Supporting Information

Chameleon-inspired active tunable structural color based on smart skin with multi-functions of structural color, sensing and actuation

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Material optimization of photonic crystal film

Sylgard 184 used in this paper is suitable material selection for mechanochromism. However, the Elastic Modulus of the Sylgard 184 is still too large for the LCE. The method to decrease the Elastic modulus is reducing the usage of curing agent during the preparation of photonic crystals films. Therefore, the films with different proportion of curing agent are fabricated. In practical process, the samples with proportion less than 1:15 are unable to cure. After the fabrication, the films with the proportion of 1:10, 1:13 and 1:15 is obtained (Fig. S4a). Fig. S4b shows the SEM images of these films with obvious periodic micro holes array.

Thus, the mechanical properties of these films were tested, as shown in Fig. S4c. By hanging the same weight on the lower ends of the films, the length changes before and after the loading are obtained. For linear strain, the elastic modulus can be calculated by the following equation:

$$E = \frac{F/S}{\Delta L/L} \quad \text{(S1)}$$

where E is the Elastic Modulus of the film, F is the force applied to the film, S is the cross-sectional area, and ΔL is the length change in the direction of the force, and L is the initial length. Therefore, the Elastic modulus of the films with different proportions are calculated and presented in the Fig. S4c. The elastic modulus of the film of 1:15 is 0.32MPa that is the smallest among the three films shows that this method has significant effect on the promotion of the tensile properties of the material. Then, the tunable color performance is tested for the influence of the change of proportion. In Fig. S4d. the films' color have no obvious difference between the result with different proportions in same strain, indicated that the decrease of the usage of curing agent has no noticeable influence on the color performance.

Theoretical analysis of CNT resistance

According to Equation (3), for the structure in Fig. 4a, its resistance is affected by length and resistivity. Suppose there is no change in resistivity during deformation, according to the Equation (3) and $\varepsilon = \Delta l/l$, the following equation can be obtained:

$$\frac{\Delta R}{R} = (2\varepsilon - \varepsilon^2) \tag{S2}$$

This equation shows the variation of resistance change ratio with strain without considering the effect of temperature. Thus, the curve of Equation (S2) was compared with the actual experimental results, as shown in the Fig. S8. As can be seen, the trend of theoretical value is the same as the results in Figure 4b, but it is larger in value. The reason is that the CNT coatings' own resistance will increase due to the temperature rise in practical tests, thus the resistance change ratio will be smaller than theoretical value. However, the resistance change caused by the temperature of the CNT coatings will not affect the general trend of resistance change. Therefore, the influence of deformation was mainly considered to explain the resistance change of the CNT coatings.

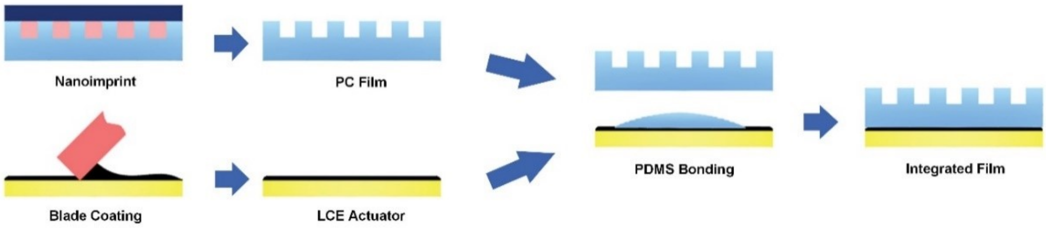

Fig. S1 Fabrication of integrated smart skin film.

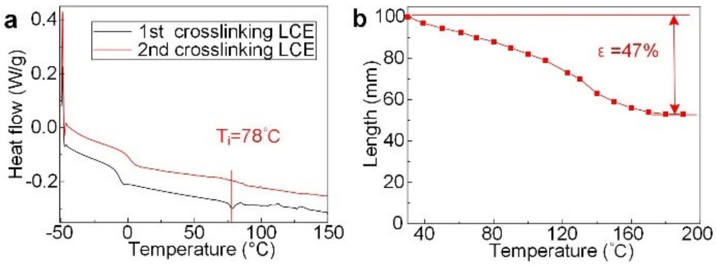

Fig. S2 (a)DSC results of 1st crosslinking LCE and 2nd crosslinking LCE. The isotropic transition temperature is 78°C. (b)Thermal deformation of LCE stripe.

