3D printing of fully recyclable continuous fiber self-reinforced composites and remanufacturing

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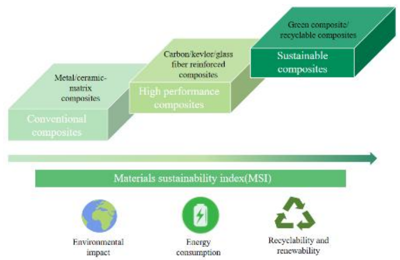
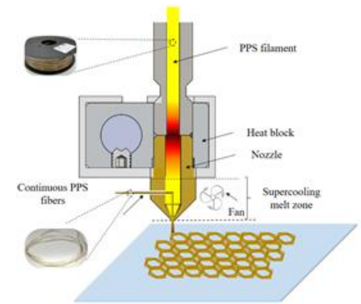
Outline

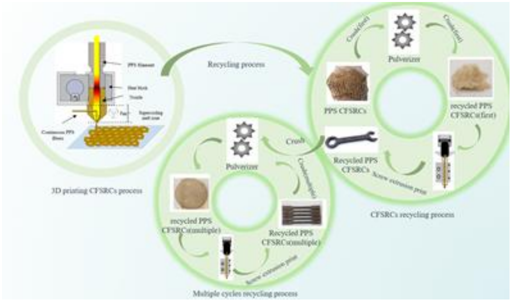
Research background



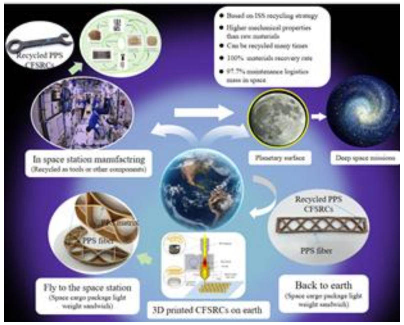
3D printing of continuous fiber self-reinforced composites



Recycling and thermal degradation mechanism

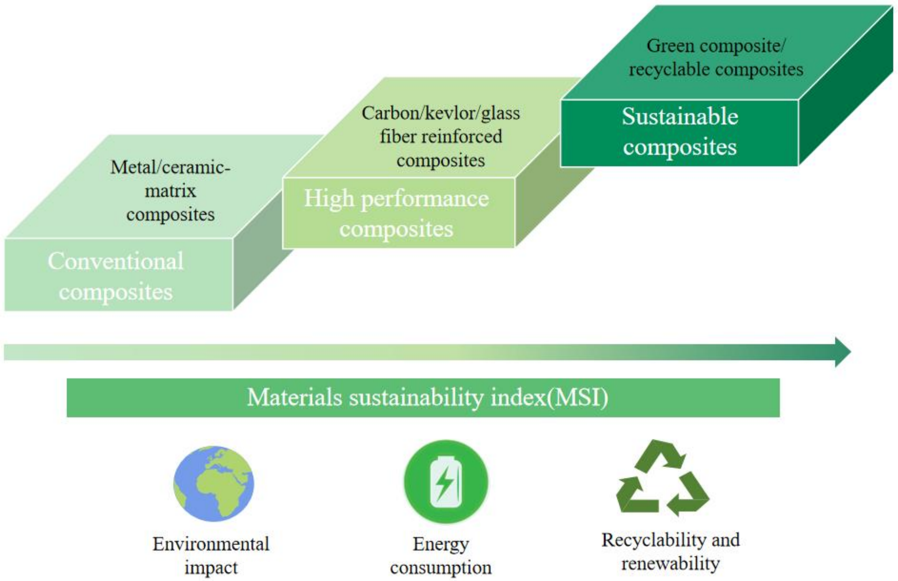


Perspective

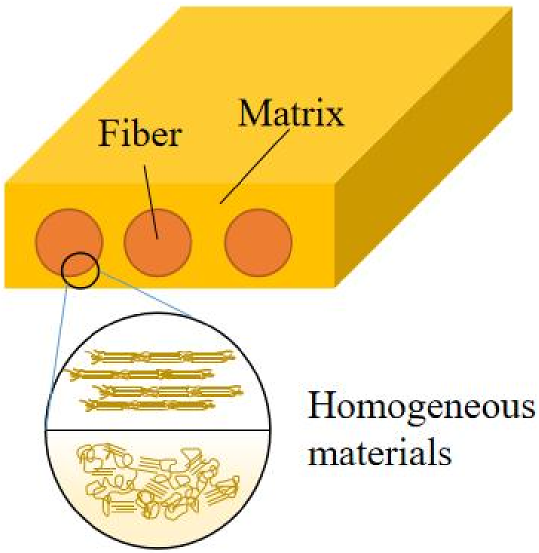


1. Research background

- **The demand of high-performance composites has evolved from conventional composites to green and sustainable composites**



Advancements in composite materials

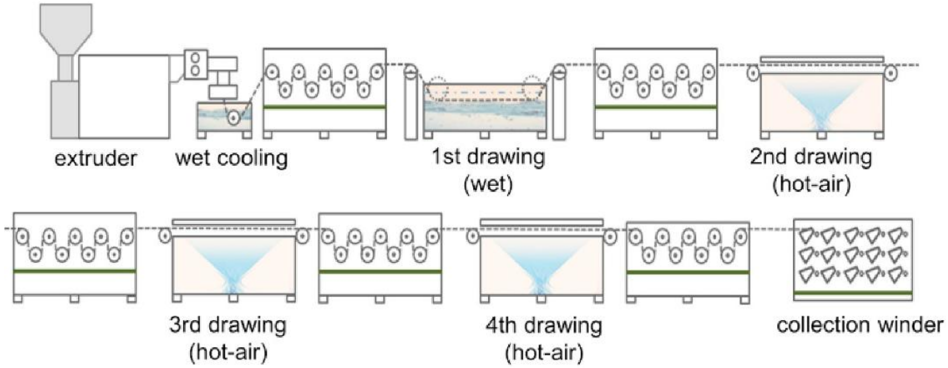


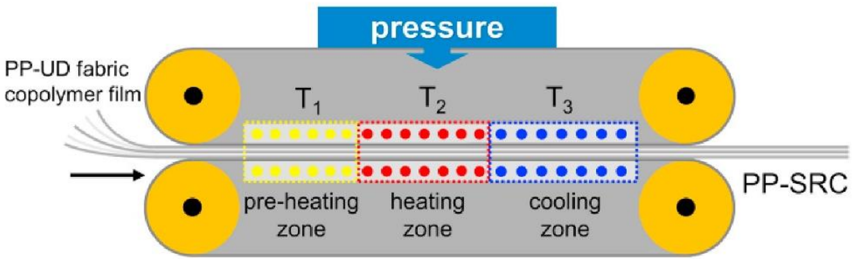
Continuous fiber self-reinforced composite

