Electronic Supplementary Material (ESI) for Nanoscale.

Supplementary Information

3D Printable Composite Dough for Stretchable, Ultrasensitive and Body-Patchable Strain Sensors

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KEYWORDS: 3D, three dimensional, stretchable, sensitive, sensor

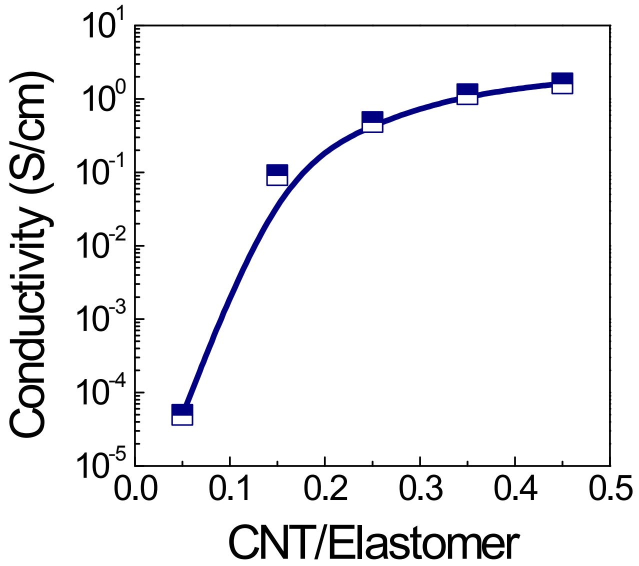

Figure S1. The evolution of the conductivity of line patterns printed with doughs containing GO-free composites, for MWNT/SIS ratios of 0.05, 0.15, 0.25, 0.35 and 0.45.

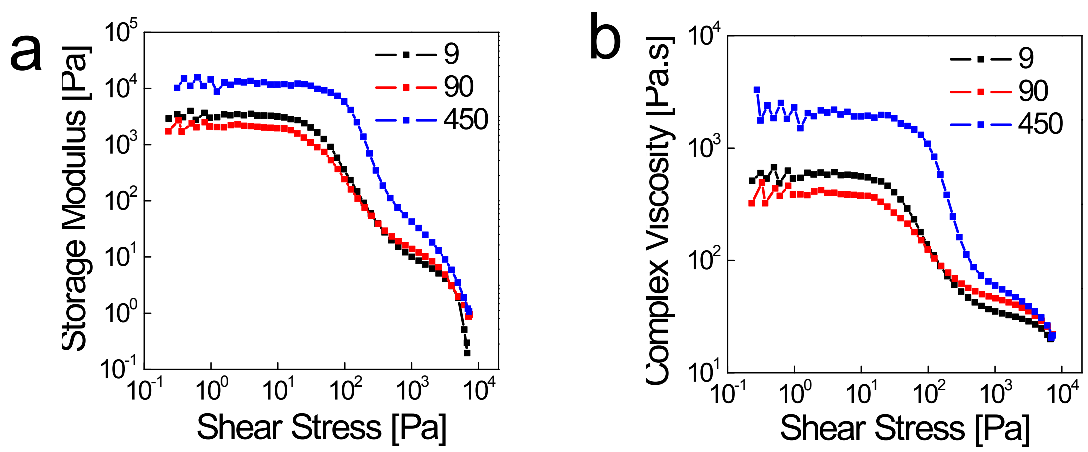

Figure S2. The rheological properties of (a) storage modulus and (b) complex viscosity of doughs containing NH_2-MWNT/RGO composites, with NH_2-MWNT/GO ratios of 9, 90 and 450. The ratio of composite /SIS was kept at 0.45.

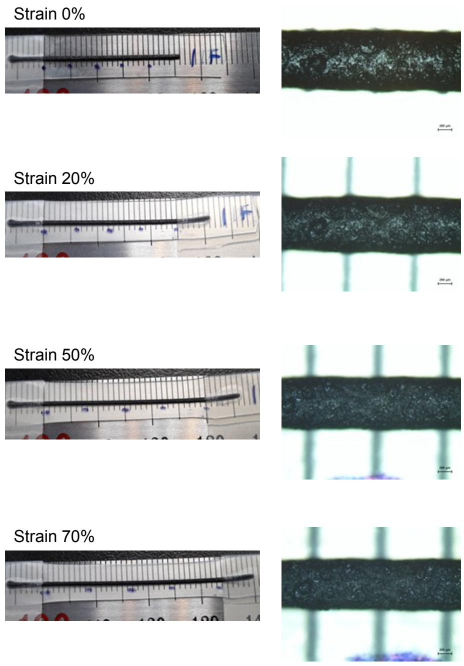

Figure S3. Optical microscopy images for line patterns prepared from dough samples containing NH_2-MWNT/RGO composites, with NH_2-MWNT/GO ratios of 9, as a function of an applied strain. The ratio of composite/SIS was kept at 0.45.

