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Electronic Supplementary Information

A pre-strain strategy for developing a highly stretchable and foldable one-dimensional conductive cord based on a Ag nanowire network

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Experimental method

Preparation of the Stretchable Conductive Cord

100% polyurethane (PU) cords, which are normally used as stretchable elastic beading threads and has typical Young's modulus of approximately 25 MPa, were used as the templates for preparing the stretchable conductive cords with diameter of approximately 0.7 mm. The PU cords were cut into 30 mm long cord and cleaned with ethanol in a sonication bath for 10 min. After cleaning and drying, the PU cords were treated in an O_2 plasma cleaner for 10 min to enhance the wettability of the AgNWs ink. For the pre-strained cords, both ends of the PU cords were clamped with a suitable strain. AgNWs were coated on the PU cords using the AgNWs dispersion ink (AgNW-25, Seashell Technology, CA, USA) by brushing. For one cycle of coating procedure, 2.4 μl of the ink was utilized. The AgNW-coated PU cord was dried in an oven at 70 °C for 3 min, and the coating and drying processes were repeated to obtain a AgNW layer with a sufficient thickness.

Characterization and measurement

The microstructure of the AgNWs-PU cords was observed by a confocal laser scanning microscope (OLS3000, Olympus, Japan). The scanning electron microscopy (SEM) images were taken using a JEOL 7001 FE-SEM. The stretching and bending tests of the composite fibers were also carried out using a testing machine developed in-house. The electrical resistance of the samples (subjected to mechanical deformation) was measured by a two-probe method using a FLUKE-15B digital multimeter. To enhance the electrical contact, a small amount of gallium-indium eutectic (EGaIn) was smeared at the contacting position between the multimeter probe and AgNWs-PU cords.

Pre-strain induced transverse-directional stress

The elastic PU cords underwent simultaneous changes in length (longitudinal dimension) and diameter (transversal dimension) during the pre-straining and the subsequent releasing. For example, as illustrated in **Fig. S1**, at $\varepsilon_{\mathrm{pre}}$= 100%, the length ($L$) of the cord during the pre-straining was twice of its original length (L_o) in the released situation. In the case of the 100%-stretched cord ($\varepsilon_{\mathrm{pre}}$=100%), the radius ($r$) decreased after the stretching depending on the Poisson's ratio of the PU cord. The diameter of the PU cord was found to be about $0.7r_o$ at $\varepsilon_{\mathrm{pre}}$=100%. It implies that when the cord recovers its original released state, the AgNW film deposited in the pre-strained was exposed to a transversal stress, which originated from the transversal expansion of the cord. Stresses would be incremented with the increasing pre-strain values which make pre-strained diameter of the cord smaller. Therefore, the application of too much pre-strain during the fabrication of cord-type conductors can lead to the formation of cracks in the AgNWs film in the transverse direction (perpendicular to the pre-strain direction), as shown in **Fig. 2e**.

Strain calculation during bending

Strain applied on the inner and outer surfaces of bent AgNWs-PU cord as a function of bending radius (*r*) was calculated based on the fact that neutral axis exists at the centroid of the cord (See **Fig. S4a** for visualized explanation). As the neutral axis stands for the length-invariable line during the bending, we can calculate the strain according to the following equations:

Strain of inner side = (variation in length)/(original length)

= [(length of inner arc) – (length of neutral axis)]/(length of neutral axis)

$= -0.35/(r+0.35)$

Strain of outer side = (variation in length)/(original length)

= [(length of outer arc) – (length of neutral axis)]/(length of neutral axis)

= 0.7/(r+0.35)

Using these equations, the strain against *r* can be plotted in **Fig. S4b**.

