Direct Ink Writing of Complex 3D Structures from Titanium Alloy

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BACKGROUND

Titanium (Ti) alloys are used in aerospace and biomedical industries due to their low cost and high strength-to-weight ratio. Manufacturing relies on CNC machining, casting, and additive manufacturing but current 3D printing techniques have drawbacks such as causing residual thermal stress and being high-energy processes, which lead to expensive production costs. Direct ink writing (DIW) provides a simple, cost-effective approach for producing metal parts.

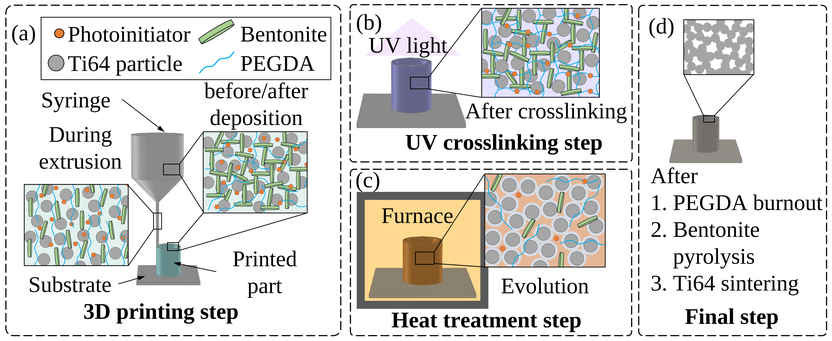

Fig. 1. Ti alloy component manufacturing process through DIW.

TITANIUM AND BENTONITE RHEOLOGICAL TESTING

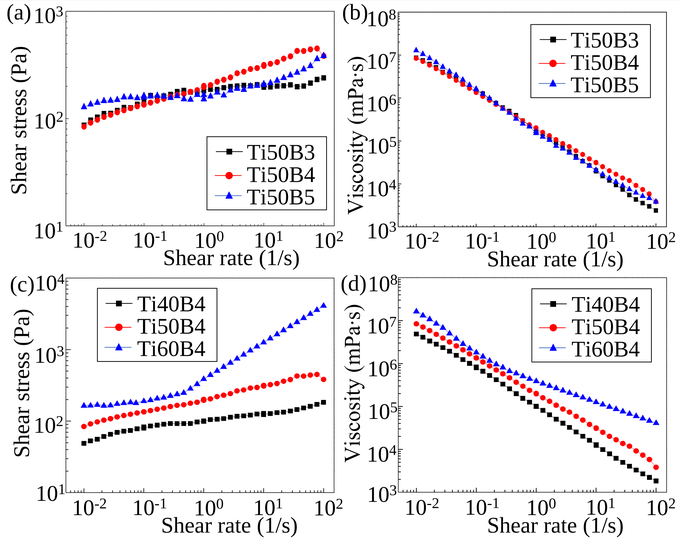

Fig. 2. a) Shear stress of three inks with 50% (v/v) Ti and various bentonite percentages, **b)** viscosity of three inks with 50% (v/v) Ti and various bentonite percentages, **c)** viscosity of three inks with various Ti percentages and 4% (w/v) bentonite, **d)** shear stress of three inks with various Ti percentages and 4% (w/v) bentonite.

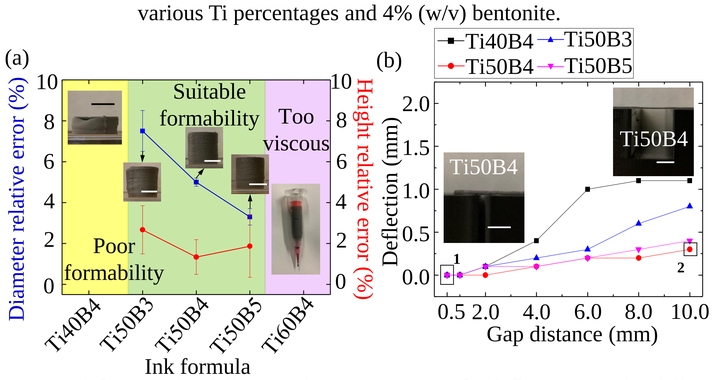

Fig. 3. a) Formability test for different ink concentrations, **b)** deflection test for different ink concentrations.

SINTERING PROCESS AND MECHANICAL PROPERTIES

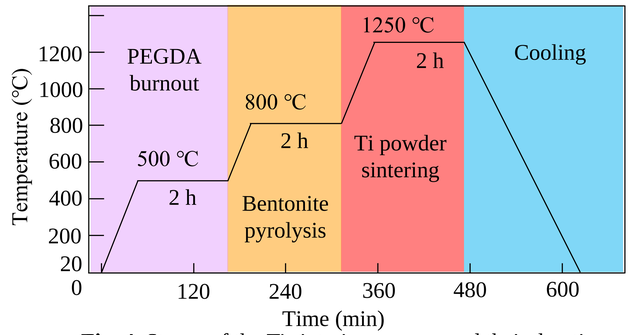

Fig. 4. Stages of the Ti sintering process and their duration.

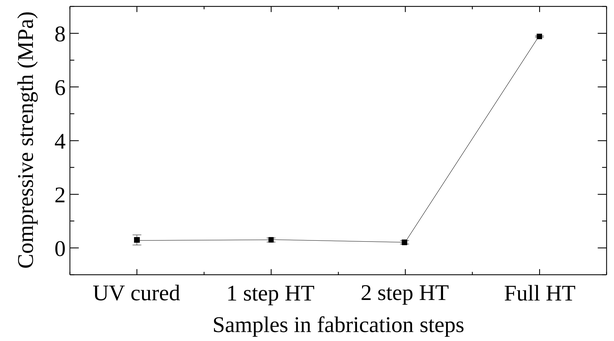

Fig. 5. Compressive strength of titanium samples at different steps during fabrication.

