Electronic Supplementary Material (ESI) for Nanoscale.

Supplementary Information

Humidity- and light-driven actuators based on carbon nanotube-coated paper and polymer composite

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Supplementary Notes

Supplementary Note S1: Bending curvature calculation principle of the CNT-paper/BOPP actuator

The parameters are defined as follows (shown in Figure S2):

L: The length of the CNT-paper/BOPP actuator.

r: The radius of the arc of the curved CNT-paper/BOPP actuator.

x: The horizontal displacement of the curved CNT-paper/BOPP actuator.

y: The vertical displacement of the curved CNT-paper/BOPP actuator.

θ/2: The chord tangent angle of the curved CNT-paper/BOPP actuator.

θ: The bending angle of the arc of the curved CNT-paper/BOPP actuator.

The curvature is defined as the reciprocal of radius (1/*r*).The chord tangent angle is given by

$$\frac{\theta}{2} = tan^{-1}\frac{x}{L-y} \quad (1)$$

As the bending angle is given by

$$\theta = \frac{L}{r} \quad (2)$$

The curvature 1/*r* is deduced as

$$k = \frac{1}{r} = \frac{\theta}{L} \quad (3)$$

Hence, the curvature of the actuator can be calculated by using the bending angle and length of the actuator.

Supplementary Note S2

Characterization and measurement

The morphology and microstructures of the materials were characterized by a field emission scanning electron microscope (Hitachi SU8010). HORIBA JobinYvon Evolution Raman spectrometer was used to record the Raman spectra with the 532 nm He-Ne Laser line at room temperature. The photos of the actuator and the gripper were captured by a digital camera (SONY ILCE 6000). The Philips BR125 was used as a NIR light source. The light power density was measured by an IR Power Meter (Linshang LS122A). The temperature of the actuator was recorded by a laser sight infrared thermometer (Optris LS) with temperature resolution of 0.1 ℃. The temperature data were captured from the CNT-paper surface of actuator. The emissivity

coefficient was set to be 0.95. The weights of samples were measured by a precision balance (YOKEFA1004CS). The high RH (e.g., 90%) was supplied by a humidifier and monitored by a hygrometer, while the low RH was available by exposure to the ambient environment or obtained by a dehumidifier.

Humidity-driven test

To measure the curvature of the CNT-paper/BOPP actuator when RH changes from 60% to 14% (or 90%), the actuator was firstly fabricated at RH of 60%. Then, it was placed in a humidity control chamber at different RH (14% or 90%) as soon as possible. To measure the curvature of the actuator when the RH increased from 14% to 90%, the actuator was firstly fabricated at RH of 60%. Then, it was placed in the humidity control chamber. The curvature and RH were measured synchronously during the RH changing process. In the repeatability test of humidity-driven actuation, the actuator was undergoing repeated RH changes from 14% to 90%. The actuator was tested for 100 cycles.

Light-driven test

We fabricated and measured the CNT-paper/BOPP actuator at RH of 60%. The light-driven tests were carried out in the humidity control chamber with RH of 60%, in order to keep the same initial flat state.

Blocking force measurement

The CNT-paper/BOPP actuator was cut into a strip shape with dimensions of 20 mm × 5 mm. One end of the actuator (5 mm) was fixed, while the other end was connected to a preload PDMS cube (11.1 mN). The PDMS cube was placed on a precision balance with an axial configuration. We measured the generation forces of the actuators with different light power densities (irradiation for 10 s).

Supplementary Figures

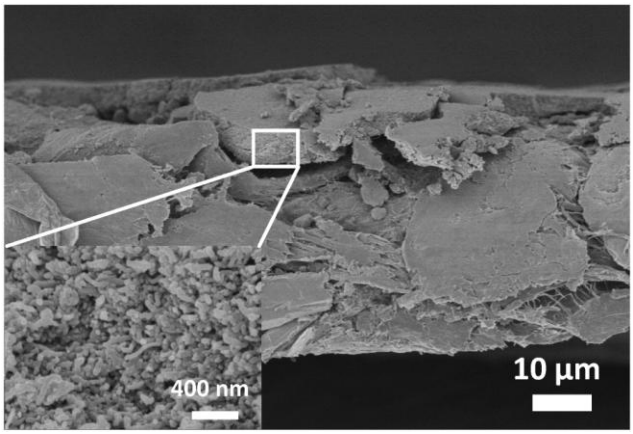

Figure S1. Cross-sectional SEM image of the CNT-paper composite.