- Perfect interfaces
- Fully recyclable

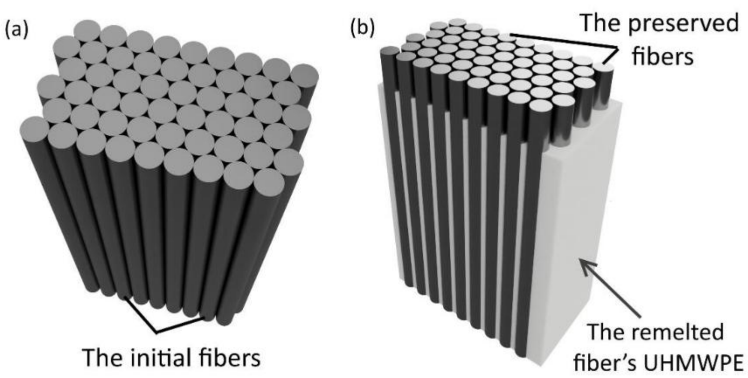
1. Research background

- **Shortages of conventional fabrication processes may limit further applications for self-reinforced composites.**





continuous double-belt press process



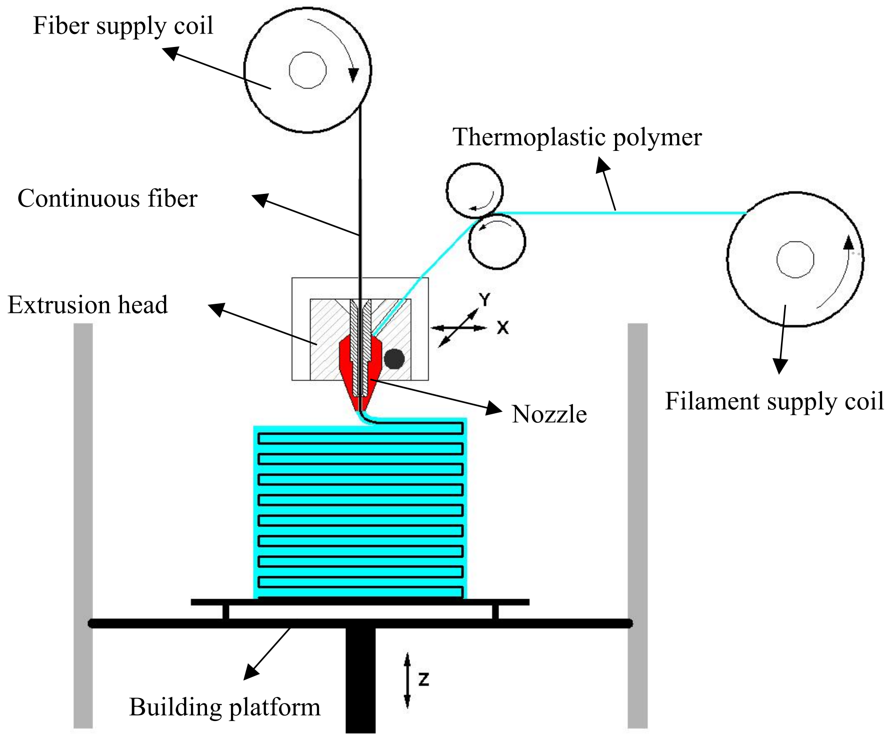
Hot press of fiber process

- Complex and time-consuming process
- Difficult to fabricate complex components
- Narrow processing window

Qiao, Y., Fring, L. D., Pallaka, M. R., Simmons, K. L., Polym. Compos. 2023, 44(2), 694.

1. Research background

■ **Composites Additive Manufacturing is a rapid and mouldless prototping technology compared with composite conventional processes.**



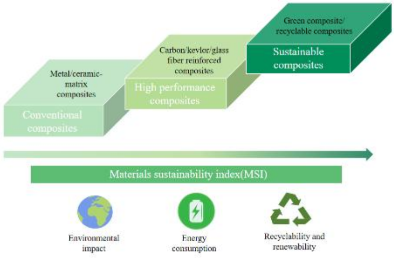
Schematic of 3D printed continuous fiber reinforced thermoplastic composites

- Design and manufacture of complex composite structures
- low energy consumption
- Inexpensive cost

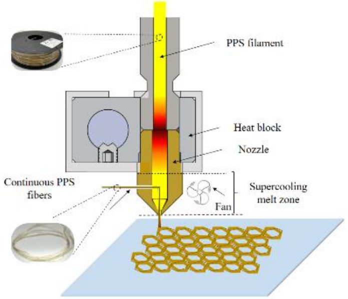
Tian, X.; Liu, T.; Yang, C.; Wang, Q.; Li, D. Compos. Part A Appl. Sci. Manuf. 2016, 88, 198–205.

Outline

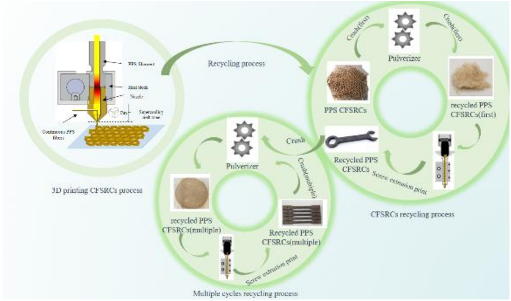
Research background



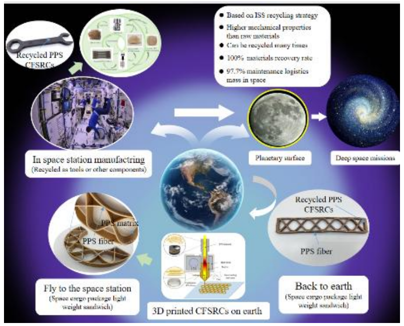
3D printing of continuous fiber self-reinforced composites(CFSRCs)



