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Structured 3D elastomeric composites with hybrid functionalities via 3D printing

Yu Liu [1], Jiawen Xu[1], Erwei Shang[1], Yanqiu Chen[1], Zhenyu Wang[1], Qiang Zhang[1], Jun Ren[1]

1 School of Mechanical Engineering, Jiangnan University, Wuxi, China

Email: yuliu@jiangnan.edu.cn

Abstract

Soft materials possessing different functionalities, including both of sensing and actuating, are greatly favoured in many sectors, which require 3D surface mounting and / or deliver complex mechanical environments. This work will present our latest efforts on development of in – situ 3D polymeric printing for rapid fabrication of magnetic and conductive NP filled soft filaments based on a proposed segmented deposition technique being comprehensively studied. Precision deposition control with on – line material preparation is presented, and process parameters on each individual performance index are discussed. Electric circuit model is developed for theoretical predication on conductivity, magnetic – induced stretchability and dynamic response with 3D fabricated part features. Different structures are also given with experimental demonstrations on its meta properties. We therefore are able to obtain hybrid components carrying both of strain sense, temperature sense and stretching movement capabilities. Technical reviews and next steps will be finally remarked through demonstration of practical applications with local manufacturing collaborators.

3D printing, soft electronics, precision deposition, manufacturing.

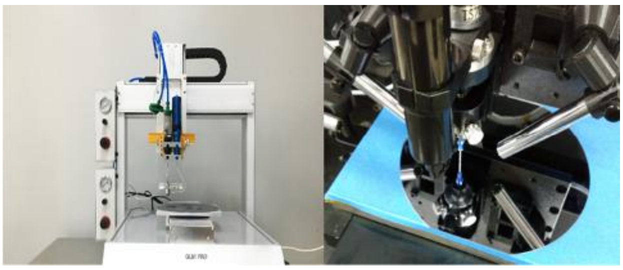
1. Introduction

When meeting with 3D printing, functional materials can be programmably deposited layer by layer and both of more complex structure and more comprehensive functionalities can therefore be manufactured, much beyond the rapid prototyping in general use with additive manufacturing (AM) []. Soft parts with stretchability but retaining their major functionalities, are lately emerging as mandatory components to consist mechatronic systems in advance, useful for applications in wearable devices, soft robots, biomedical chips, aerospace and transportation []. Thus, direct 3D printing of soft materials with different functions becomes attracting in our AM field []; and more recently, layered manufacturing based on elastomeric material or its composites is representing the frontier in both of material and manufacturing []. Associated with elastomeric materials, 3D printing by direct ink writing is one in general consideration so far, which is based on a continuous extrusion of ink filament. In this presentation, major discussion will be focused on how to prompt this technique in leading fabrication of Structured 3D Elastomeric Composites with Hybrid Functionalities.

2. Materials and Methodology

For elastomeric ink, polydimethylsiloxane (PDMS, SE1700, Dow Corning Inc.) was prepared by mixing the base and catalyst with 3-Butyn-1-ol at the weight ratio of 100:10:1. For functionalities, the elastomeric ink can be doped with graphene or silicone. For stretchable conductor, pure indium and gallium chemicals were purchased for direct use as the flowable conductive material. The eutectic concentration was controlled by weight ratios of 68.5% for gallium, 21.5% for Indium, and 10% for indium, respectively, which allows its liquid state in ambient applications with low viscosity of ~ 2.4mPaS [ ] and electrical resistivity of ~ 10-6 Ω·cm.

In our group, a gantry frame, consisted of three linear stages with resolutions down to 1 μm, has been developed and used in our many work (**Figure 1a**). For elastomeric ink, pneumatic dispenser with pressure up to 35 bar can be selected to handle with high ink viscosity. For other materials listed here, syringe pumping was applied with piston movement at a speed to precisely control the amount of deposited sacrificial layer. All movements were programmed in C# to follow a specified tooling path. Finest linewidth by our direct ink writing can be controlled less than 75 μm for PDMS.



(a)

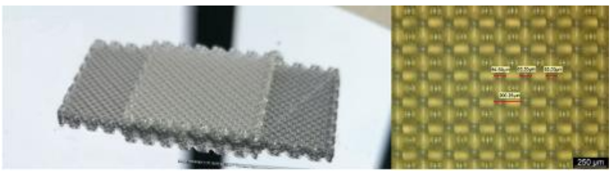


Figure 1. System frame and printed resolution for high viscous ink

3. Results and Products

Efforts have been delivered for preparation of functional samples. Shown in **Figure 2(a)**, this work presents our new findings on fabrication of cellular ceramic parts and controlling its shape distortion after firing. There, both of process parameter control and structure design can impact this distortion degree.

In **Figure 2(b)**, in – situ heating was introduced for extruding the hollow tubing when high viscous elastomeric ink was supplied. Wherein, it can form highly controlled tubular shape with both of inner and outer diameter. It will play as a stretchable conductor and strain sensor to be displayed in our presentation.

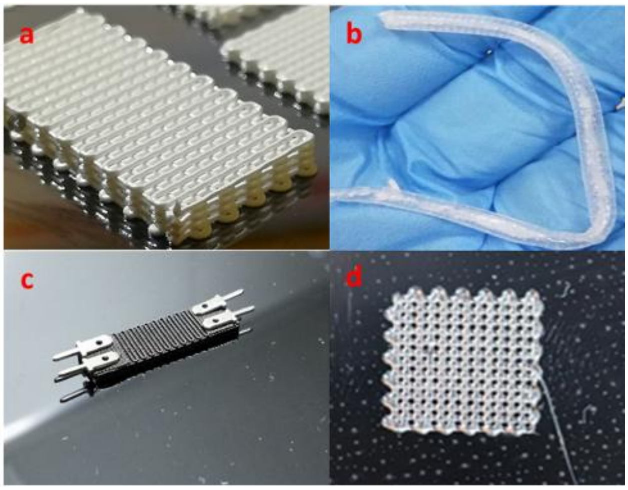


Figure 2. Printed functional samples : a. ceramics; b. tulular channel; c. graphene / PDMS temperature sensor; d. expoxy network.

Furthermore, in **Figure 2(c)**, graphen doped PDMS composite with its resistance change with strain has also been printed for direct fabrication of temperature sensor, which owns stable temperature sensitivity upon large stretching up to 20%. Electric circuit model was developed to analyse for conclusion there that cellular structure could dislocate the strain along cell wall to compensate the deformation induced resistance change, when a proper structure was designed.

Expoxy materials with high reactivity can be tighly controlled by our introduced in – situ moderation of catalytic material, and form cured ink filament during deposition as shown in **Figure 2(d)**. For this study, we will comprehensively discuss our in – situ heating and pre – curing technique.

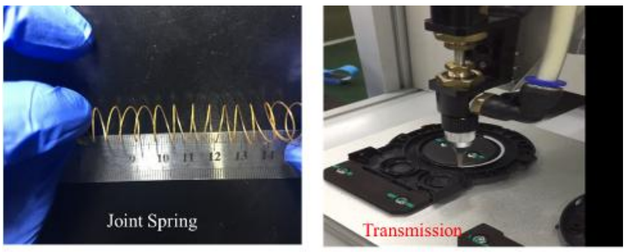


Figure 3. Printed polyimide spring and transmission lubricating string

Last, some more examples are shown in **Figure 3**. Herein, two studies on joint spring and transmission lubricating string have been introduced for automotive industry. For both case, direct ink writing can offer other functional devices at the acceptable production rate.

4. Acknowledgements

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