Performances of Co-extrusion Printing Shape Memory Poly(ether-ether-ketone) Composites Actuator

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Introduction

Shape memory polymers (SMPs) gradually are fresh replacements in biomedical and mechanism fields as deformable bodies due to the transformation between two configurations. However, most of the SMPs are have a low glass transition temperature and not suitable for harsh circumstances with a temperature above 100 ℃. Polyether-ether-ketone (PEEK) is endowed with thermal-response shape memory behavior while having a high glass transition temperature of 143 ℃. The outstanding mechanical property of PEEK is suitable for deformable actuators used in untouchable and extreme environments such as deployable space structures. Here, we manufacture a PEEK composites actuator integrated with conductive fibers by co-extrusion printing strategy to stimulate the shape memory deformation by the current.

Methods

A fused deposition molding printer equipped with two extruders - one for both the PEEK filament and metallic fiber, and the other for the PEEK filament only in Figure 1. This allows us to print the polymer structure with a defined metallic fiber path. Metallic fiber is gradually encompassed by the molten polymer in the feeding throat and is subjected to a downward force of friction.

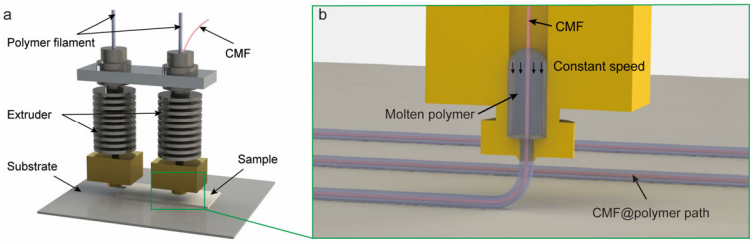

Figure 1

We studied the macroscopical shape memory properties of PEEK in bending behavior in Figure 2. A flat sample was heated up by the power wire connected with a source, while the flexible sample was shaped by applied strain. The shape recovery of PEEK was recorded by a camera. After colling down, the sample kept a temporary shape with a fixed angle θ_F, which was the angle between the horizontal line and the free side of the sample. Thus, we could calculate the shape fixed ratio R_f.

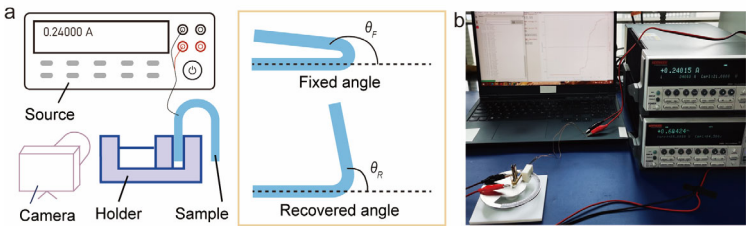

Figure 2

Discussion/Results

We investigated the shape memory effect of PEEK under full-bending deformation at different actuated currents in Figure3. When the current increased 0.02 A, the recovery ratio increased by 14%, and the maximum speed increased by 10%. The actuated force decreased by 0.2 N for every 20 ℃ increase in temperature.

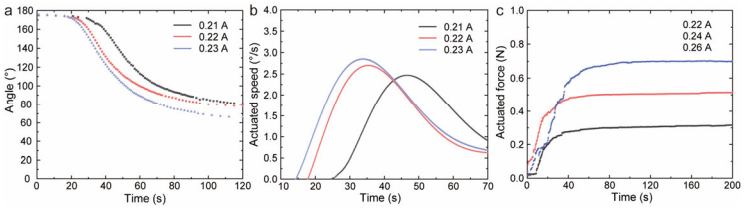

Figure 3

An aerospace actuator was needed to work a few weeks after installation. So we investigated the effect of idling time on shape memory effect in Figure 4. The recovery ratio decreased by 7.7% with after 37 days, besides, the recovery force decreased by 15% leading to a weaker actuated capacity.

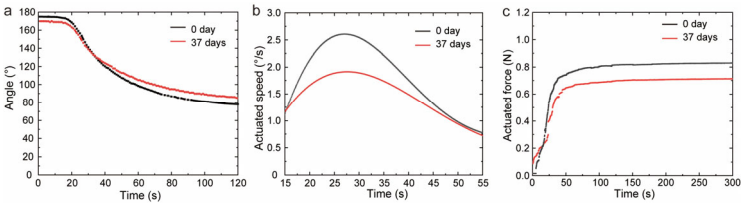

Figure 4

An experimental simulation of deployed drag sail by PEEK actuators is in Figure5.

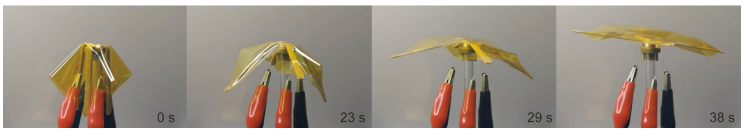

Figure 5

Conclusions

High-temperature PEEK embedded with wire was manufactured by composite 4D printing for combining the SMP and stimuli in actuation technology. The stable and consistent shape memory properties were verified in multiple shape memory deformation, representing great working capacities and deformation accuracy of PEEK actuators. The lightweight structure and non-motor portability showed the breakthrough in special environments. This study paves the way in front of designing and optimizing the future electro-active PEEK actuator in aerospace.