Recycling and thermal degradation mechanism

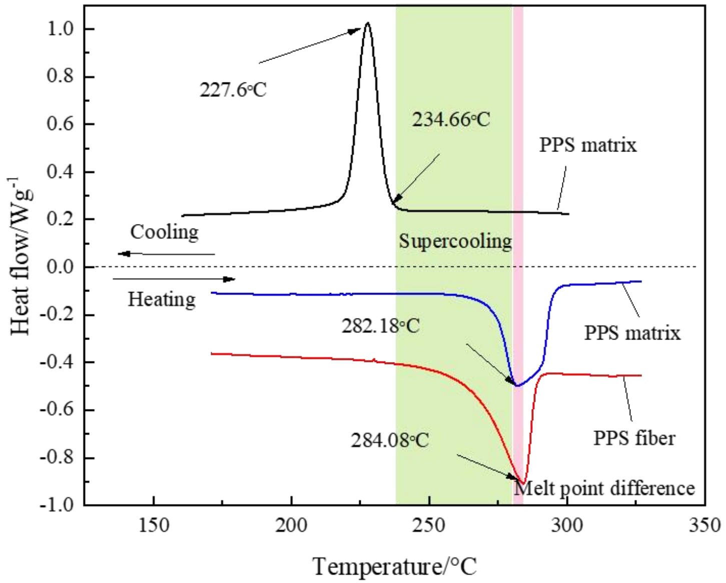


Perspective

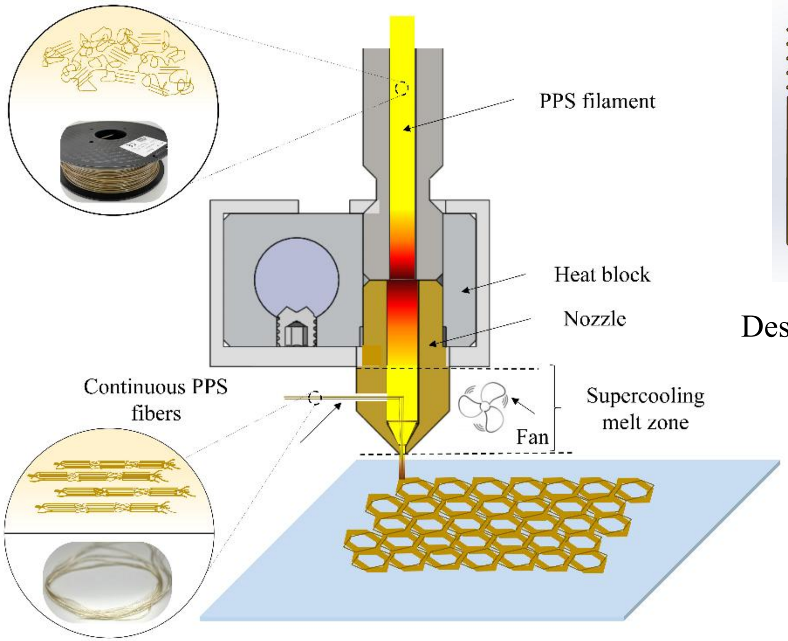


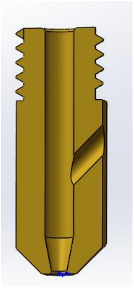
2.1 3D printing of continuous fiber self-reinforced composites

- **The processing temperature range are enlarged utilizing supercooling melts**



Melting temperature difference of fiber and matrix





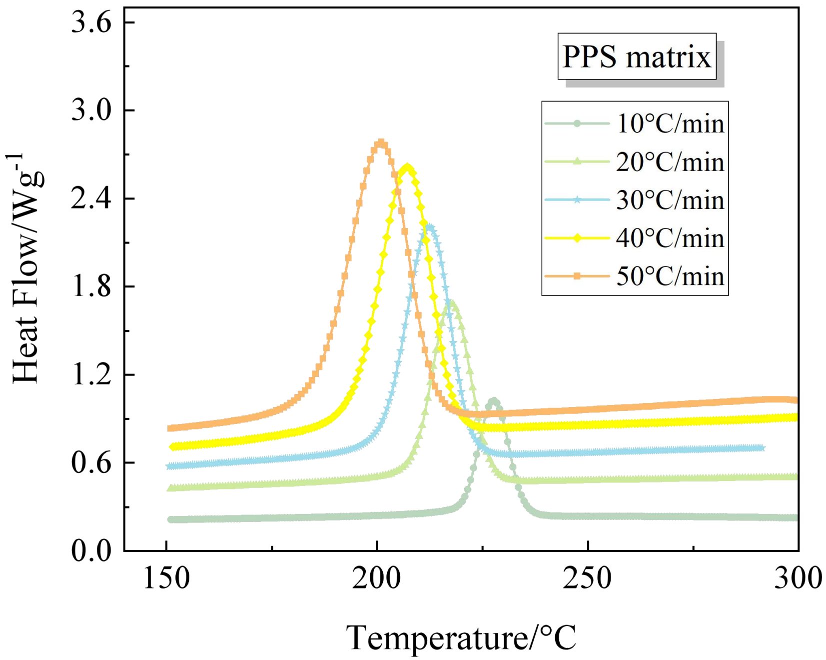
Design of nozzle

Schematic of 3D printed continuous fiber self-reinforced composites

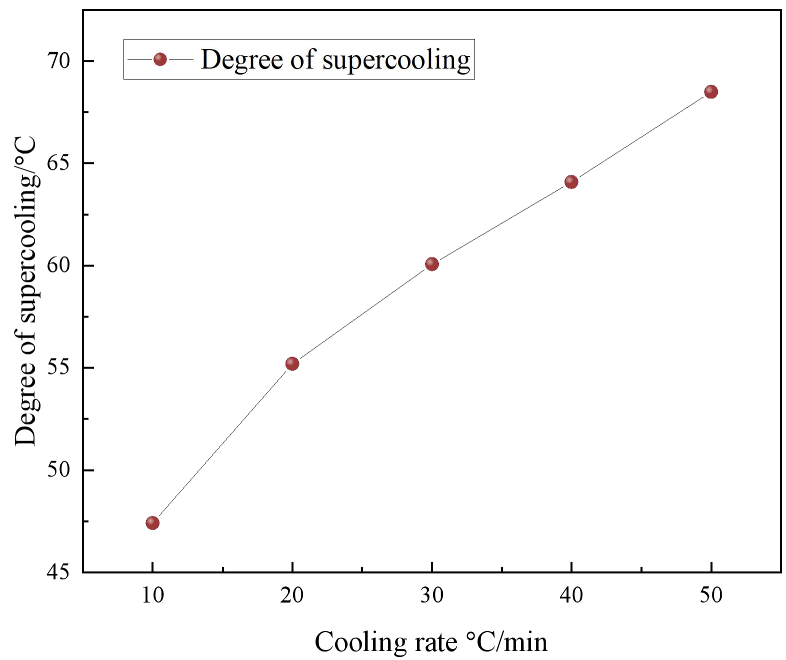
Manyu Zhang, Xiaoyong Tian, et al. 3D printing of fully recyclable continuous fiber self-reinforced composites utilizing supercooled polymer melts, Compos. Part A Appl. Sci. Manuf.,2023.

