HIGH-PERFORMANCE AND MULTI-FUNCTIONAL SHAPE MEMORY POLYMER COMPOSITES

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Introduction

Compared with traditional shape memory materials such as metals and ceramics, shape memory polymers (SMPs) have many outstanding advantages such as light weight, easy processing, and adjustable shape memory effect, which make them a hot topic in the field of smart materials. To overcome their disadvantages such as low mechanical modulus, slow response, and lack of non-thermal stimuli, adding inorganic or metallic fillers to form composites has become an important and attractive strategy. In our recent work, various fillers such as carbon nanotube (CNT), carbon fiber (CF), boron nitride (BN), and titanium dioxide (TiO_2) have been employed to improve the mechanical properties and multiple functions of different types of SMPs such as chemically crosslinked polyolefin, cured epoxy, and chemically crosslinked polyurethane (PU). Some new results are reported in this presentation.

Results and Discussion

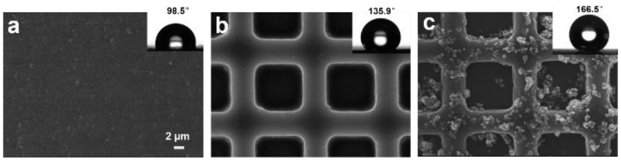

Figure 1. Scanning electron microscope (SEM) images of smooth surface (a), patterned surface (b), and TiO_2 coated patterned surface (c) of chemically crosslinked polycyclooctene (PCO). The insets in the upper right corner of each part show the measurements of water CA.[1]

As shown in **Figure 1**, the contact angle (CA) of the patterned surface (ca. 135.9°) is much higher than that of the smooth surface (ca. 98.5°), which indicates that increased surface roughness has been achieved by the formation of micrometer scale patterns. Coating TiO_2 nanoparticles onto the surface pattern can further increases the CA to ca. 166.5°, which already lies in the superhydrophobic region.

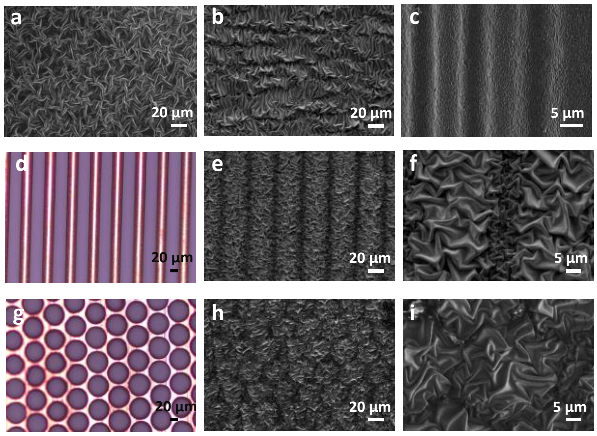

Figure 2. SEM image of hierarchical surface patterns obtained by controlling the shape recovery of chemically crosslinked PE in the bilayer system of sputtered Au/chemically crosslinked PE.[2]

Figure 2 shows that various hierarchical surface patterns can be obtained by tuning the shape recovery of chemically crosslinked polyethylene (PE) in the bilayer system of sputtered gold (Au)/chemically crosslinked PE. Such functional surfaces can be used to prepare pressure sensors and wettability-adjustable surface.[3]

Figure 3 shows the shape memory behaviors of shape memory epoxy and its CNT nanocomposites after different cycling times. It demonstrates that the addition of fillers not only makes the response much faster but also significantly increases the cycling stability of the materials.

Figure 4 shows that the mechanical modulus can be remarkably increased by adding fillers. Among them, longitudinal directional pre-preg CF filled composites could achieve the maximum storage modulus (E') and recovery force of 37 GPa and 4.4 GPa, respectively, which are even higher than those of the shape memory alloys (SMAs).

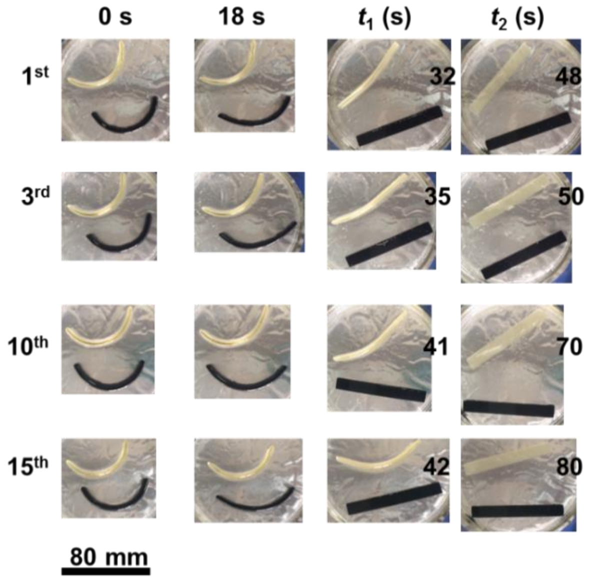

Figure 3. Photographs showing the shape recovery process of the shape memory epoxy (yellow) and its CNT nanocomposites (black) for various repetition times. The t_1 and t_2 are the time needed for the complete recovery of the composites and pure polymer materials, respectively. 1st, 3rd, 10th, and 15th are the shape memory cycle number.[4]

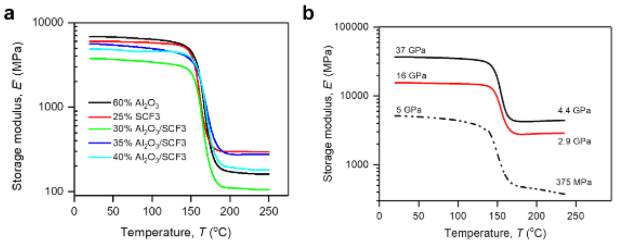

Figure 4. Dynamic mechanical thermal analysis (DMTA) curves showing the E' change during heating of shape memory epoxy composites with with non-continuous (a) and continuous (b) fillers.[5]

The last but not the least important is that 3-D printing technique has been used in our work for shape memory polyolefin, cured epoxy, and polyurethane (PU) to fabricate smart devices with complex structures and improved properties (as shown in **Figure 5**).

Conclusions and Outlook

Adding fillers to fabricate composites can significantly improve the comprehensive properties of SMPs, which is beneficial to their real applications. 3-D printing can also help in this direction. However, to further improve the properties of SMP composites are still a big challenge.

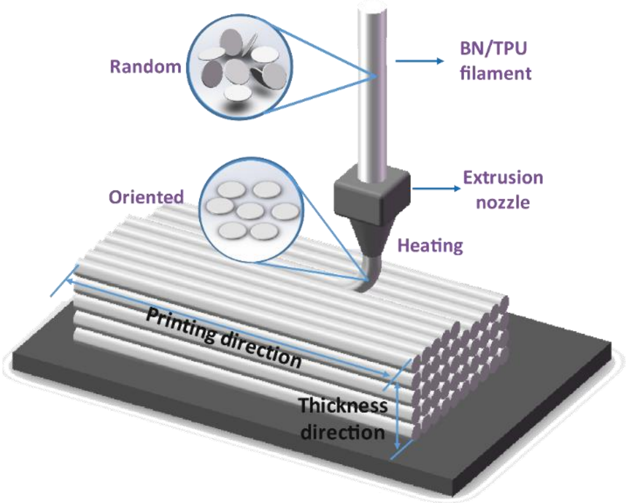

Figure 5. Schematic illustration of the progressive alignment of high aspect ratio fillers within the nozzle during composite ink deposition of 3-D printing.[6]

References

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