} : \varepsilon_{nonoverlap} = \frac{\frac{E_{sub}}{E_{patch}} * \frac{h_{sub}}{h_{patch}}}{\left(\frac{E_{sub}}{E_{patch}} * \frac{h_{sub}}{h_{patch}} + 1\right)}$$

$$\varepsilon = \varepsilon_{overlap} * \frac{L_{patch}}{L_{sub}} + \varepsilon_{nonoverlap} * (1 - \frac{L_{patch}}{L_{sub}}) = [\frac{\varepsilon_{overlap}}{\varepsilon_{nonoverlap}} * \frac{L_{patch}}{L_{sub}} + (1 - \frac{L_{patch}}{L_{sub}})] * \varepsilon_{nonoverlap}$$

Therefore,

$$\varepsilon : \varepsilon_{nonoverlap} = [\frac{\varepsilon_{overlap}}{\varepsilon_{nonoverlap}} * \frac{L_{patch}}{L_{sub}} + (1 - \frac{L_{patch}}{L_{sub}})] = [\frac{\frac{E_{sub}}{E_{patch}} * \frac{h_{sub}}{h_{patch}}}{\left(\frac{E_{sub}}{E_{patch}} * \frac{h_{sub}}{h_{patch}} + 1\right)} - 1] * \frac{L_{patch}}{L_{sub}} + 1 = 1 - \frac{1}{\left(\frac{E_{sub}}{E_{patch}} * \frac{h_{sub}}{h_{patch}} + 1\right)} * \frac{L_{patch}}{L_{sub}}$$

b

Numerical assessment of the relationship between strain ratio and stiffness ratio of substrate and gauge patch

E_{sub}:E_{patch}	h_{sub}:h_{patch}	L_{patch}:L_{sub}	strain ratio
0.1	10	0.4	0.8
0.2	10	0.4	0.866667
0.3	10	0.4	0.9
0.4	10	0.4	0.92
0.5	10	0.4	0.933333
0.6	10	0.4	0.942857
0.7	10	0.4	0.95
0.8	10	0.4	0.955556
0.9	10	0.4	0.96
1	10	0.4	0.963636
2	10	0.4	0.980952
3	10	0.4	0.987097
4	10	0.4	0.990244
5	10	0.4	0.992157
6	10	0.4	0.993443
7	10	0.4	0.994366
8	10	0.4	0.995062
9	10	0.4	0.995604
10	10	0.4	0.99604

c

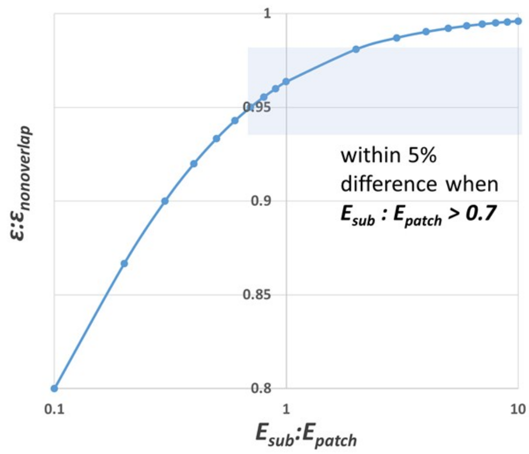


Fig. S5 The effect of tissue-gauge stiffness mismatch on tissue strain. a) Schematics and the formulas of calculation. b) The calculation reuslts, here we give numerical values to the geometric parameters as L_{sub}=5 cm, L_{patch}=2 cm, h_{sub}=1 mm and h_{patch}=0.1 mm, which are typical numerical numbers for the samples in our tensile tests, and obtain c) the strain ratio (ε:$\varepsilon_{nonoverlap}$) as a function of stiffnee ratio (E_{sub}: E_{patch}), which suggest that for E_{sub}: E_{patch}>0.7, the strain ratio(ε:$\varepsilon_{nonoverlap}$) is lager than 95%.

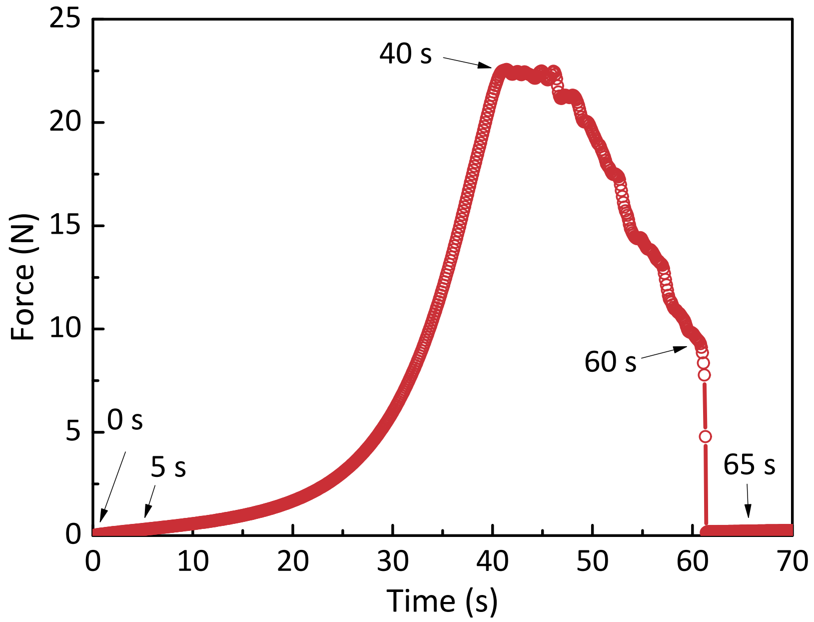


Fig. S6 Force-time plots of pig skin in tensile test, accroding to the tensile test results presented in Figure 5 in the main paper.