2.2 Characteristic of supercooling melts

- **The cooling rate influenced the extent of matrix supercooling; With rising of cooling rate, the higher degree of supercooling**



Crystallization curve of matrix at different cooling rates

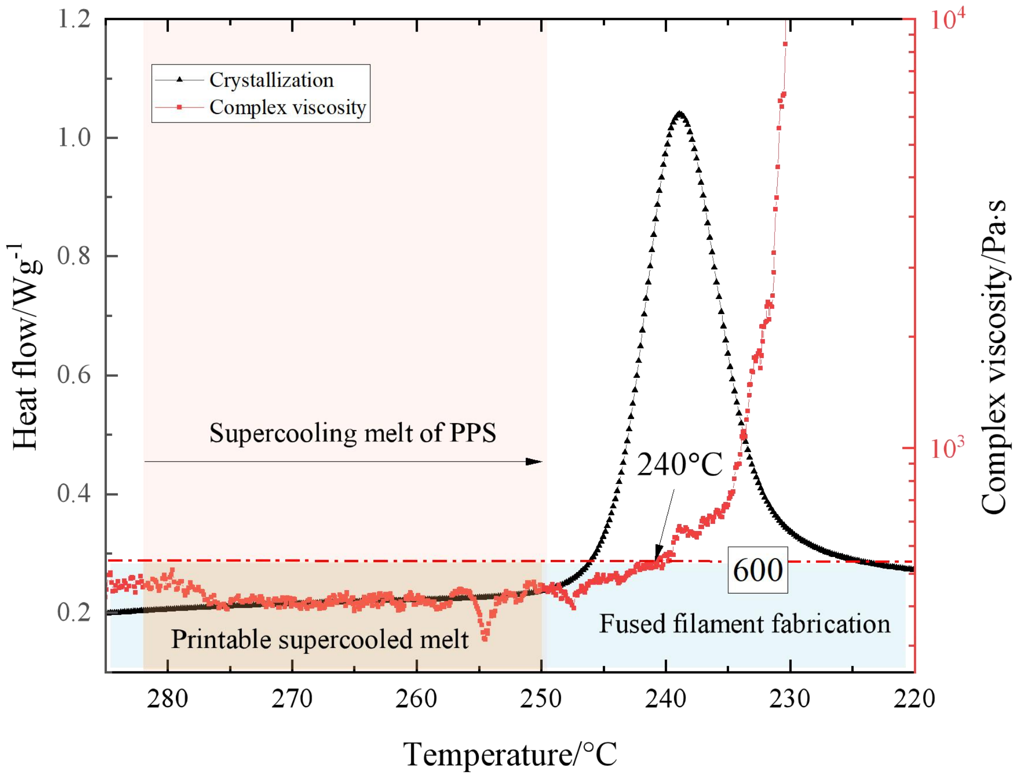


Degree of matrix supercooling influenced by cooling rates

Manyu Zhang, Xiaoyong Tian, et al. 3D printing of fully recyclable continuous fiber self-reinforced composites utilizing supercooled polymer melts, Compos. Part A Appl. Sci. Manuf.,2023.

2.3 Determination of process temperature window

- **Process temperature window of matrix supercooling melts is synergistic effected by crystallization and viscosity**

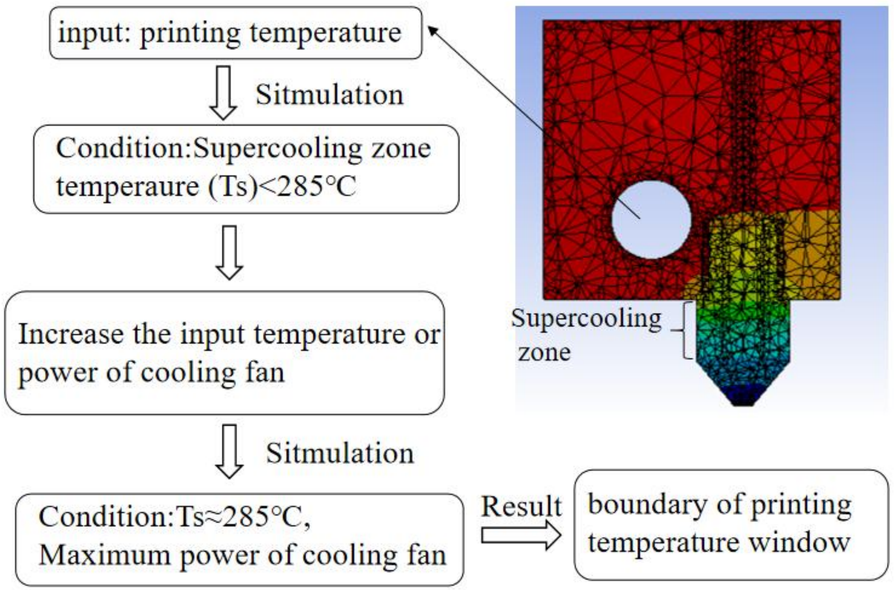


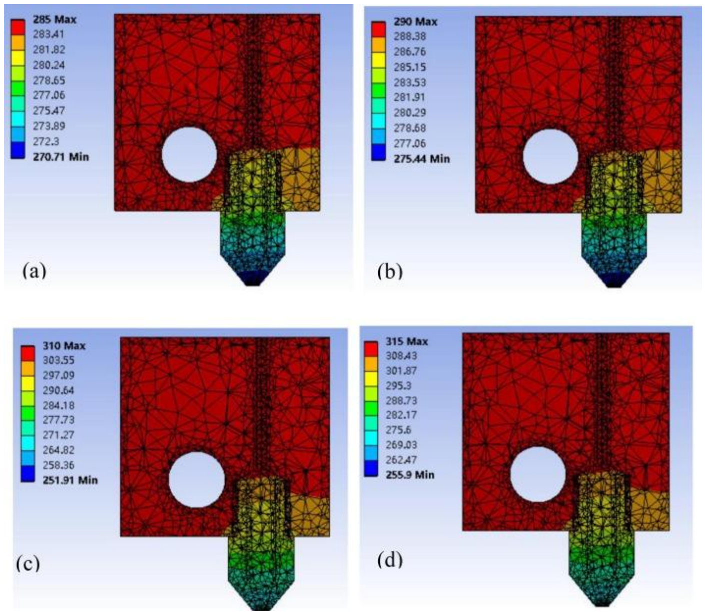
Complex viscosity and crystallization of matrix as a function of temperature during cooling from the molten state

Manyu Zhang, Xiaoyong Tian, et al. 3D printing of fully recyclable continuous fiber self-reinforced composites utilizing supercooled polymer melts, Compos. Part A Appl. Sci. Manuf.,2023.

2.4 Temperature simulation of 3D printing CFSRCs process

- **3D printing temperature domain, considering the simulation analysis and characteristics of the supercooled melt, was determined as approximately 285–315 °C.**