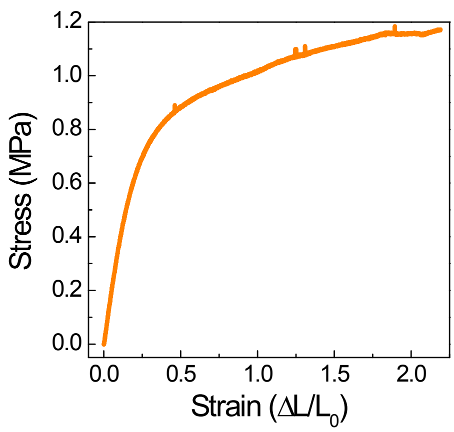

Figure S4. The stress-strain curve of bare SIS film.

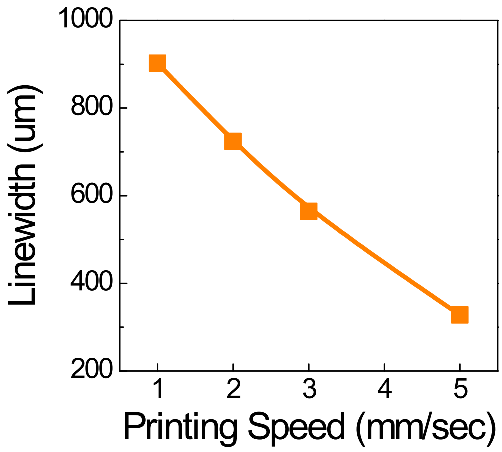

Figure S5. The variation in linewidth for patterns printed with various printing speeds from 1 to 5 mm/sec.

