Supporting Information

Crisscross-Designed Piezoresistive Strain Sensors with Cracked Microtectonics for Direction-Selective Tensile Perception

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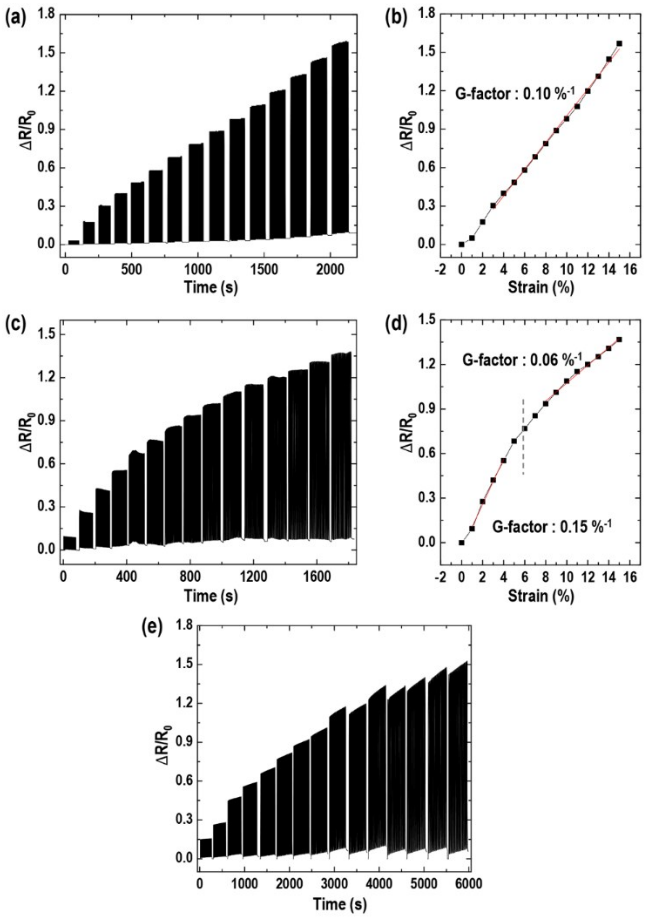

Figure S1. **(a,c,e)** Durability test of $\Delta R/R_0$ variations during 30 repeat measurements at strains from 0 to 15% in 1% intervals and **(b,d)** the $\Delta R/R_0$ changes as a function of strain degree from 0 to 15%. **(a,b)** showed the sensing performances of the cracked strain sensors based on 1.0 ± 0.1 mm thick-PDMS template. **(c,d)** and **(e)** were the cases based on thin (0.6 mm) and thick (1.8 mm) PDMS templates, respectively.

According to our experiments with variously changing the sample fabrication conditions, one of the important factors to affect the operating preformation of our strain sensor is the thickness of PDMS template. Note that we used the 1.0 ± 0.1 mm thick-PDMS template to fabricate the direction-selective strain sensor in our system. For the case of applying the same-thick PDMS template to the strain sensor as in the paper, we repeatedly confirmed that the sensing performances were almost similar to the results in Figure 2. If the thin PDMS template having a thickness of less than 1 mm is used (for example, 0.6 mm thick PDMS template in Figure S1(c,d)), the gauge factor at 6 % strain was somewhat reduced from 0.15 to 0.06 $\%^{-1}$, and the linearity for the $\Delta R/R_0$ variation with increasing the tensile strain tends to decrease, as a whole. On the other hand, when the strain sensor was fabricated using the thick PDMS templates of 1 mm or more, the reliability of the signal was somewhat lacking, although some periodicity of the $\Delta R/R_0$ change was observed as shown in Figure S1(e). The results could be explained by the physical strength differences depending on the thickness of the PDMS template in the strain sensors. Low physical strength of the thin PDMS template case leads to the excessive formations of the metal cracks under tensile stress and then the slow releasing action during the removal of a tensile stress. For the case of the thick PDMS template, however, excessively fast releasing action occurs due to the high physical strength of the template.

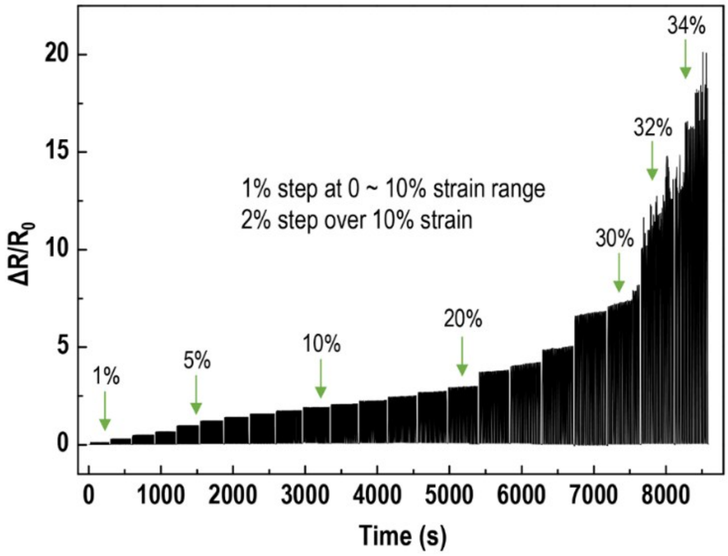

Figure S2. Durability test of crisscross-designed strain sensor in which ΔR/R0 was measured during 30 repeated stretching/releasing cycles at applied strain for strains from 0 to 34% in intervals of 1 or 2%.

We obtained the $\Delta R/R_0$ variations as a function of strain values up to 34% for the crisscross-designed strain sensor as shown in Figure S2. The developed strain sensor exhibited highly reproducible and reliable changes up to the strain values of 20%, and the signal reliability was lowered at over 30%. However, even if our direction-selective strain sensors were applied more than the tensile strain of 30%, it was confirmed that the sensor repeatedly drove stable in the range of 20% or less strain. The results in Figure 3 of the main text was obtained from the measurements of these devices. As the results, the direction-selective strain sensors with cracked microtectonics introduced in this study were found to be able to apply the tensile strain sensing up to 30% strain value.

Strain (%)	Measured response time (s)	Measured releasing time (s)	Moving rate (mm/s)	Actual distance deformed by strain (mm)	Time moved by strain (s)	Calculated response time (s)	Calculated releasing time (s)
1	0.22	0.22	20	0.4 (0.2*2 times)	0.01	0.21	0.21
5	0.51	0.43	20	2 (1*2 times)	0.05	0.46	0.38
10	0.73	0.59	20	4 (2*2 times)	0.10	0.63	0.49
15	0.88	0.81	20	6 (3*2 times)	0.15	0.73	0.66
20	1.09	0.95	20	8 (4*2 times)	0.20	0.89	0.75

Table S1. Variables used to normalize the response and releasing times in Figure 4.