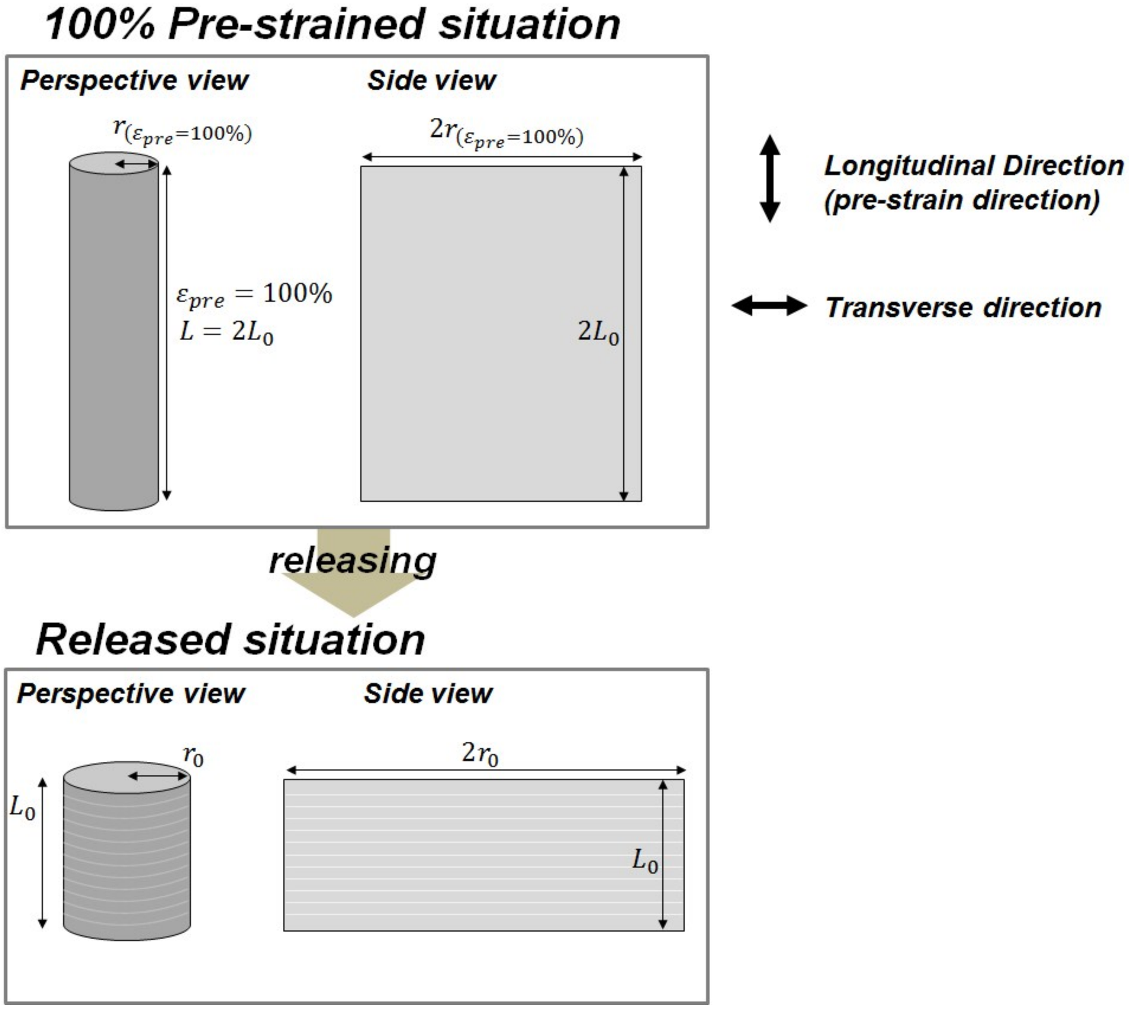

Fig. S1 Graphical illustration of the longitudinal and transversal dimension changes induced in the 1-D cord material by 100% pre-strain and the subsequent release.

