Supplementary

Bioinspired conductive structural color hydrogels as robotic knuckle rehabilitation electrical skin

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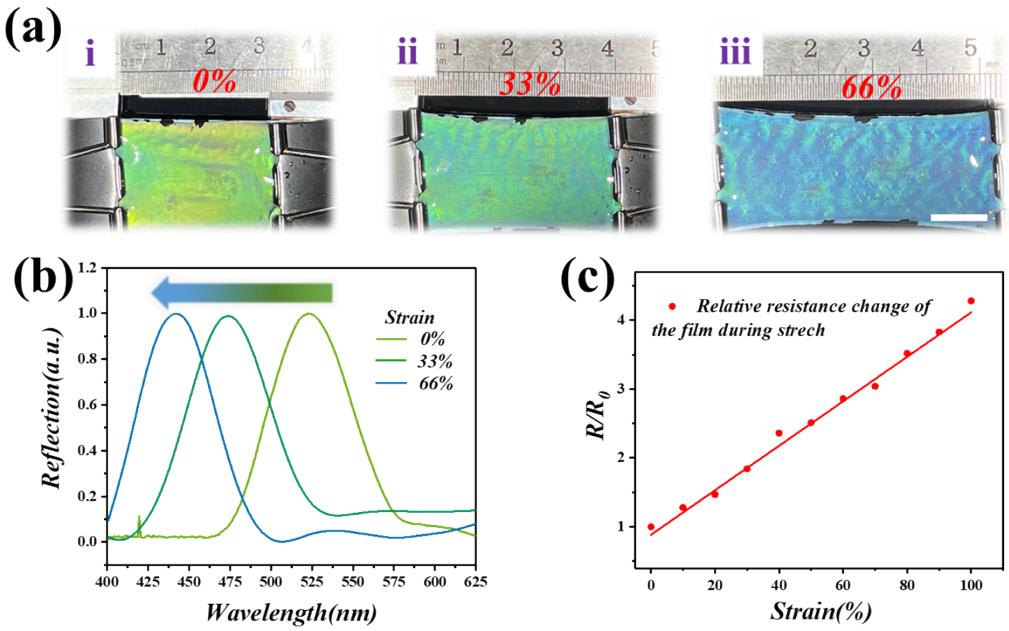

Figure S1. Optical image, spectral change and conductivity characterization of hydrogel structure during tensile process. (a) Color changes of inverse graphene films prepared by rGO doping P(NiPAAm-bis-AA) (2mg/mL) under different tensile conditions. (b) Reflection spectra under different tensile forces. (c) Change of relative resistance when the film is stretched. Scale bar is 1cm.

In the stretching process, it is found that the hybrid film can achieve dual signal

response, which can not only show the color change from the polyurethane anti protein layer, but also show the resistance change from the conductive region. Firstly, the mechanical properties were explored by tensile test. In order to obtain dual signal response, strain sensitivity experiments were carried out. The results showed that when the membrane stretched from 0% to 33%, the structure color of the hybrid hydrogel membrane changed from light green to dark blue, as shown in **Figure S1 (a)**. During the stretching of the film from 0% to 60%, the reflection spectrum has a significant blue shift from 525 to 433 nm (**Figure S1 (b)**) In addition, the hybrid hydrogel membrane can also respond to pressure. These characteristics show that the resulting hybrid film can be considered as a photon sensing platform through its dynamic color change. In addition to the visual signal, the relative resistance change of the hybrid hydrogel film was recorded when the film stretched from 0% to 100% (R/R_0), where R was the real time resistance, and R_0 was the original resistance (**Figure S1 (c)**). When the strain increases, the relative resistance of the film changes significantly, and reaches 4.1 at 100% strain, indicating a good response to large-scale deformation. In addition, it should be noted that due to the elasticity of polyurethane polymer, the change of resistance with the stretching of hybrid film is reversible.