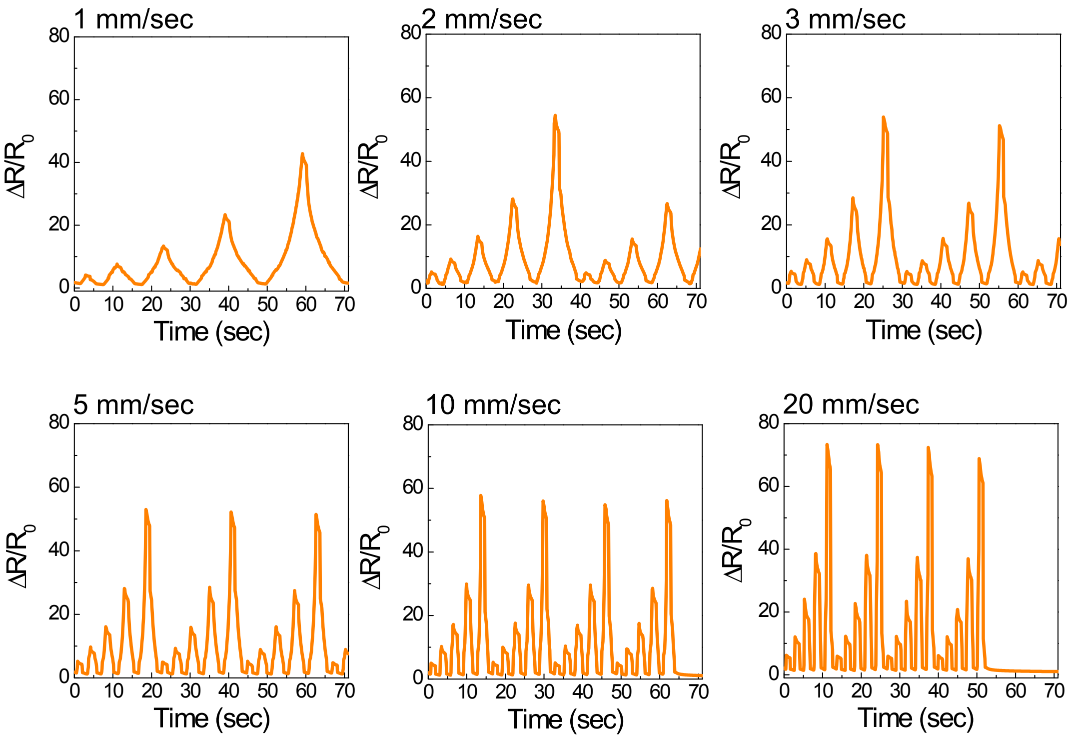

Figure S6. The time dependent $\Delta R/R_o$ responses under subsequent stretching/releasing tests at strains of 10, 20, 30, 40 and 50% at strain rates of 1, 2, 3, 5, 10 and 20 mm/sec. All of the strain sensor devices were fabricated by a single printing with a printing speed of 1 mm/sec.

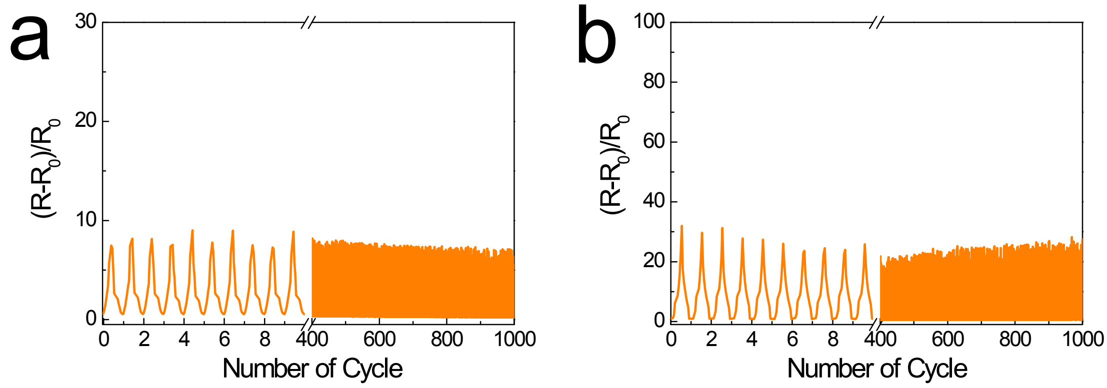

Figure S7. The $\Delta R/R_o$ responses under subsequent stretching/releasing tests at strains of (a) 30 % (at a strain rate of 5 mm/sec) and (b) 50% (at a strain rate of 10 mm/sec). All of the strain sensor devices were fabricated by a single printing with a printing speed of 1 mm/sec.

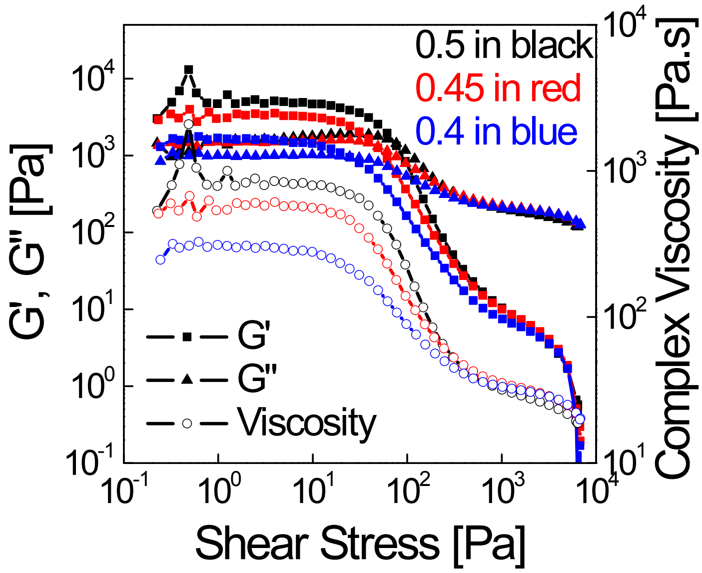

Figure S8. Rheological properties of doughs with different composite/SIS ratios of 0.4, 0.45 and 0.5. The NH_2-MWNT/GO ratio was kept at 9.