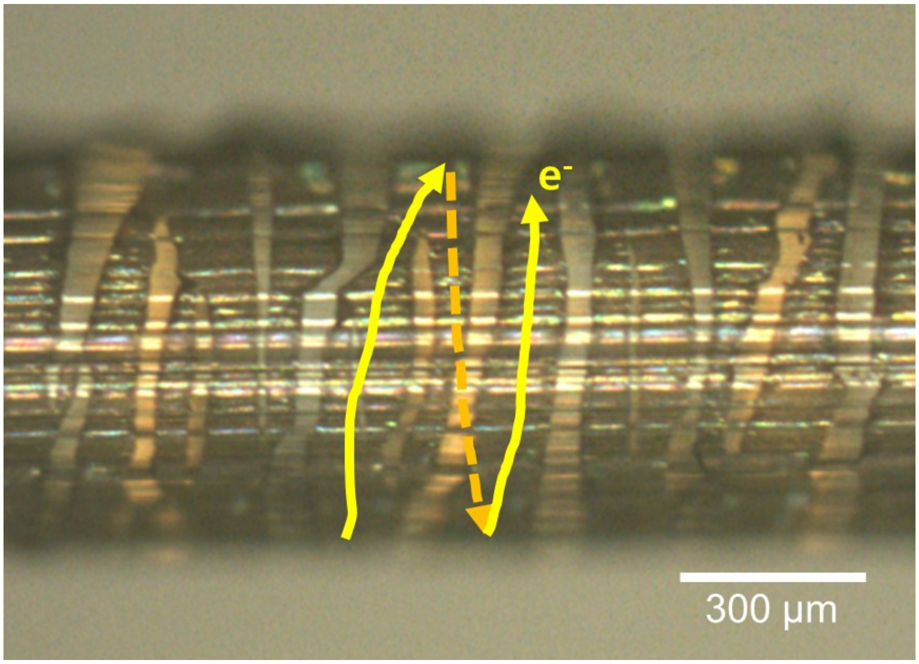

Fig. S2 Optical microscope image showing the possible current pathway detouring the crack on the AgNW layer