PRINTING CHARACTERISTICS

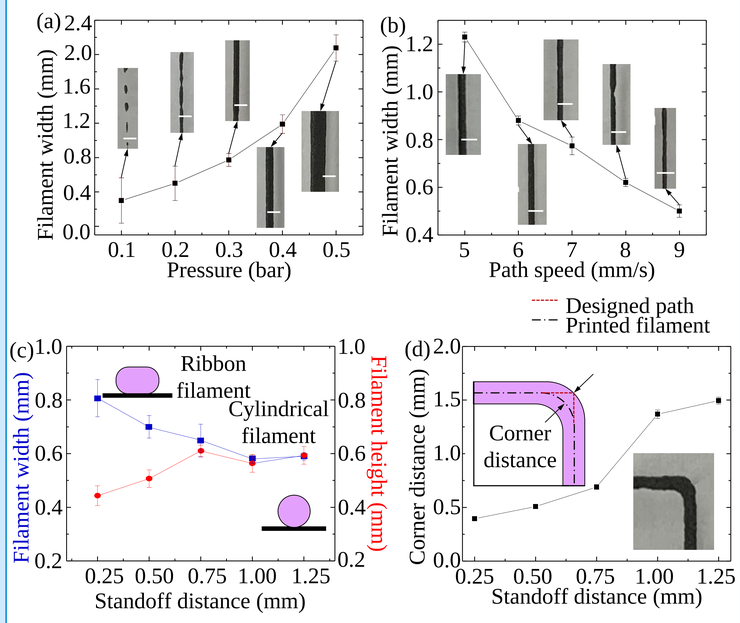

Fig. 6. a) Printed filament width with increasing pressure (scale bars: 2 mm), **b)** printed filament width with increasing path speeds (scale bars: 2 mm), **c)** printed filament shape, ribbon filament & cylindrical filament, with increasing standoff distance, **d)** effect of standoff distance between the designed path and the printed filament (corner distance).

DIRECT INK WRITING OF INCLINED TUBES

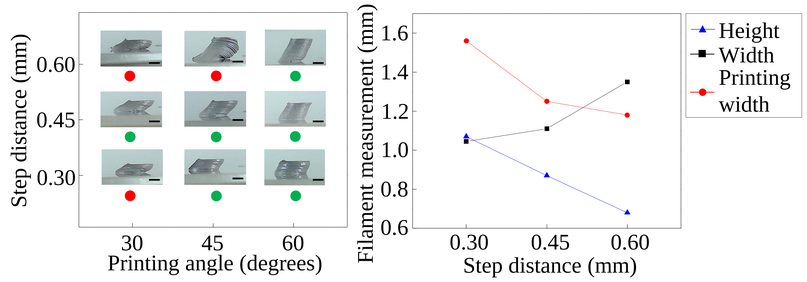

Fig. 7. a) Diagram showing the successful DIW range of 3D printed tubes at various angles and step distances (scale bars: 5 mm), **b)** filament height, width, and printing width of the step distances used to print inclined tubes.

REPRESENTATIVE STRUCTURES

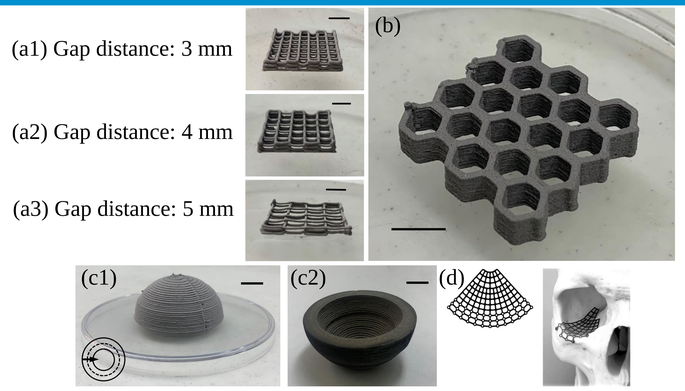

Fig. 8. a) 3D printed structures with various gap distances, **b)** 3D printed honeycomb structure, **c)** 3D printed titanium acetabular cup, **d)** titanium eye socket used for biomedical purposes. All scale bars: 5 mm.

CONCLUSIONS

- Titanium alloys are the ideal material for aerospace component manufacturing.
- DIW offers an efficient and cost-effective production of titanium alloy parts.
- To fully realize this potential:
  - The titanium printing process at different angles must be perfected.
  - Produced parts must have optimal compressive strength for aerospace applications.

FUTURE WORK

- Produce titanium alloy:
  - Fastening components.
  - Airframes.
  - Landing gear.
- Manufacture and sinter spacecraft components.

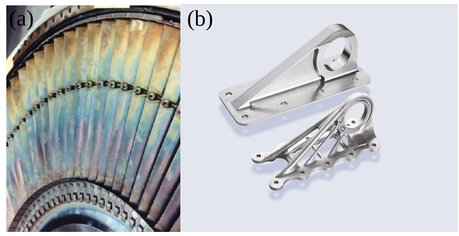

Fig. 9. Ti alloy **a)** turbine blades and **b)** wing brackets.

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3PL UNR 3D Printing Lab