Near-Infrared Light “Writing” Strategy for Adaptive Three-Dimensional Shape Transition with Infinitely Adjustable Shaping Sequences

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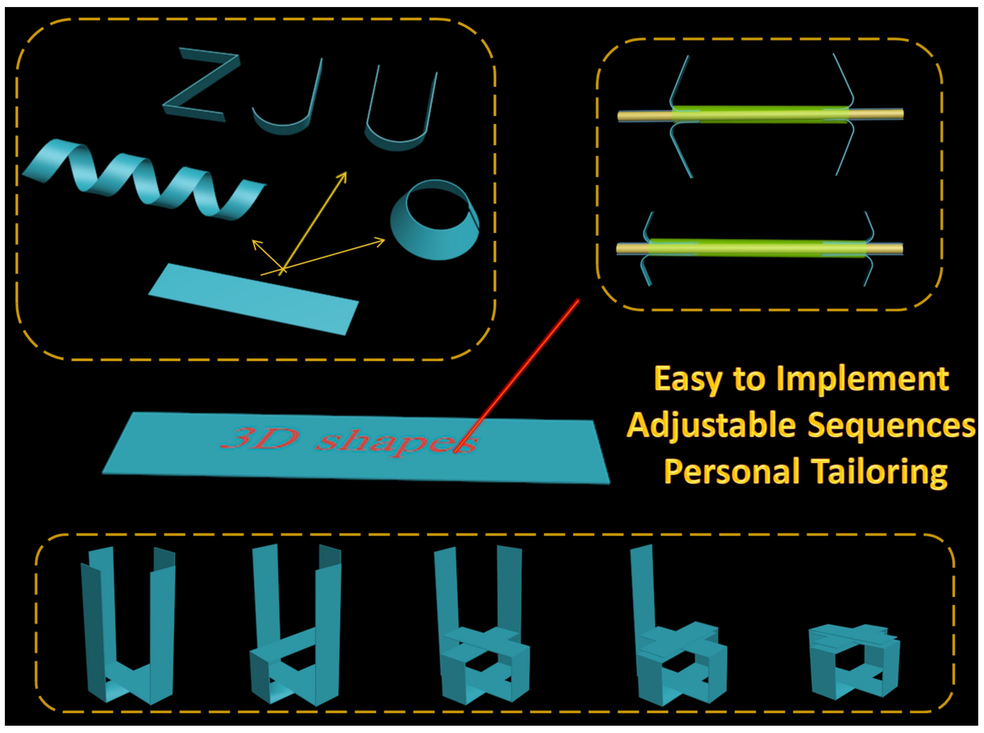
Introduction

A light "writing" strategy is described to generate easy-to-implement, sequential and "personalized tailoring" three-dimensional (3D) shape transition by exploiting photothermal conversion capability of polydopamine (PDA) and shape memory effect of Nafion films. The Nafion/PDA composite film in uniform stretched temporary shape and the near infrared (NIR) laser are employed as paper and pen, respectively. With localized heat generated from tunable NIR light irradiation, well controlled inner stress can be "written" into the film precisely and thus trigger complex 2D-3D shape transition instantly. The tunability and predictability of obtained 3D shapes are verified. Compared with the previous methods, such a light "writing" strategy can be used to modulate both the target shape and the shape transition process in situ at the same time with no need to tune the material compositions or structures. Stepwise shape transitions with infinitely adjustable shaping sequences are firstly realized in this work, which is of crucial importance in constructing overlapped structures. Furthermore, the 3D shapes can be adjusted flexibly to meet on site individual requirements. This adaptability makes it a new way to tackle the contradiction between individual variation and standardized manufacturing techniques in fields like personalized healthcare.



*Scheme 1. **Near-Infrared Light “Writing” Strategy** for easy-to-implement, sequential and “personalized tailoring” 3D shape transition.*

Method

Nafion films were swollen in water to load dopamine molecules for in situ formation of PDA. The composite films were stretched uniformly and fixed in their temporary shape to act as paper. Well controlled inner stress can be “written” into the material precisely and thus trigger complex 2D-to-3D shape transition instantly with spatiotemporally controllable near infrared light. In this way, we can easily obtain different predictable 3D shapes with identical planar sheets by adjusting the intensity, facular region shape and position of the laser beam. Stepwise shape transition with infinitely adjustable shaping sequences is feasible through a series of “writing” steps. More impressively, on-demand shape transition with in-situ shape tunability can be realized to meet individual requirements.

Results and Discussion

Nafion film with uniformly dispersed PDA was successfully fabricated and it maintained outstanding shape memory capability after PDA modification.