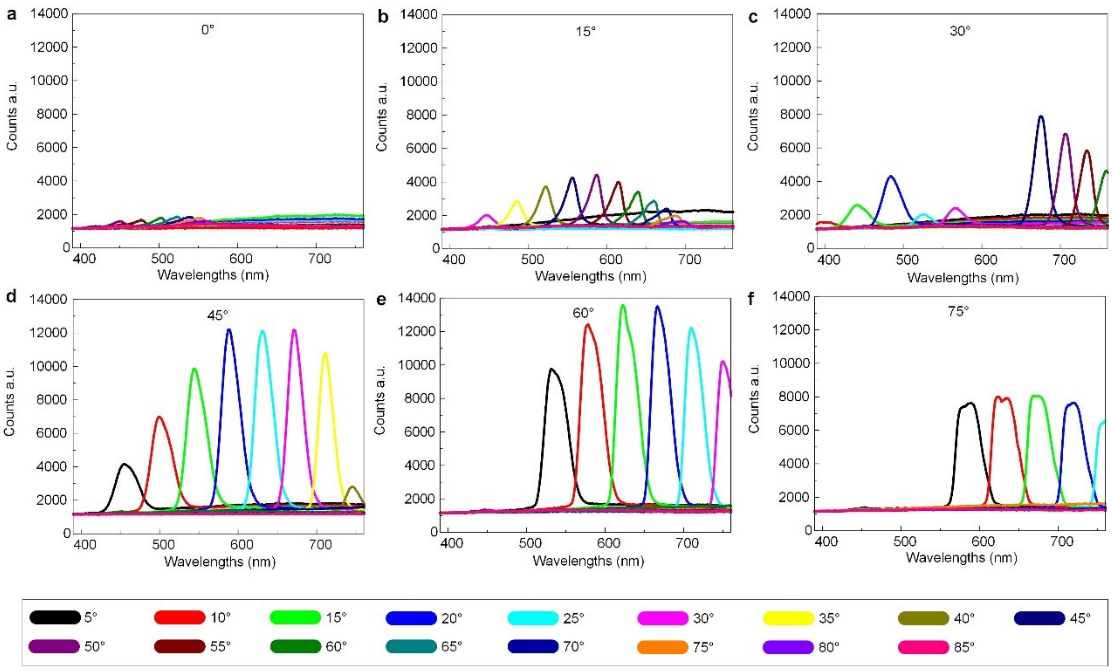

Fig. S3 Colors of photonic crystal films in different incident angles and observation angles. The angle in the title of graphs are observation angles, include 0°(a), 15°(b), 30°(c), 45°(d), 60°(e) and 75°(f).

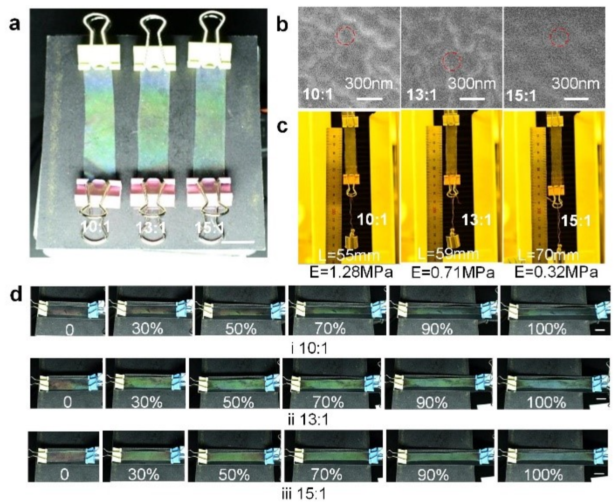

Fig. S4 Material optimization of photonic crystal film. (a)Colors of films with different proportions. (b)SEM images of films with different proportions. (c)Elastic modulus of films with different proportions. (d) Colors of films with different proportions under different deformations.