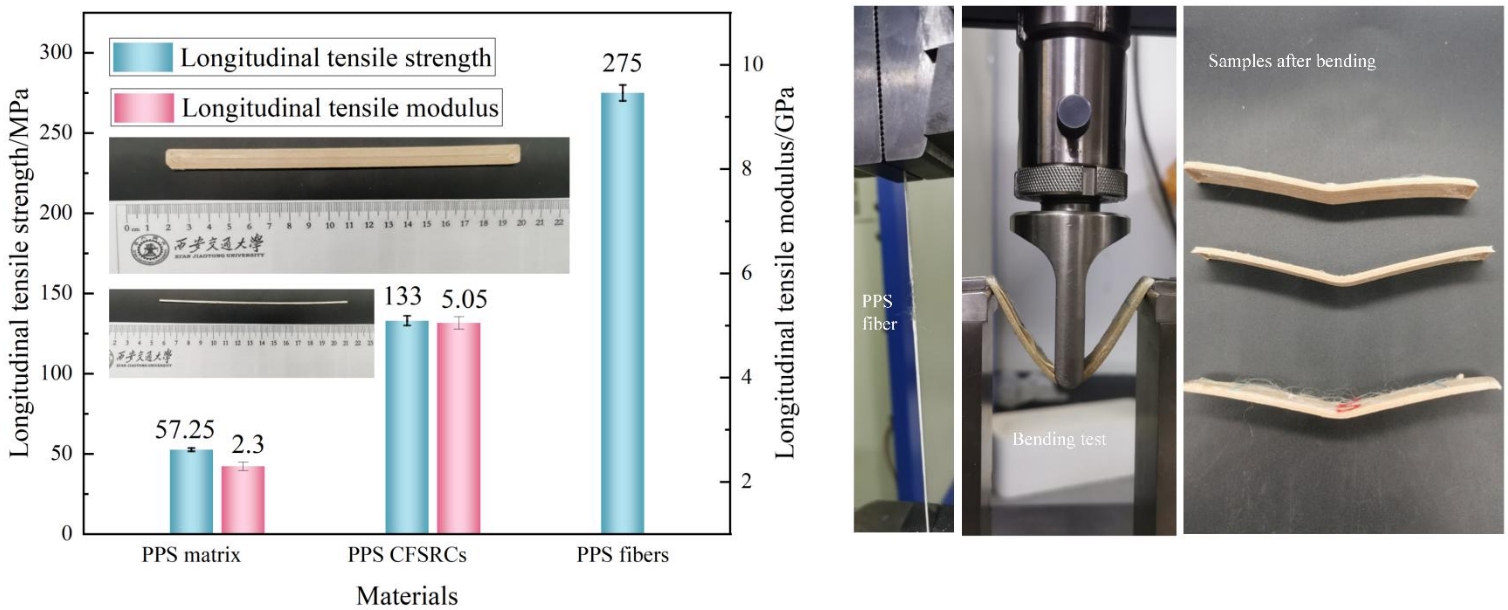


Iterative temperature field simulation considering supercooling; Printing temperature at 285°C,290°C,310°C,315°C

Manyu Zhang, Xiaoyong Tian, et al. 3D printing of fully recyclable continuous fiber self-reinforced composites utilizing supercooled polymer melts, Compos. Part A Appl. Sci. Manuf.,2023.

2.5 Mechanical property of 3D printing CFSRCs

■ **Significantly improved mechanical properties, especially flexural toughness**

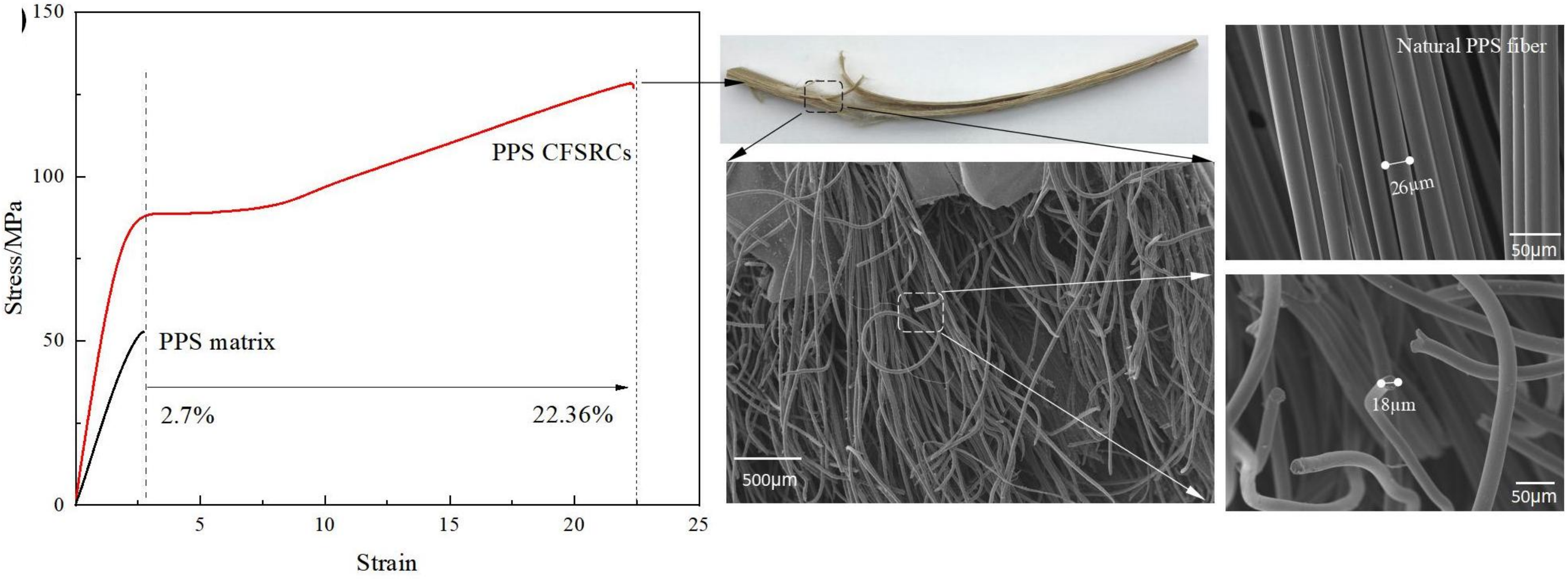


Longitudinal tensile strength and modulus and flexural testing

Manyu Zhang, Xiaoyong Tian, et al. 3D printing of fully recyclable continuous fiber self-reinforced composites utilizing supercooled polymer melts, Compos. Part A Appl. Sci. Manuf.,2023.

2.5 Mechanical property of 3D printing CFSRCs

- **The PPS CFSRCs showed plastic deformation, owing to the incorporation of continuous PPS fibers in the composites, led to a superior tenacity**