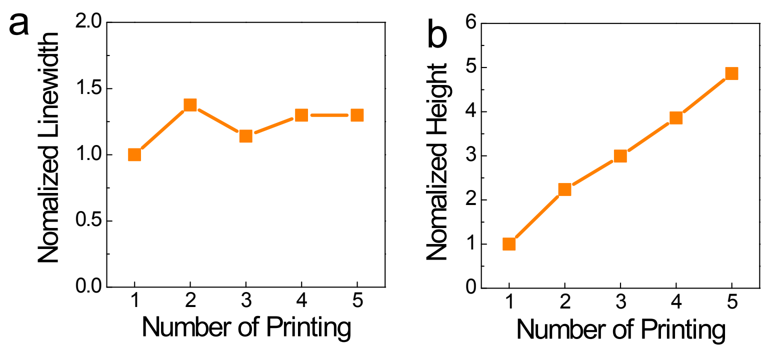

Figure S9. The variation in the normalized (a) linewidth and (b) height of printed patterns depending on the number of printing steps. The printing speed was 5 mm/sec.

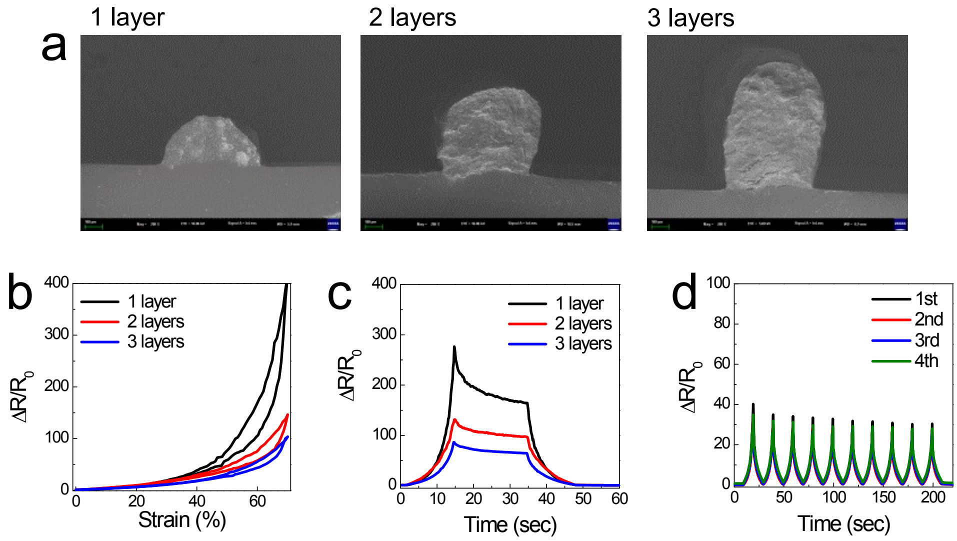

Figure S10. (a) Cross-sectional SEM images of patterns formed by 1-, 2- and 3-layer multiple printing processes. (b) The strain dependent and (c) time dependent $\Delta R/R_o$ responses as a function of the number of printed layers. The time-dependent measurements were carried out with stretching up to a strain of 70%, holding for 20 sec, and releasing to the original dimension. (d) The time dependent $\Delta R/R_o$ responses for 4 times-repeated stretching/releasing tests at a strain of 50%. All strain sensor devices were fabricated with a printing speed of 3 mm/sec and measured with a strain rate of 1 mm/sec.