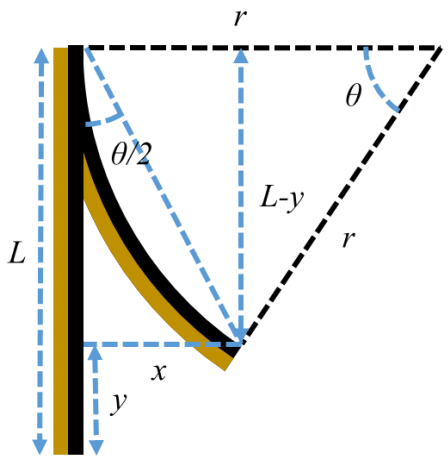

Figure S2. CNT-paper/BOPP actuator with correlative parameters for calculating the bending curvature.

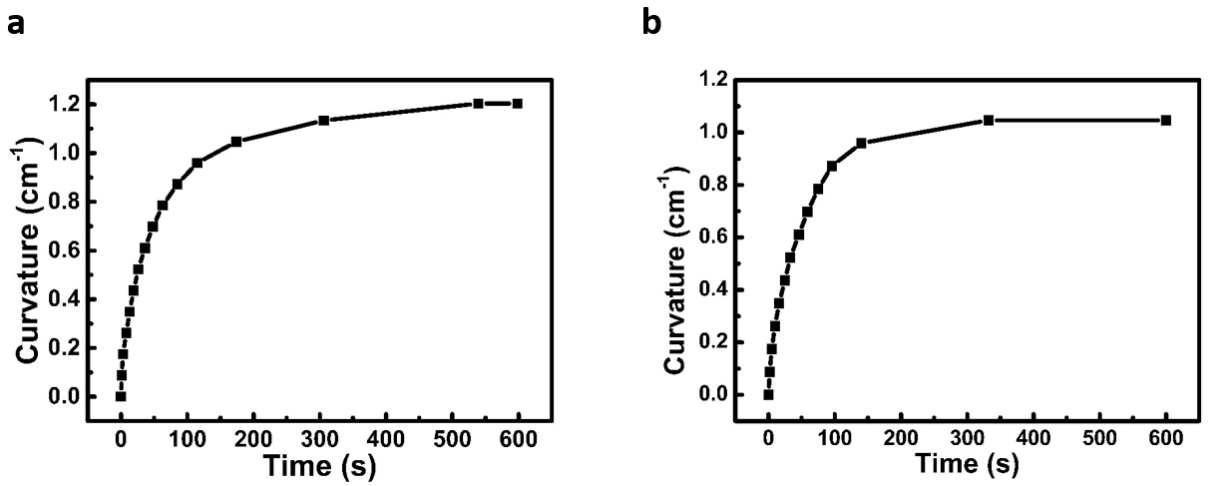

Figure S3. (a) Bending curvature of the CNT-paper/BOPP actuator when RH changes from 60% to 14%. (b) Bending curvature of the CNT-paper/BOPP actuator when RH changes from 60% to 90%.