Stress-strain curves and SEM of CFSRCs

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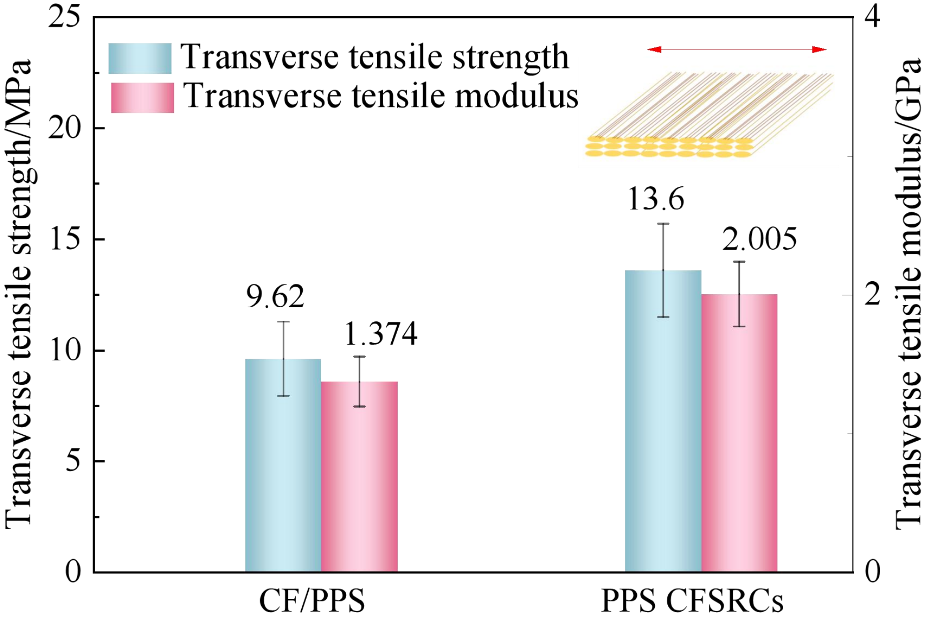
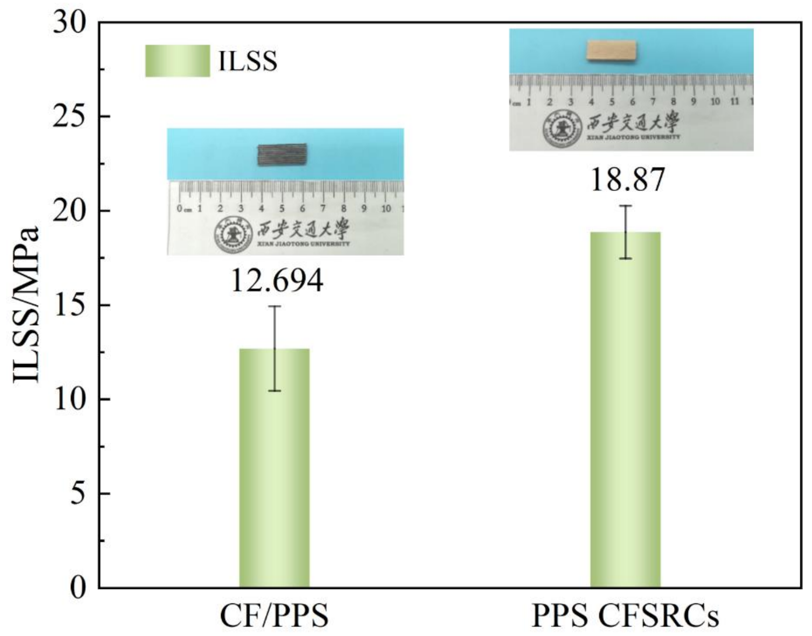
2.5 Mechanical property of 3D printing CFSRCs

- **Homogeneous materials of CFSRCs resulted in stronger fiber-to-matrix adhesion and interlaminar shear strength (ILSS) than CF/PPS**



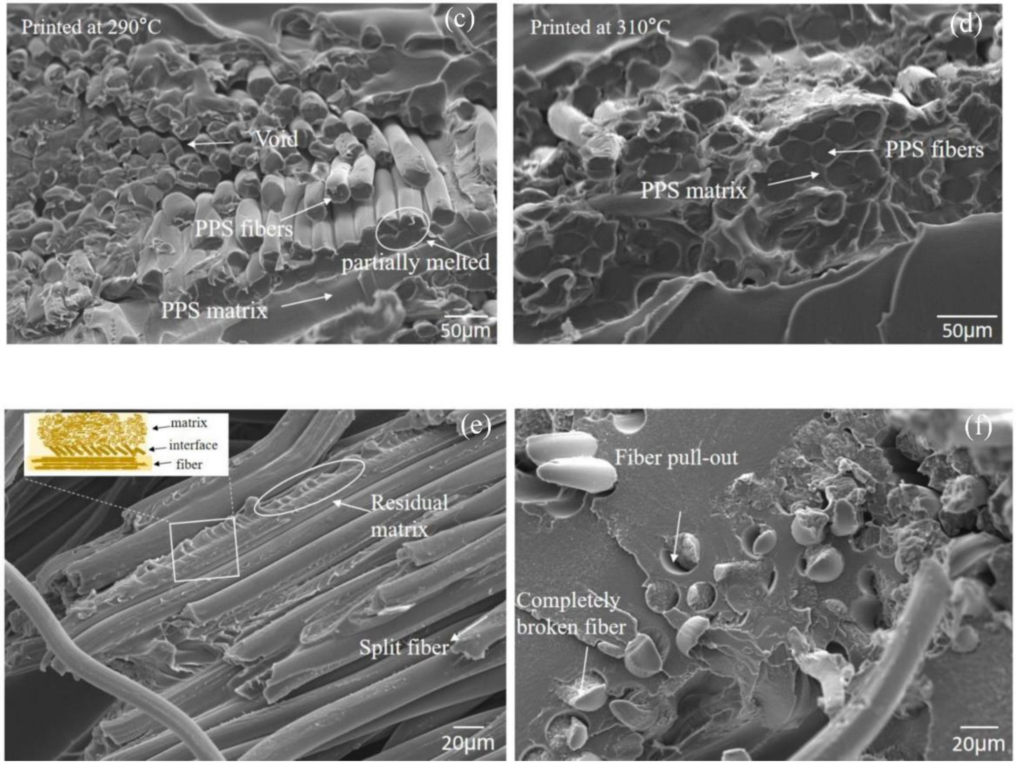


(a)Transverse tensile strength and modulus of PPS CFSRCs compared with CF/PPS,
(b) a comparison of ILSS for PPS CFSRCs and CF/PPS

Manyu Zhang, Xiaoyong Tian, et al. 3D printing of fully recyclable continuous fiber self-reinforced composites utilizing supercooled polymer melts, Compos. Part A Appl. Sci. Manuf.,2023.

2.6 Microstructure of 3D printing CFSRCs

- **The similarity and compatibility of the fibers and matrix result in the excellent impregnation behavior and interfacial adhesion**