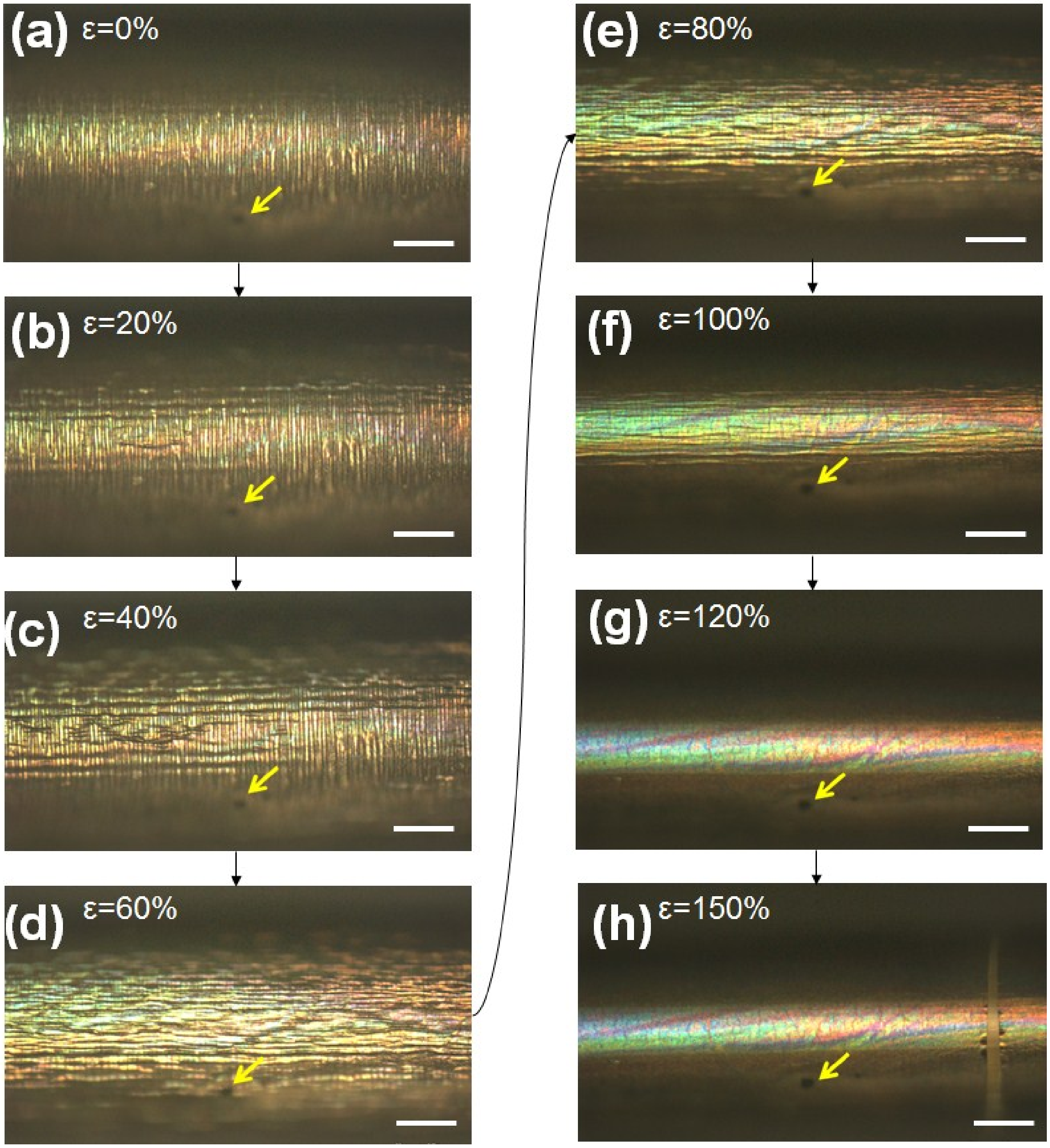

Fig. S3 Optical microscope images of the AgNWs-PU cord prepared by pre-straining during stretching from 0 to 150% strain at the same position (arrow symbol indicates marked spot). Scale bar = 160 μm.

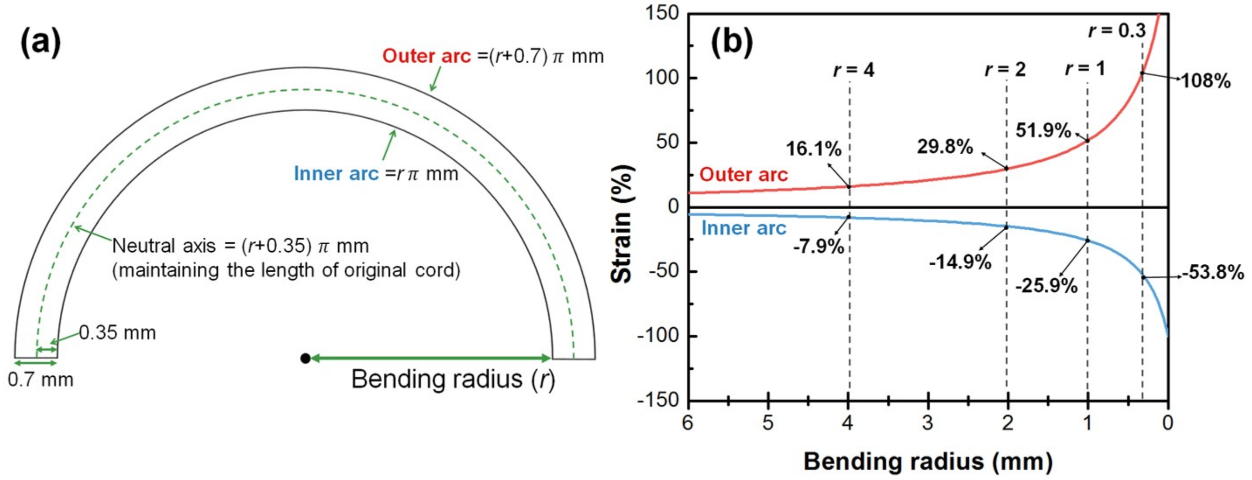

Fig. S4 (a) Graphical illustration of bent AgNWs-PU cord with bending radius of *r* (note that neutral axis denotes the line where the length is not changed before and after bending; (b) calculated strain of outer arc and inner arc of AgNWs-PU cord as a function of bending radius.