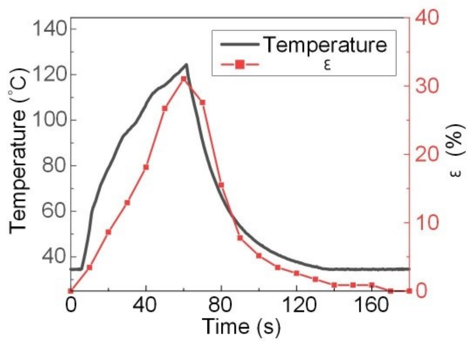

Fig. S5 The temperature and strain change of the LCE actuator under a voltage. The maximum ε here is about 30%, which corresponds to the deformation required for color-tuning.

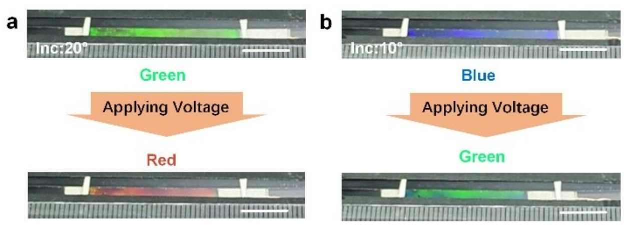

Fig. S6 Color changes with external voltages when the incident angle is 20°(a) and 10°(b). The observation angle is 45°.

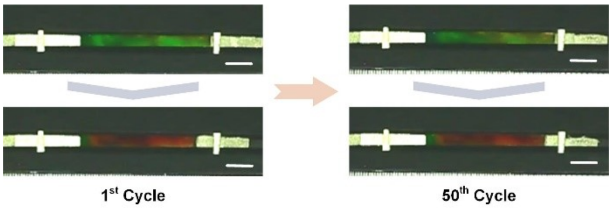

Fig. S7 Color performance of integrated smart skin after 50 cycles of repeated contraction under voltage. The incident angle is 20° and the observation angle is 45°. The scale bar is 1cm.

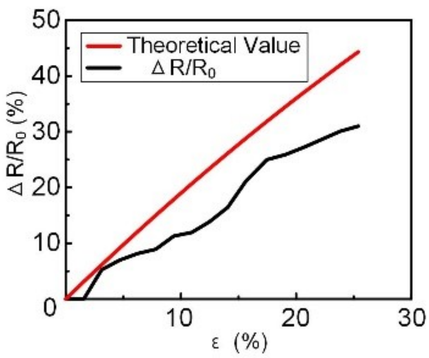

Fig. S8 Resistance change ratio of theoretical value and the $\Delta R/R_0$ calculated by experiment.

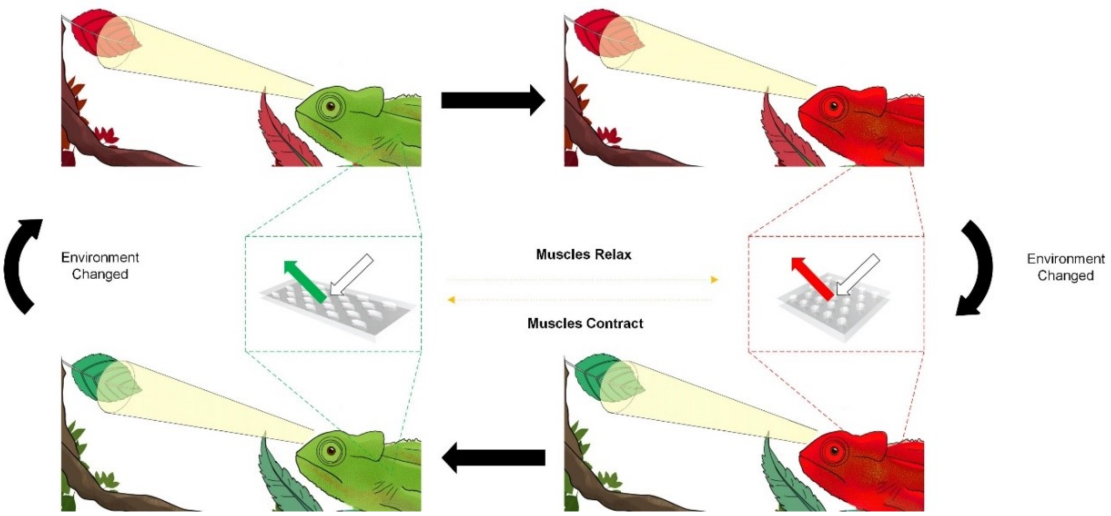

Fig. S9 Schematic of the tunable color on chameleon responding to various environment.