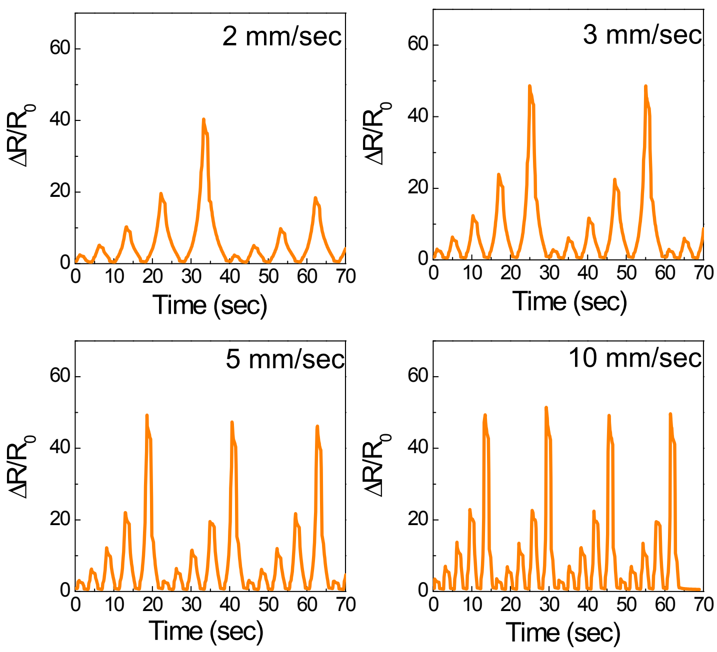

Figure S11. The time dependent $\Delta R/R_o$ responses for subsequent stretching/releasing tests at strains of 10, 20, 30, 40 and 50%. The strain rates were varied from 2 to 10 mm/sec. The strain sensor devices were fabricated by 5 times-multiple printing process with a printing speed of 5 mm/sec.

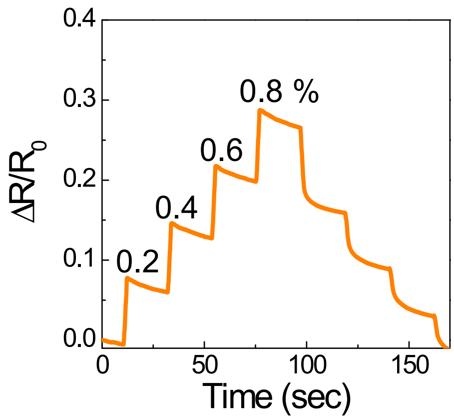

Figure S12. The time dependent $\Delta R/R_o$ responses while applying a forward/reverse sequence of strains from 0 to 0.8%.

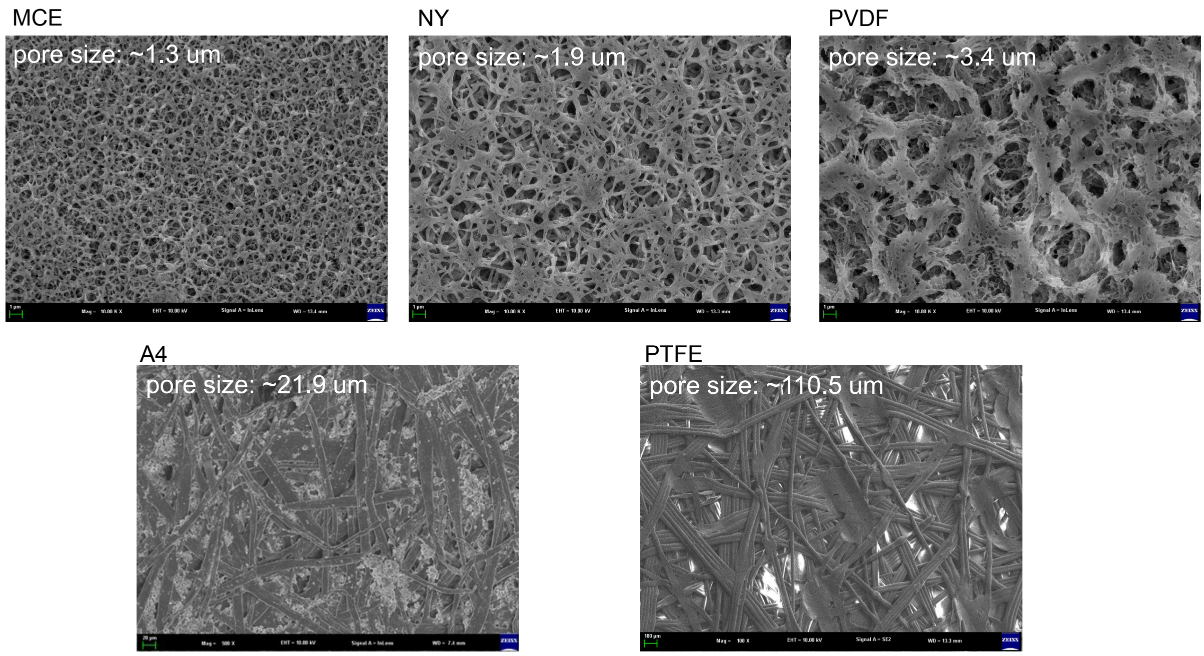

Figure S13. Top-view SEM images of various paper substrates.