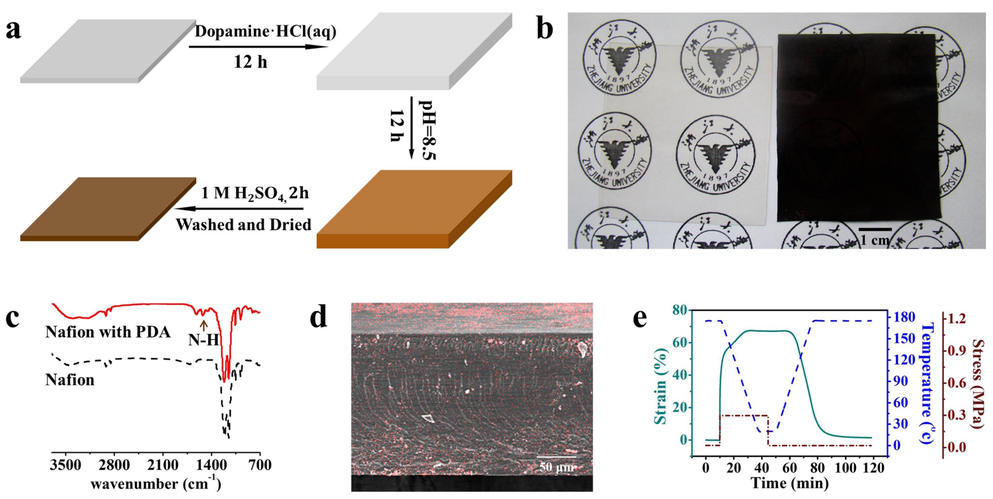


Figure 1. Schematic representation of PDA-modification process. b) Photographs of Nafion films before and after PDA modification. c) FT-IR/ATR spectra of Nafion films with and without PDA modification. d) Merged SEM and EDX image of the cross-section of PDA-modified Nafion film. e) Shape recovery cycle of PDA-modified Nafion film.

The highly controllable light enables a strong modulation of the morphological transformations so as to generate innumerable different 3D shapes with identical planar sheets simply by adjusting the NIR laser.

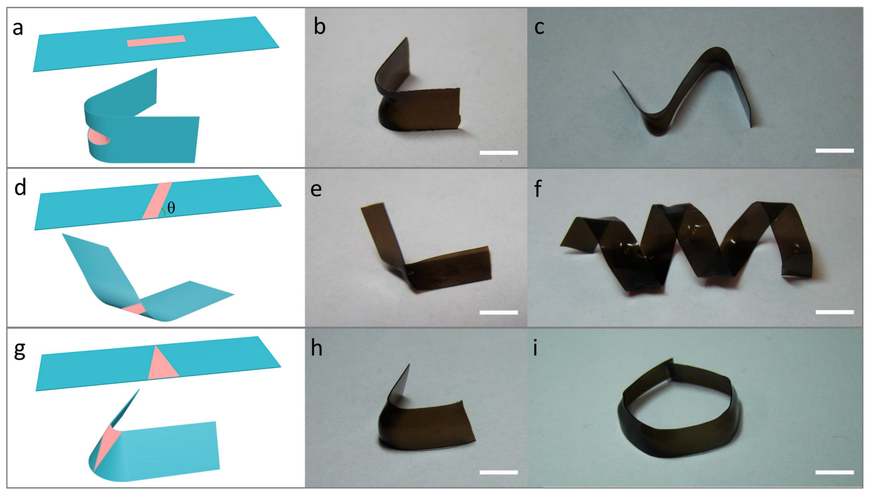


Figure 2. Different 3D shapes generated from the same stretched Nafion/PDA films treated with NIR laser with different facular region shapes. Scale bars: 0.5 cm

