Resistive crack-based nanoparticle strain sensors with extreme sensitivity and adjustable gauge factor made on flexible substrates

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Calculation of strain from the bending angle

Figure 1 shows a graphic representation of a bended substrate. Tensile and compressive stresses will be applied to the substrate causing the upper surface to increase their distance from l_0 to l'. Uniform substrates remain unstrained at their medium (l_0 in Figure S1).

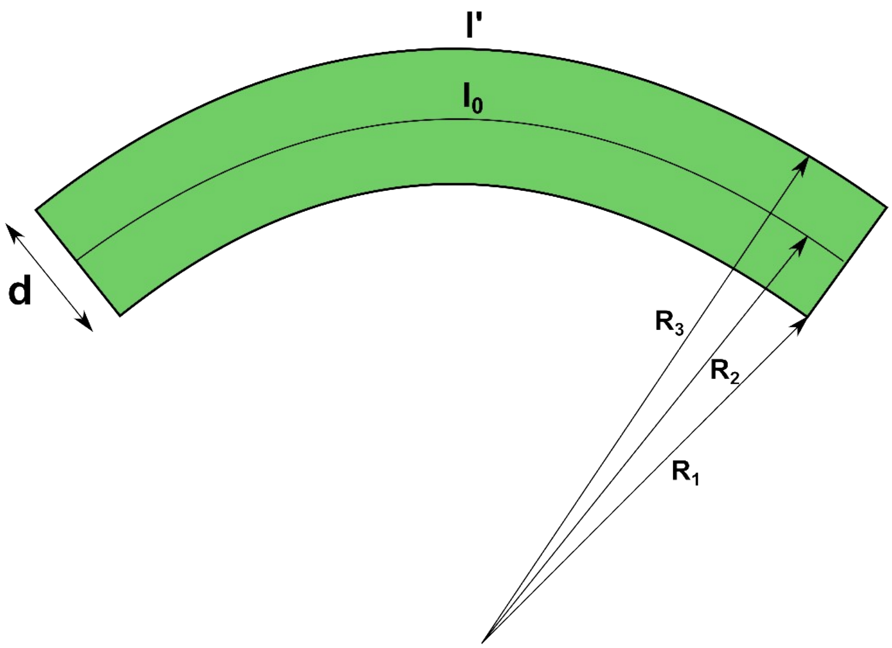

Figure S1: Schematic representation of a bended substrate with d thickness.

The distance l_0 is given by the following equation:

$$l_0 = R_2\theta \qquad (1)$$

Where θ is the angle corresponding angle of the arc length. The distance l' can be calculated by the equation:

$$l^{'} = \left(R_2 + \frac{d}{2}\right)\theta \qquad (2)$$

The definition of strain is:

$$\varepsilon = \frac{l^{'} - l_0}{l_0} \qquad (3)$$

And by applying (1) and (2) to (3):

$$\varepsilon = \frac{\left(R_2 + \frac{d}{2}\right)\theta - R_2\theta}{R_2\theta} = \frac{\frac{d}{2}}{R_2}$$

$$\varepsilon = \frac{d}{2R_2} \qquad (4)$$

Since radials R1 R2 R3 are much larger than the thickness d it can be therefore assumed that they are all equal to R_2, aif the sensor is bent according to what can be seen in Figure S2.

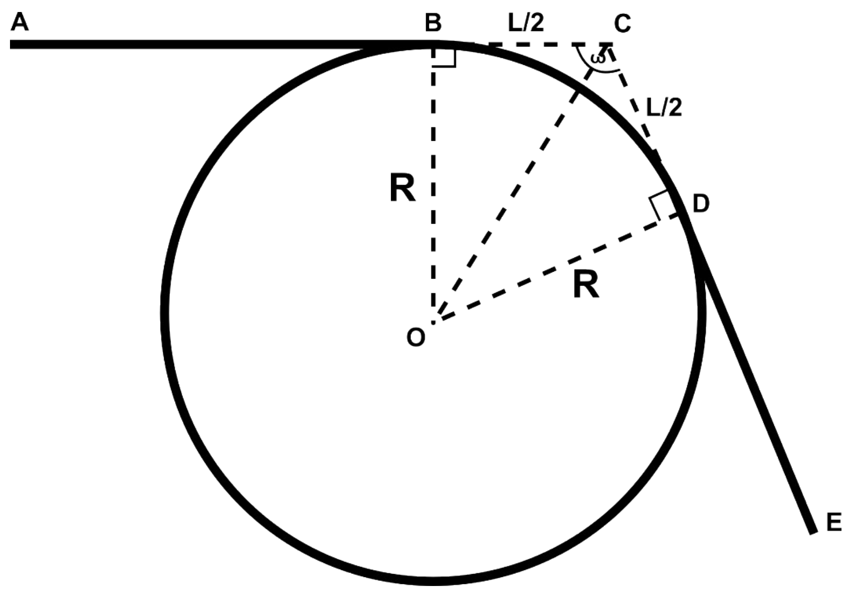

Figure S2: Schematic representation of the bended sensor and the circle with radius equal with the bended radius. The strain-sensor extends from point A to point B. and can be bent according to the bending angle ω

As can be seen in Figure S2, the sensor can be deformed between two fixed points B and D. The distance between B and D when no bending occurs equals to L, which in our case is 3000μm. Therefore, the overall distance of the two straight sections BC and CD is L. In addition, the straight section OC bisects the angle ω and the angle BOD. The schematic representation in Figure S2 shows the circle with a radius equal to the bending radius R. The radius R can be calculated by the following equation:

$$R = \frac{L}{2\cot\left(\frac{\omega}{2}\right)} \qquad (5)$$

By applying the equation (5) to equation (4):

$$\varepsilon = \frac{d\cot\left(\frac{\omega}{2}\right)}{L} \qquad (6)$$