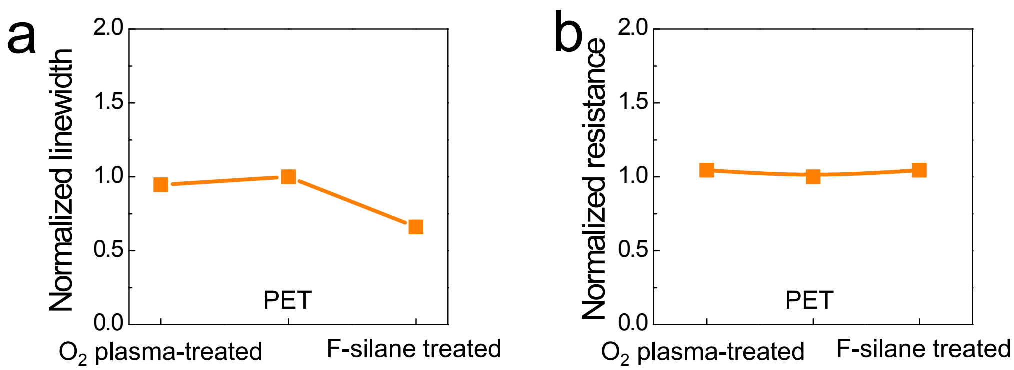

Figure S14. The variation in normalized linewidth and resistance for patterns printed on oxygen plasma-treated glass substrate, PET substrate and F-silane treated Si wafer substrate. F-silane stands for (tridecafluoro-1,1,2,2-tetrahydrooctyl)trichlorosilane.

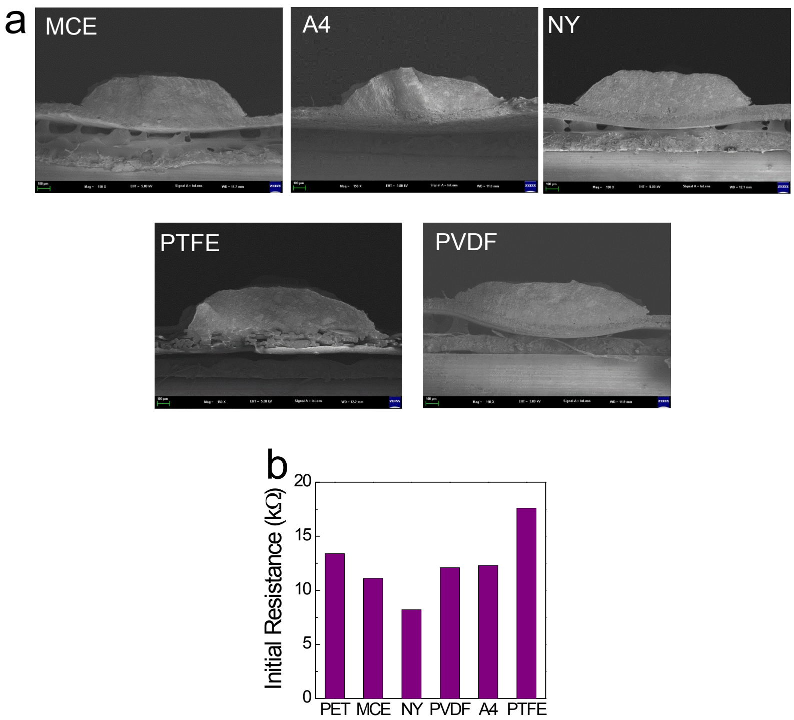

Figure S15. (a) Cross-sectional SEM images and (b) resistances for strain sensor layers printed on paper substrates.

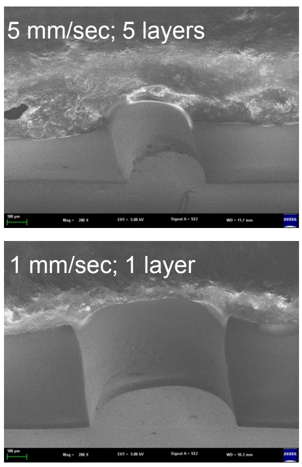

Figure S16. SEM images of strain sensor devices fabricated on uneven SIS substrates. The upper device was 5-times multiple-printed with a printing speed of 5 mm/sec and the lower device was single-printed with a printing speed of 1 mm/sec.

Movie S1. Video file showing the stable operation of strain sensor device employing active layer 5-time printed with a printing speed of 5 mm/sec.

Movie S2. Video file showing the stable operation of strain sensor device loaded on the robot finger.