Microstructure and cross-section of 3D printed CFSRCs

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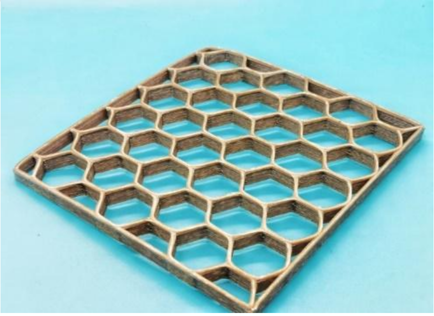
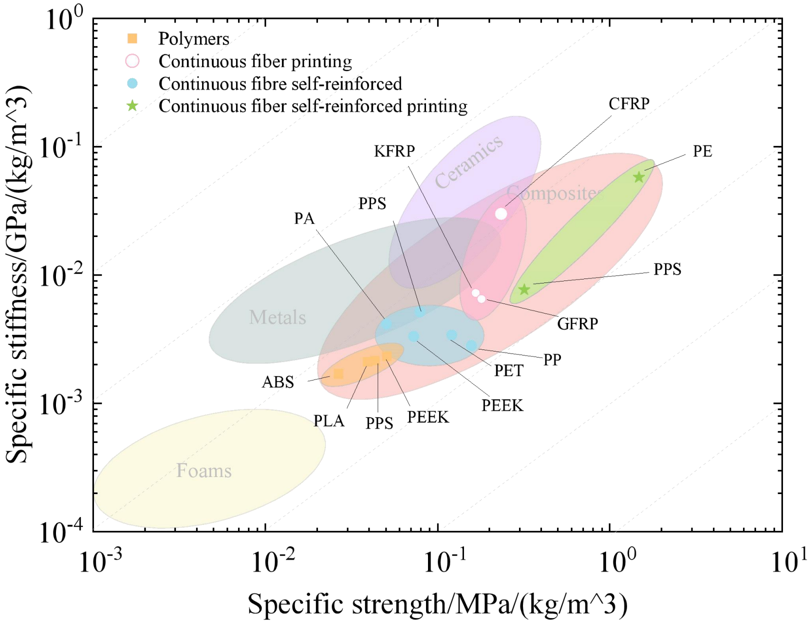
2.7 Lightweight structure of 3D printing CFSRCs

- **CFSRCs exhibit comparable specific stiffness strength with GFRP and KFRP, but has the additional benefit of being entirely recyclable and economical compared with CFRP**

Lightweight sandwich structure

Honeycomb structure



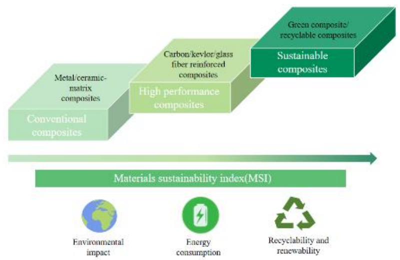


The specific stiffness and specific strength of continuous fiber self-reinforced composites compared to polymers and reinforced composite materials.

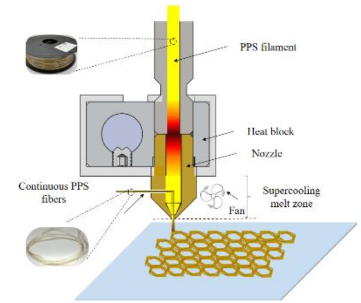
Manyu Zhang, Xiaoyong Tian, et al. 3D printing of fully recyclable continuous fiber self-reinforced composites utilizing supercooled polymer melts, Compos. Part A Appl. Sci. Manuf.,2023.

Outline

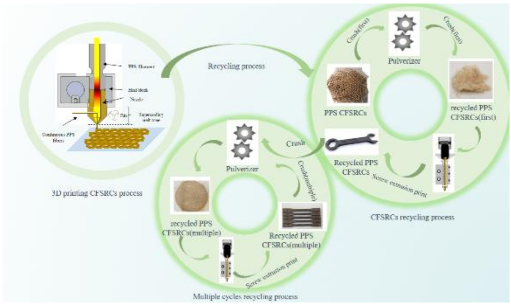
Research background



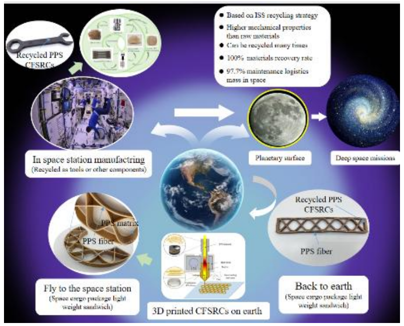
3D printing of continuous fiber self-reinforced composites