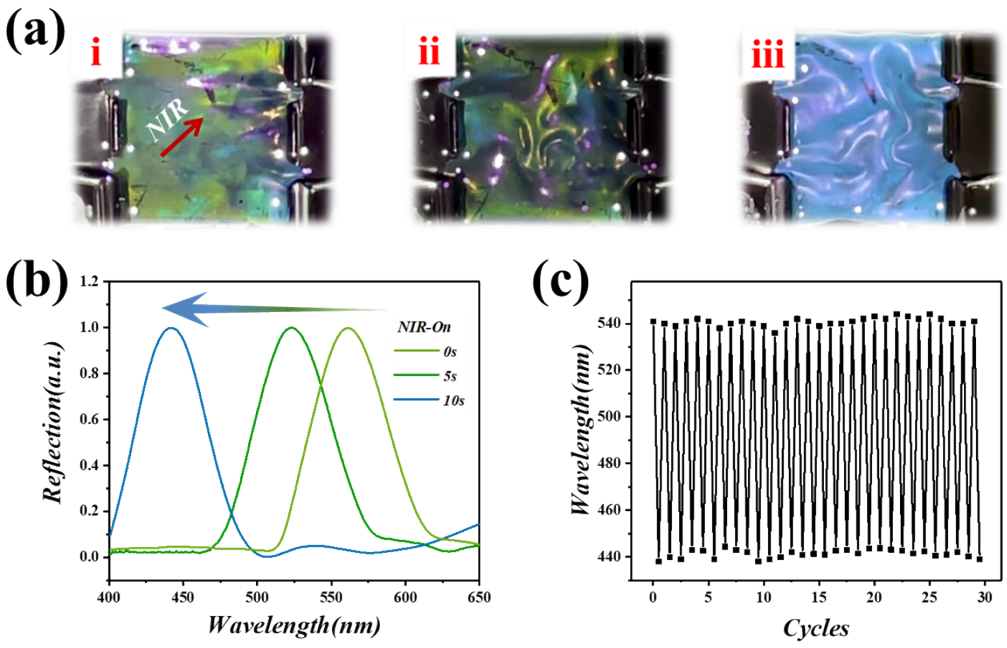

Figure S2. Optical properties and stability Characterization of hydrogel on NIR. (a)

Structural color change of the inverse opal scaffold hybrid film prepared by rGO doping P(NiPAAm-bis-AA) (2mg/mL) under NIR irradiation. (b) Reflectance spectra at different NIR illumination times. (c) Changes of structure color reflection peaks under 30 light cycles. Scale bar is 1cm.

Due to these outstanding characteristics, the hybrid hydrogel film will show broad prospects in wearable electronic products. In order to explore its potential, a blue hybrid hydrogel membrane was fabricated and connected to a folder. The signal changes of hybrid hydrogel membrane were studied under the near infrared light (**Figure S2 (a)**). As shown in **Figure S2 (b)**, the color of the mixed hydrogel film is changed from blue to green under the stimulation of infrared. In addition, the temperature changes and real-time resistance changes of the hybrid hydrogel membrane were recorded in response to the environment, as shown in **Figure S2 (c)**. Under the same condition of near-infrared radiation, the film kept good structural color change characteristics. When repeatedly irradiated, the film can keep a stable structural color change trend under repeated irradiation. Under the LCST response of the system, the stop band of Figure S2 actually causes blue shift.

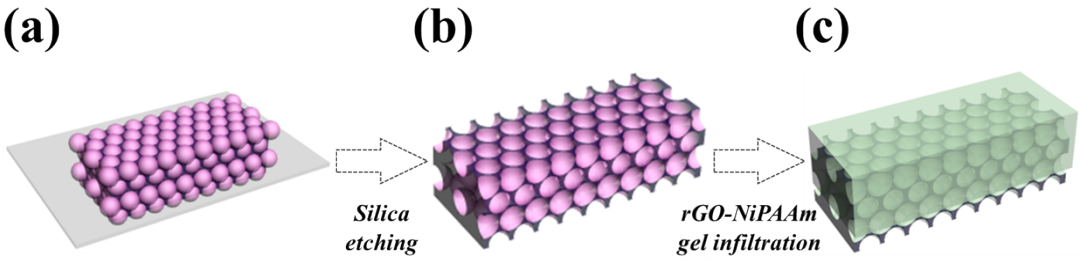

Figure S3. Preparation scheme of hydrogel film. Schematic diagram of generation process of polymer-conductive hydrogel hybrid color film.

In the **Figure S3 (a)**, polymer infiltrated opal template. After silica etching, the free inverse opal structure is formed (**Figure S3 (b)**). **Figure S3 (c)** is formed when rGO/P(NiPAAm-bis-AA) is infiltrated into the inverse opal structure.

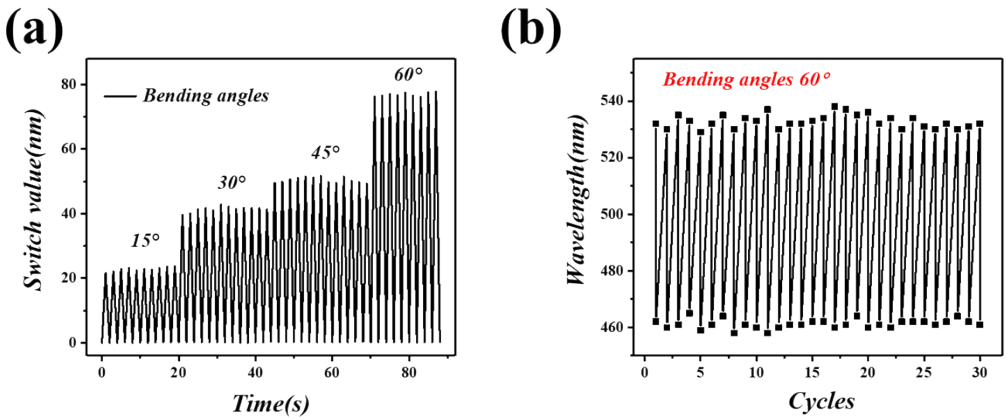

Figure S4. Durability test of hydrogel film bending cycles. (a) The wavelength shift values of the film in response to different bending angles. (b) Durability wavelength cycling test of structural color hydrogel film with bending angle of 60°.