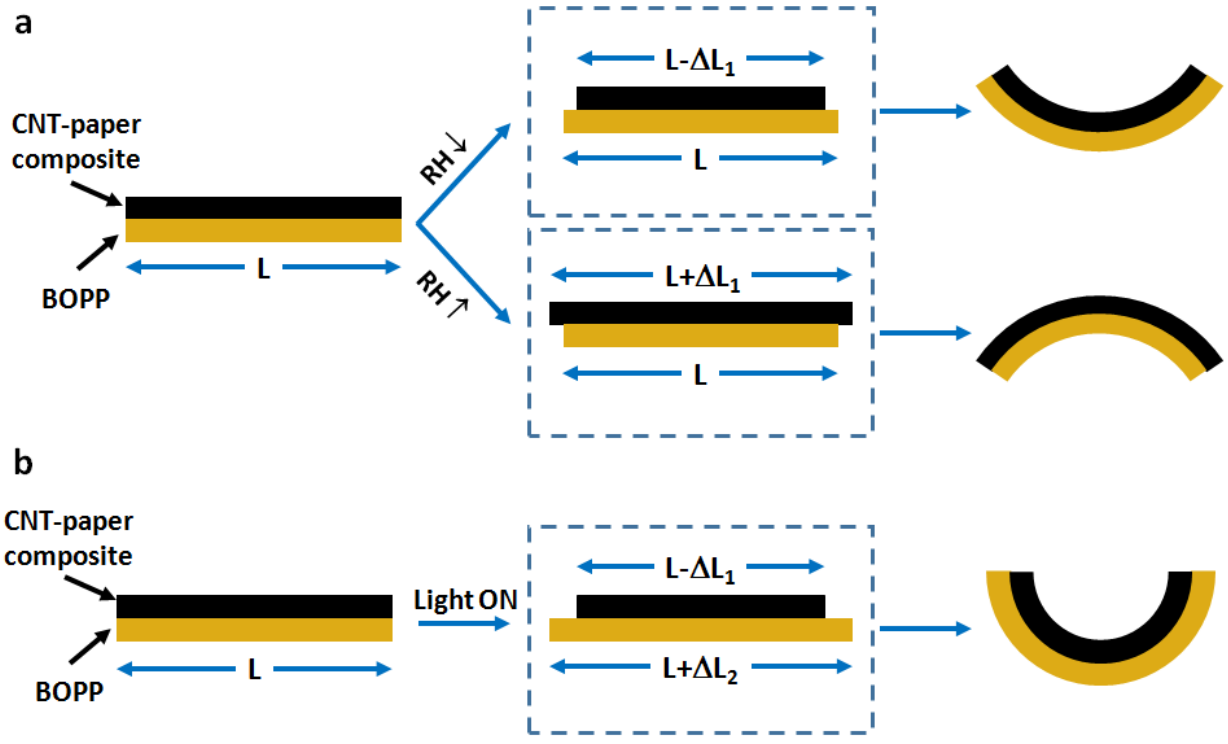

Figure S4. (a) Schematic illustration of the humidity-driven actuation mechanism of CNT-paper/BOPP actuator. (b) Schematic illustration of the light-driven actuation mechanism of CNT-paper/BOPP actuator.

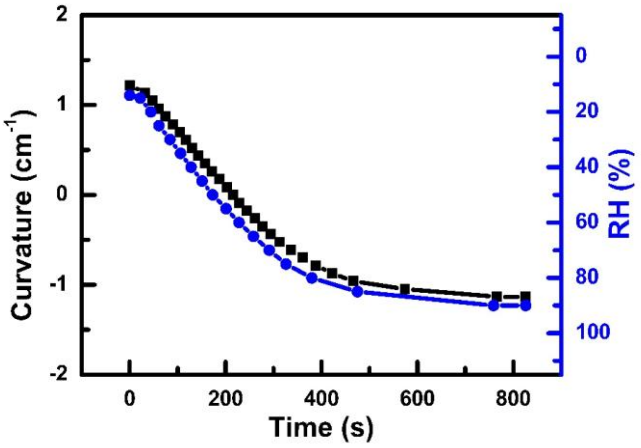

Figure S5. Bending curvature of the CNT-paper/BOPP actuator as a function of time when the RH increased from 14% to 90%.

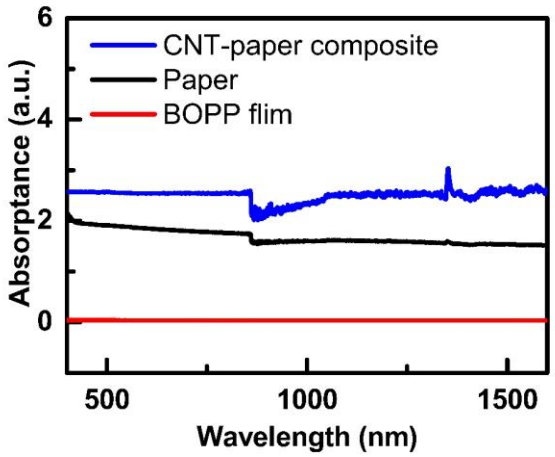

Figure S6. Absorption spectrum of CNT-paper composite, paper and BOPP.

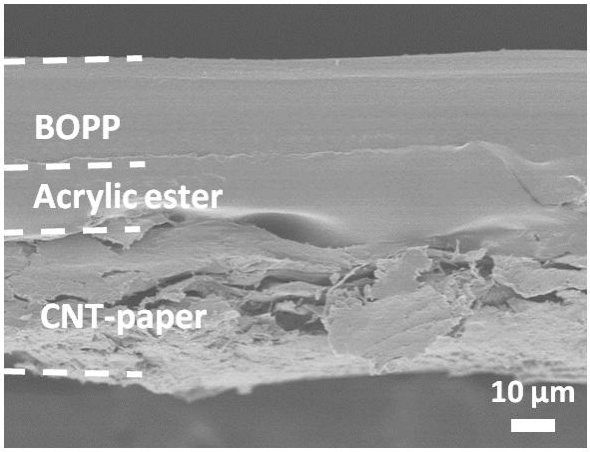

Figure S7. Cross-sectional SEM image of the CNT-paper/BOPP actuator after light-driven repeatability test.