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Abstract

Shape Memory Polymer Microstructures Using Melt Electrowriting †

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† Presented at the XXXV EUROSENSORS Conference, Lecce, Italy, 10–13 September 2023.

Abstract: Melt electrowriting is a relatively new additive manufacturing technique capable of the controlled deposition of polymeric fibers to manufacture pre-programmed structures at micron scale. In this research, a blend of poly (ε-caprolactone) and thermoplastic urethane displaying shape memory properties is processed using melt electrowriting. The bulk material at macro scale shows a transition temperature of around 60 °C. Fibers with diameter less than 60 µm were deposited as sinusoids and grid-like scaffolds. A high strain fixity ratio of 92% was obtained for the polymer, which is in accordance with the literature on shape memory polymers. These shape memory structures can be used for applications such as micro-sensing and actuating.

Keywords: 4D printing; electrohydrodynamic; melt electrospinning writing; stimuli responsive

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Citation: Tandon, B.; Sabahi, N.; Farsi, R.; Kangur, T.; Li, X.; Brugger, J. Shape Memory Polymer Microstructures Using Melt Electrowriting. *Proceedings* **2024**, 97, 213. https://doi.org/10.3390/proceedings2024097213

Academic Editors: Pietro Siciliano and Luca Francioso

Published: 10 May 2024

1. Introduction

Melt electrowriting (MEW) is a fiber manufacturing technique that involves the fabrication of micron-sized polymeric fibers by extruding a polymer melt through a nozzle that is maintained at a high voltage relative to the collector (Figure 1a). The electric field across the nozzle-to-collector gap acts as the driving force to initiate and maintain the polymeric jet, which can be deposited in a controlled way. MEW is a relatively recent technology, and therefore there are few studies showing the printability and processability of functional or stimuli-responsive polymers [1,2]. Shape memory polymers (SMPs) are a class of stimuli-responsive polymers that have found application in various fields, such as biomedical devices, flexible electronics, sensors, and actuators [3]. These materials can be programmed into a temporary shape, which can be reverted to the original shape upon the application of an external stimulus. The fabrication of SMPs at micron scale has recently been gaining increased interest as it improves the versatility and potential for further applications in different areas [4].

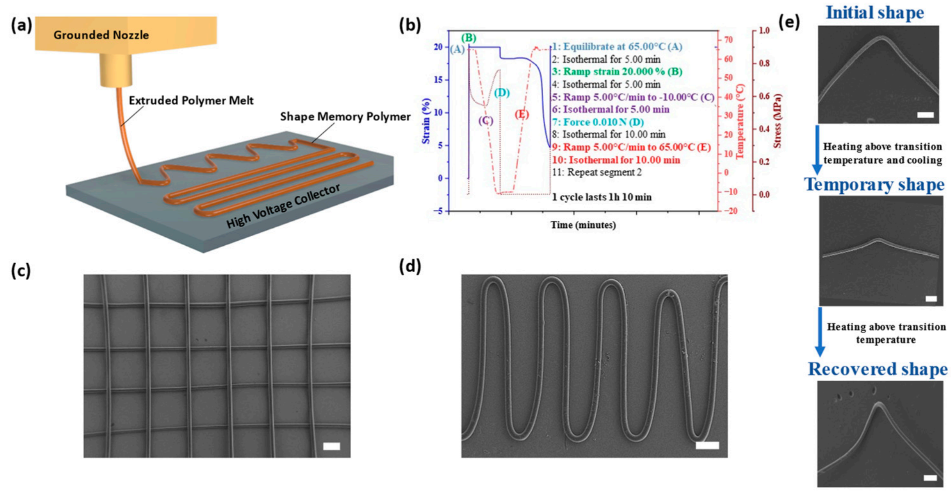

Figure 1. (**a**) Schematic of the MEW process; (**b**) DMA data obtained and process steps used; (**c**) grid-like structure; (**d**) sinusoid structure obtained for SMP; (**e**) shape memory effect in printed fibers. Scale bars: 200 µm.

2. Materials and Methods

The shape memory polymer blend (30% poly (ε-caprolactone) and 70% thermoplastic urethane) was fabricated as a 1.75 mm filament using a twin extruder system. An open-source Voron FDM printer was modified into a MEW system by making changes to the extruder assembly [5]. SMP structures were printed and characterized using scanning electron microscopy (SEM). A dynamic mechanical analysis (DMA, TA Q800, TA Instruments, New Castle, DE, USA) test was performed on the macro-filament to study the shape memory properties. The process flow used for DMA tests is summarized in Figure 1b. The printed fibers were carefully removed from the collector and a hot air oven or a water bath at 60 °C was used to qualitatively analyze the shape memory properties.

3. Discussion

The shape memory behavior of the macro-filament was studied using DMA (Figure 1b). These data were utilized to extract information about the strain recovery ratio and the strain fixity ratio, which were found to be about 73% and 92%, respectively. Grid-like scaffold and sinusoidal structures were fabricated from the SMP using electrowriting (Figure 1c,d). These structures were found to have an average fiber diameter less than 60 µm. The fabricated microstructures responded quicker than macro-scale equivalents to changes in temperature, which can be attributed to efficient heat absorption due to the scale effect [6].

Author Contributions: Conceptualization, B.T. and J.B.; methodology, B.T.; software, B.T., R.F. and T.K.; validation, B.T. and J.B.; formal analysis, B.T.; investigation, B.T. and T.K.; resources, N.S., X.L. and J.B.; data curation, B.T.; writing—original draft preparation, B.T.; writing—review and editing, B.T., N.S., R.F., T.K., X.L. and J.B.; visualization, B.T.; supervision, B.T. and J.B.; project administration, X.L. and J.B.; funding acquisition, X.L. and J.B. All authors have read and agreed to the published version of the manuscript.

Funding: Part of this work received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (Grant No. ERC-2016-ADG, Project "MEMS 4.0" Grant No. 742685).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data that support the findings of this study are available from the authors upon reasonable request.

Conflicts of Interest: The authors declare no conflicts of interest.

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