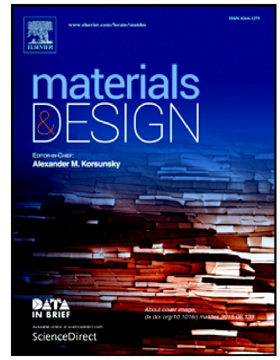

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4D Printing of High Performance Shape Memory Polymer using Stereolithography

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Abstract

High shape fixity, shape recovery, and prolonged shape memory cycle life are desirable aspects of 4D printed parts; however, the durability of 4D printed parts is rarely investigated. Here, we demonstrated a photopolymer printable by stereolithography apparatus (SLA) which uses a tBA-*co*-DEGDA network based on dual-component phase switching mechanism to build parts of complex geometries and exhibit shape memory behavior. The material can achieve a high curing rate and precise printing that are highly desired for SLA process. The mechanical strength of the printed parts is comparable statistically to industrial SMPs and shape memory tests showed excellent shape memory performance with higher durability of more than 20 shape memory cycles as compared to current 4D printed parts. This work is believed to enable the use of SLA technology to fabricate responsive components of high performance, which also significantly advances the 3D printing technology for more robust applications.

1 Introduction

Shape memory polymers (SMPs) are smart materials that can be inelastically deformed and then recover to their original shape by an external stimulus such as temperature change[1-3], known as shape memory effect (SME)[4, 5]. The reshaping capability has applications in the biomedical field such as sutures and stents for minimally invasive surgery[6-8], as well as applications in sensors[9] and actuators[10] in the field of robotics.

Manufacturing and processing of SMPs are still heavily reliant on conventional processes for polymers such as in situ polymerization, extrusion and casting[11-13], which make it difficult to fabricate complex geometries with advanced functionality. In this regard, additive manufacturing (AM), commonly known as 3D printing, which builds objects by adding materials layer-by-layer[14], can be a promising alternative that offers great flexibility in terms of product design and manufacture.

The emerging technique for 4D-printable SMPs, otherwise known as 4D printing[15], is widely demonstrated using multi-materials 3D printers with multiple nozzles to jet out different liquid photopolymers and cure under ultraviolet (UV) exposure[16]. Ge *et al.* developed active origami through a mixture of elastomeric matrix with rigid plastic and cured heterogeneously by sections to create a SME within the part[17, 18], while Yu *et al.* investigated on the precise and sophisticated design of component geometry like part thickness and control of the materials layout to achieve SME. In multi-materials printing, the designs and materials layout are the extrinsic factors towards the degree of change in the SMP. The combination of different materials is subjected to the presence of interfaces