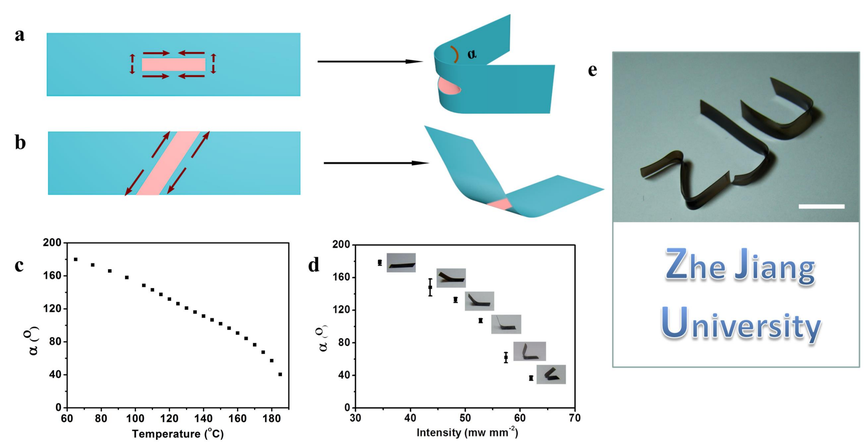


Figure 3. a, b) Schematic representation of inner stress in the planar films. c, d) Predicted and measured variation in angle with increasing temperature. e) The characters “Z”, “J”, “U” obtained from identical stretched films through different permutations of irradiation regions with the same facular shape and different intensities. Scale bars: 1 cm.

Stepwise shape transition with infinitely adjustable shaping sequences is feasible through a series of “writing” steps to construct complex overlapping 3D structures.

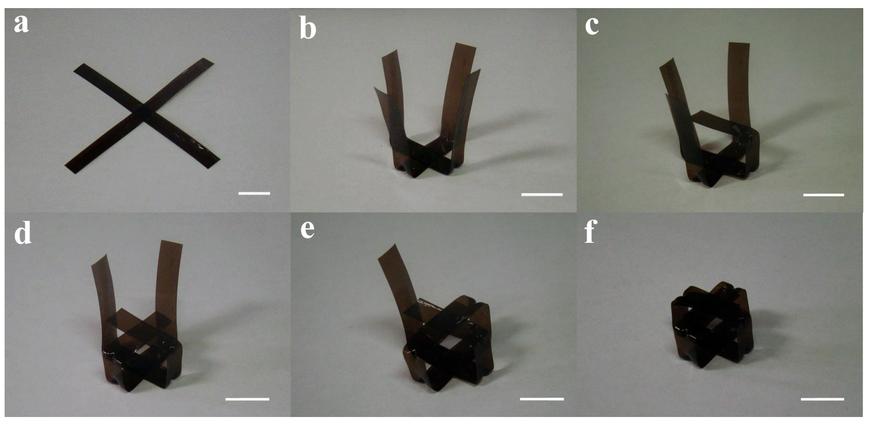


*Figure 4. 3D shape with overlapped structures generated via **s**tepwise shape transition. Scale bars: 1 cm.*

The obtained shape can be in-situ adjusted accurately to meet the requirements of different service conditions with no need to re-prepare the planar sheets just like a personalized tailoring platform.

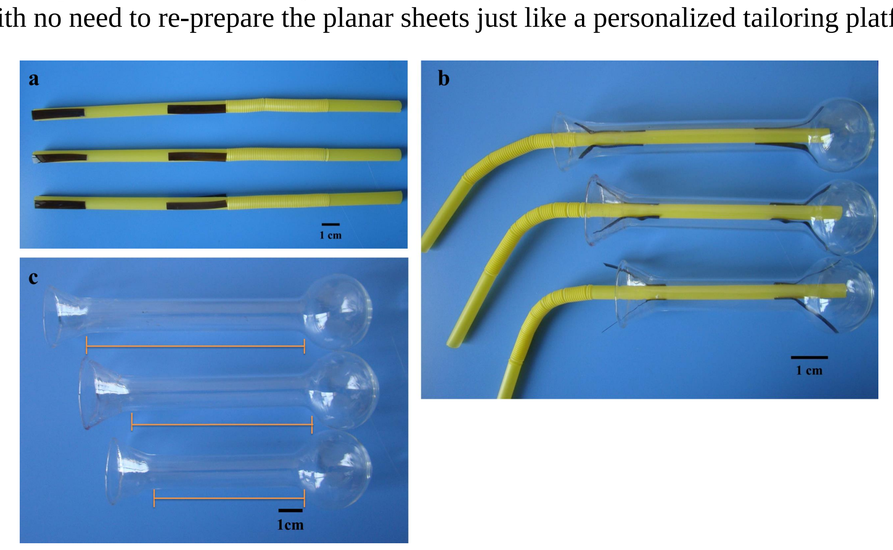


Figure 5. Model illustration of the potential of the light writing system to act as a "personalized tailoring platform".

Conclusions

A NIR light "writing" strategy is described to generate easy-to-implement, sequential and "personalized tailoring" 3D shape transition. This method can be used to modulate both the shape transition process and the target shape with standardized "paper" materials to obtain infinitely adjustable shaping sequences and adaptable 3D shapes to meet on site individual requirements.