Recycling and remanufacturing

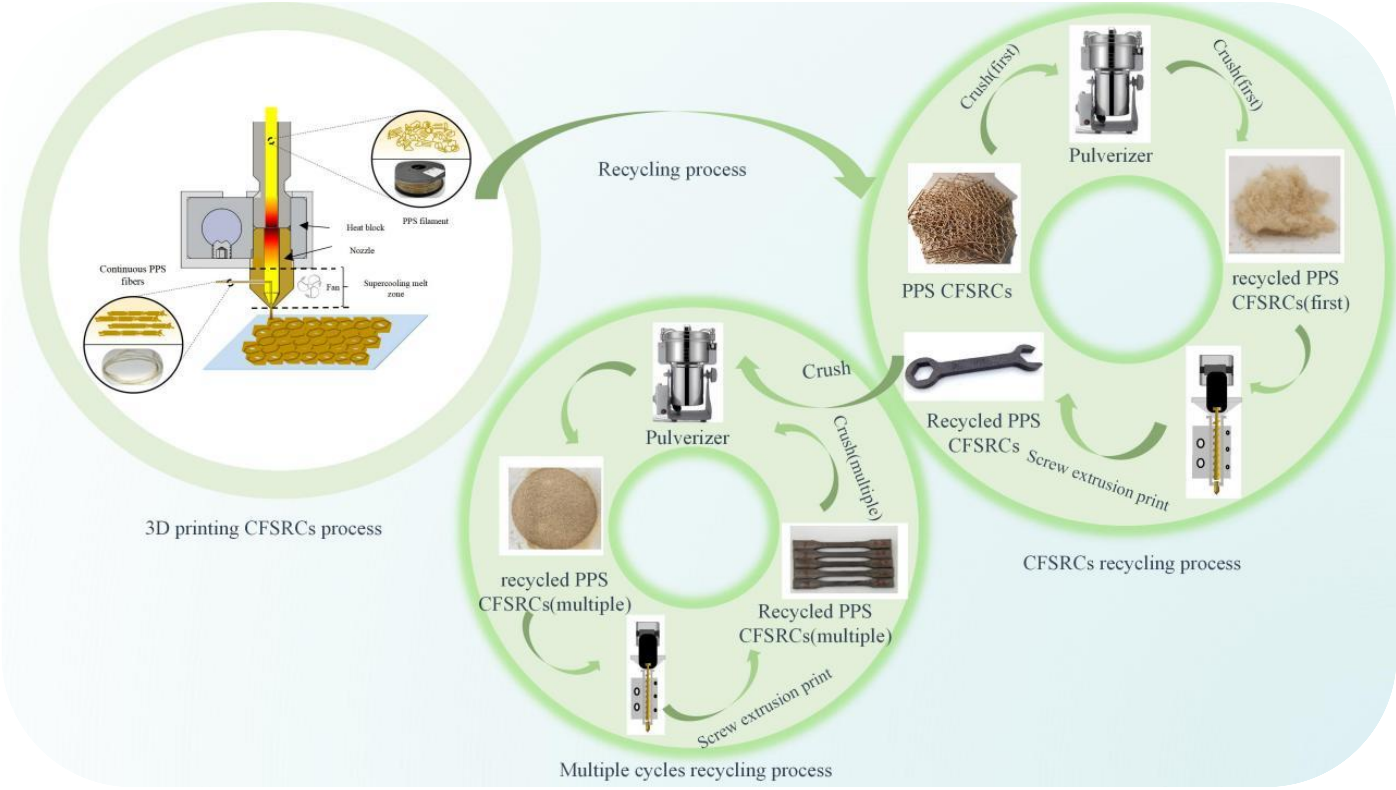


Perspective



3.1 3D printing based recycling process

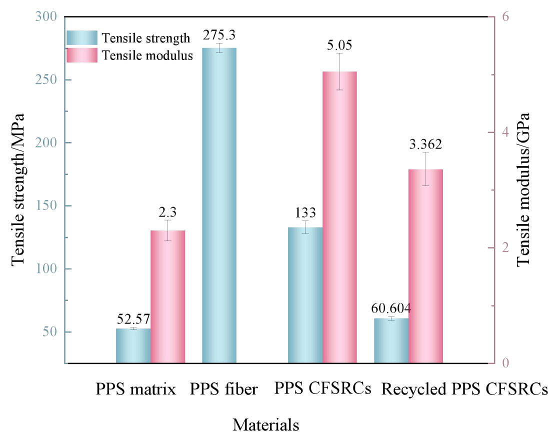
- **The 'meat floss' was remanufactured directly by a screw extrusion 3D printer without separating fiber and matrix, permits the material to be utilised multiple times**

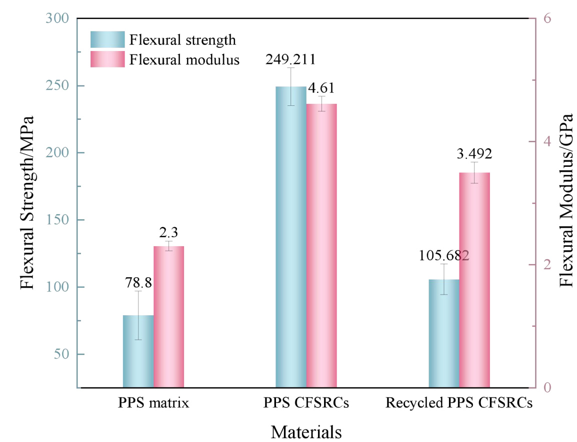


Mechanical recycling and remanufacturing process

3.2 Mechanical properties of recycled CFSRCs

- **Mechanical property loss of recycled material is insignificant compared with virgin material**

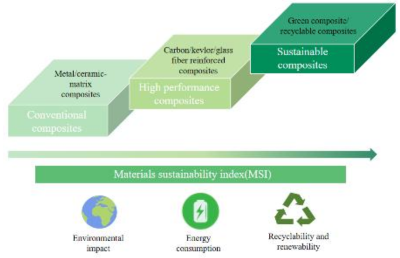




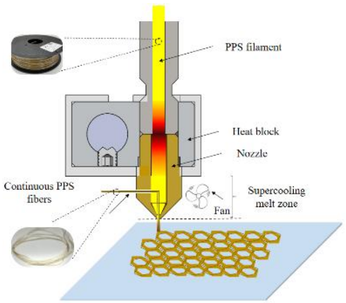
Sketch of recycle PPS CFSRCs screw extrusion 3D printing process

Outline

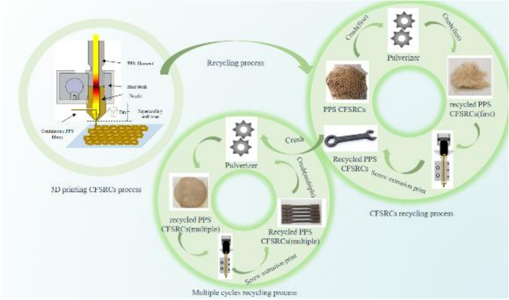
Research background



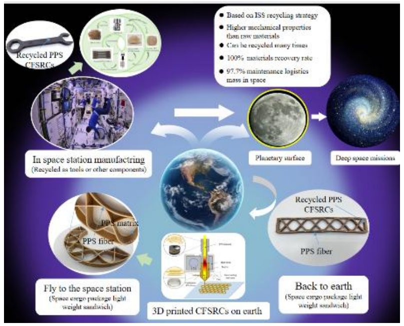
3D printing of continuous fiber self-reinforced composites



Recycling and remanufacturing

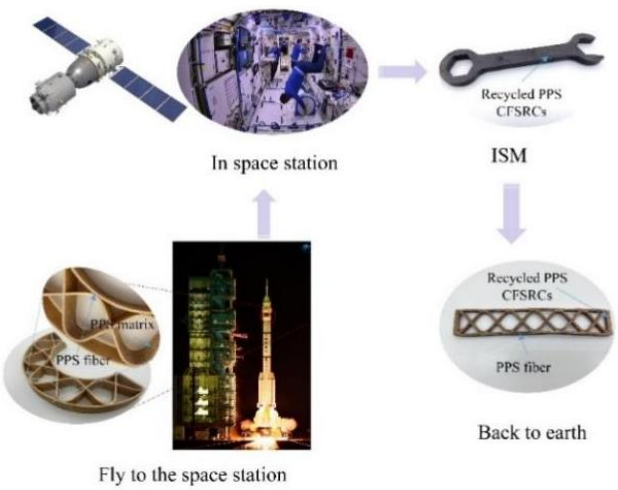


Perspective

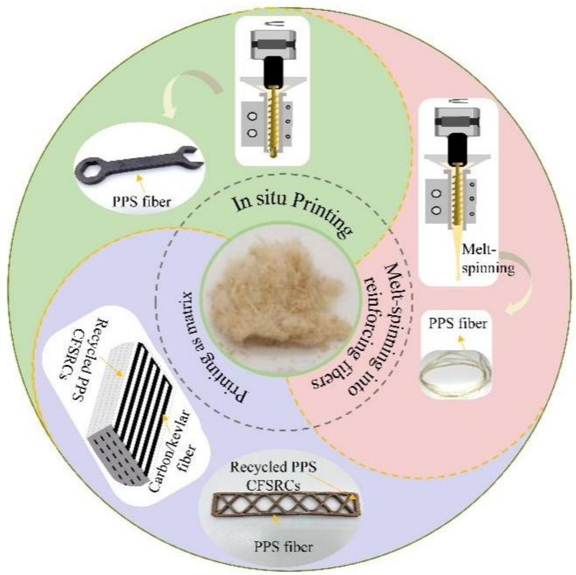


4.Perspective

- **The closed-loop recycling strategy realize maximize in-situ resource utilization in space.**



A specific application idea of PPS CFSRCs realizing in-situ resource utilization strategy



Application exploration of recycled materials in space

Acknowledgements

- The National Natural Science Foundation of China (grant nos. 52075422)
- The Rapid Manufacturing Engineering Technology Research Center of Shaanxi Province (grant no. 2017HBGC-06)
- The Youth Innovation Team of Shaanxi Universities
- The K.C. Wong Education Foundation
- The Fundamental Research Funds for the Central Universities

Thank you for your attention!

Manyu Zhang

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