FABRICATION OF POLYMER-DERIVED CERAMIC BASED ON 3D/4D PRINTED PRECURSOR

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1 General Introduction

There is growing interest in additive manufacturing (AM) of ceramic-based material due to its capacity to achieve designed shapes [1]. However, complex structures and limited printability hinder the development of ceramic AM owing to the nature of printing technologies and materials [2, 3]. Here, we present a novel paradigm for the fabrication of ceramics with highly complicated geometries through a polymer-to-ceramic process. It starts from a preceramic precursor ink that could be printed through direct ink writing (DIW) and the as-printed structure could be reconfigured into more complex structures. Moreover, preceramic precursor with shape memory ability was realized for the first time, exhibiting a rapid response (<10 s) and high recovery ratio (~100 %) under thermal activation. After sintering process, the feasibility of resulting ceramic acting as thermistors was proved by exploring the correlation between temperature and its electrical resistance. This work may provide reliable solutions to ceramic components and high-temperature sensors associated with high resolution and affordable cost.

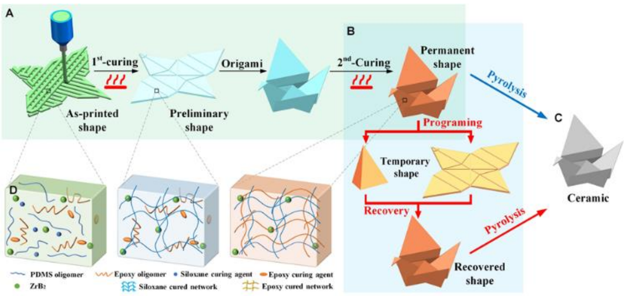

Fig. 1 Schematic fabrication process of 4D-printed PDCs from precursor inks with reconfiguration and shape memory ability. (a) Reshaping principle through separate curing steps of precursor ink. (b) Shape memory cycle under heat stimulus. (c) Ceramic product after pyrolysis process. (d) Schematic microstructure of material at different crosslinking stages

2 Experimental procedure

The prepared precursor was printed by DIW method and the ink was extruded through the printing nozzle with diameters of 260/410 μm. The as-printed part was heated to 80 °C to achieve first curing. Then it was heated to 150 °C to achieve the second curing. Finally, the green-body was sent into the tube furnace to undergo pyrolysis and sintering process (at 1300 °C) to become ceramics.

3 Results

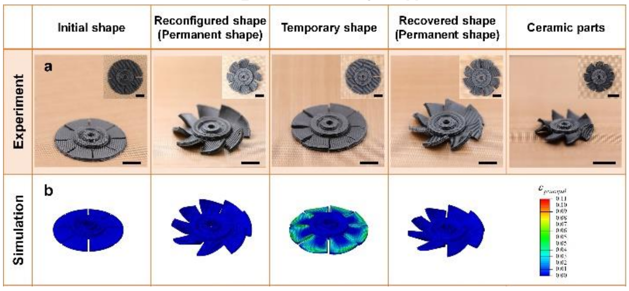

Fig. 2 illustration from 4D printed precursors to geometrically complex ceramics (a). Initial, reconfigured, programmed, recovered, and sintered shapes of 4D-printed blade model and (b) its shape changing simulation by FEA.

The as-printed part was firstly cured at 80 °C to achieve partial cross-linking. And the initial shape was reconfigured into the permanent shape by origami at this highly elastic state with the help of fixture. After the second curing at 150 °C, the precursors formed fully cross-linked networks. The completely cross-linked precursor could also be transformed into temporary shape and recover to the initial shape when activated by external stimulus. After pyrolysis and sintering operation at 1300 °C, the green-body became the resultant ceramics.

4 Conclusions

A novel paradigm for fabricating ceramic where the formulated precursor-based ink system can be printed by DIW and as-printed parts could be shaped twice was proposed. The cured precursor ink also possesses shape memory capability that could be programmed into temporary shapes and then rapidly and fully recover to its original shape under external heat stimulus. The combination of reconfiguration and preceramic precursor gives researchers new opportunities and possibilities to fabricate geometrically complex ceramic structures. These foldable properties derived from SME may dramatically help to save storage volume and meanwhile maintain accuracy after deployment. This work may open avenues for designing ceramics with geometrical flexibility and sensors with integrated functionality, which are promising in various fields.

5 References

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