Electronic Supplementary Information (ESI)

High-performance flexible strain sensor with bio-inspired crack arrays

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Figure. S1 Slit sensillum of scorpion. (a) Optical image shows the silt sensillum positioned in the distal end of the metatarsus. (b) and (c) are the SEM image of the overall slit sensillum and a crack, respectively. (d) The radial-like pattern of the cracks obtained from the recognition of image (b).



Figure. S2 The crack arrays presented on the inner surface of petri dish lid after solvent-induced. (a) Ultra deep 3D microscopic image shows the position of natural defect generated upon manufacturing process. The radial-like pattern crack arrays with nano scale initiated at the defect and propagated beyond along a linear line. Transparent feature of PS hinders the direct observation of eyes. (b) The arrangement of crack arrays under large vision captured by ultra deep 3D microscope. (c) and (d) provide a much clearer vision for the crack arrays with the help of metallographic microscope.



Figure. S3 Examples for demonstrating the practicability of the first controllable manufacturing of crack size, realizing by the solvent-induced method. Ethanol volume, heating time and the heating temperature are the influential factors for the crack size generated on the petri dish lid.^{1,2,3} We set the ethanol volume as variable, while the heating time and the heating temperature unchanged. (a), (b) and (c) shows the AFM figures and sectional height diagram of crack, upon 1 mL, 2 mL and 3 mL ethanol volume respectively. (d) Intuitive representation that both of the width and depth of crack monotonically increased with the ethanol volume.



Figure. S4 Examples for demonstrating the practicability of the second controllable manufacturing of crack size, realizing by the different coefficients of thermal expansion for the PS and Epoxy. (a) and (d) are the characteristic size of cracks on the petri dish lid after epoxy film was peeled off. For (a), the liquid epoxy was heated at 70 $^{\circ}$ C and cured for 2 hours. For (d), the liquid epoxy was heated at 80 $^{\circ}$ C and cured for 2 hours. Confocal laser scanning microscopic images show 2D and 3D information of the cracks.



Figure. S5 Microcrack arrays on the top of PDMS after sputtering coating a layer of gold film with thickness at 50 nm. (a), (b) and (c) are optical images of PDMS after twice structure transferring from the petri dish lid, captured by metallographic microscope. (d), (e) and (f) are SEM images showing the approximately parallel microcracks in a small visional field. Scale bar: 100 μ m, 20 μ m, 10 μ m, respectively. (g), (h) and (i) are the cross sectional SEM images of PDMS films with top of microcrack arrays. The cross section of PDMS was obtained by the sharp blade cutting, resulting in rough edge which hampered the observation of cracks. The thickness of PDMS film was controlled at an average value of $\approx 210 \,\mu$ m.



Figure. S6 Schematic illustration of two bending modes (tension and compression). A sheet of metal is adopt to assist in performance tests, bent into radius *r*, chord length *c*, central angle θ , as well as arc length *l*. The sensor was fixed in the central position of the metal sheet surface, with dimensions were 40 mm×10 mm×210 µm ($l \times w \times h$). And the distance from bottom (top) surface of the sensor to the neutral layer is *z*.

Under tensile mode, $l = \theta \cdot (r + h)$

$$c = 2r \bullet sin^{(r)}(\frac{\theta}{2})$$

Therefore, the tension strain $\Delta \varepsilon$ can be described as follows:

$$\Delta \varepsilon = \frac{\Delta l}{l} = \frac{l_1 - l_0}{l_0} = \frac{\theta_1 (r_1 - z) - \theta_0 (r_0 - z)}{\theta_0 (r_0 - z)}$$

Since $r_1 \gg z$, $\theta_1 r_1 \approx \theta_0 r_0$, and the eqn can be converted to $\Delta \varepsilon = \frac{\Delta l}{l} = \frac{z (\theta_1 - \theta_0)}{r_0 - \theta_0} = \frac{z}{r_0} \left(\frac{\theta_1}{\theta_0} - 1\right) \approx \frac{z}{r_0} \left(\frac{r_0}{r_1} - 1\right) = z \left(\frac{1}{r_1} - \frac{1}{r_0}\right)$

Since r_0 tends to infinity,

$$\Delta \varepsilon = z/r_1 = h/(2r_1)$$

Similarly, when under compressive mode,

$$\Delta \varepsilon = -z/r_1 = -h/(2r_1)$$

Substrate	Conductive materials	Maximal GF@ corresponding strain	References
Nanopaper/PDMS	Crumpled graphene	7.1@100%	4
Gum membrane	MWCNT	25@530%	5
PDMS	Pt	11.45@≤2%	6
TPU	Graphene/AgNPs	476@500%	7
PDMS	SWCNT	0.82@40%	8
PDMS	AgNPs	12.5@-0.8%	9
SBS	AgNWs/AgNPs	15@100%	10
Ecoflex	CSFs	22.1@350%	11
PDMS	Ti	2@30%	12
Ecoflex	Carbon grease ink	3.8@100%	13
Ecoflex	CNT fibers	47@440%	14
Paper	Graphite	536.6@0.62%	15
Paper	Graphite/methylcellulose	804.9@0.495%	16
PDMS	AgNWs	20@35%	17
Ecoflex	Au nanosheet	70.3@50%	18
PDMS	AuNPs	5888.89@2%	This work

Table S1 Performance comparison of recent reported strain sensors

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