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polymer letters

Editorial corner – a personal view

Shape memory polymer capable of gradual transformation and working

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As a prominent example of smart materials, shape memory polymers (SMPs) are now only used in narrow fields, like heat-shrinkable tubes and films, far below people's expectations. The following issues are believed to account for the situation, *i.e.* the existing SMPs can remember very few shapes, and the work density of SMPs is often too low to do work to the external world. Currently, for example, SMPs can only take up to three shapes (https://doi.org/10.1021/acsami.9b10052), and their stiffness has to be significantly reduced due to the disordering of the ordered regions when the switching phases are triggered. The latter effect prevents the materials from producing sufficient mechanical work output.

To tackle the challenges, recently we developed a stepless shape morphing polymer by simply training commercial ultrahigh molecular weight polyethylene (UHMWPE) under the joint action of heat treatment and tension (https://doi.org/10.1002/smm2.1134). Because the crystals of semi-crystalline polymers possess slightly different melting temperatures, and each type of the crystal can remember a single shape, the crystalline region of UHMWPE is allowed to remember plenty of temporary shapes after programming as a result. Meantime, the crystalline phases can be converted into the switching phases, and the reformed chain entanglements serve as the internal stress provider. The collaboration between the switching phases and internal stress provider in response to temperature change arouses the reversible shape transformation. In this context, changing the temperature of the programmed UHMWPE within its melting/crystallization temperature ranges would lead to releasing/recovery of the memorized temporary shapes.

Discretionary multiple shape memory effects can thus be implemented without the need for the elaborate design of material's structure and training process in advance as before. The maximum work density of the programmed UHMWPE is found to be 210 kJ·m^{-3}, suggesting that it is able to lift nearly 10 000 times its own weight.

For demonstrating the proof-of-concept applications of the trained UHMWPE, the latter is included in the analogue soft zoom lens and tunable capacitor as actuators, respectively. By continuously/random/proportionally varying the temperature, the focal length and capacitance of the zoom lens and capacitor indeed reversibly change following the corresponding shape morphing manners of the actuators. Besides, the trained UHMWPE can also serve as a mechanical actuator for reversibly pumping fluids (with ethanediol-droplet as an example) upon heating/cooling.

UHMWPE is a commercial polyolefin, and no chemical reactions are required for the training. Such a 'physical conversion instead of chemical modification' concept means that the technique is sufficiently scalable and of practical value.

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