Feedstock development for the additive manufacturing of titanium parts via Fused Filament Fabrication (FFF)

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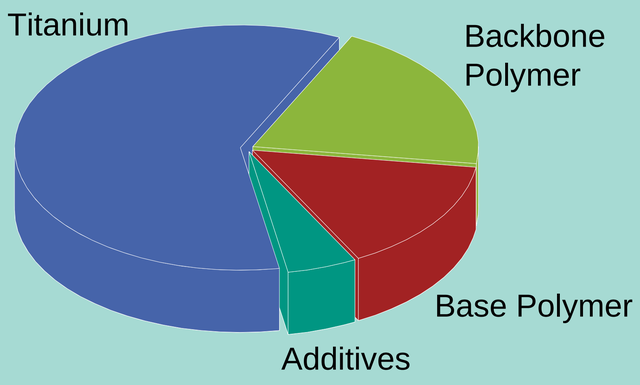
Motivation

3D printing of titanium based on Fused Filament Fabrication (FFF) offers high product quality at low costs through the use of inexpensive commercial FFF printers and the low waste of titanium. For a better usability and a higher level of detail, new feedstocks with water-soluble binder systems and superior properties were developed.

Composition

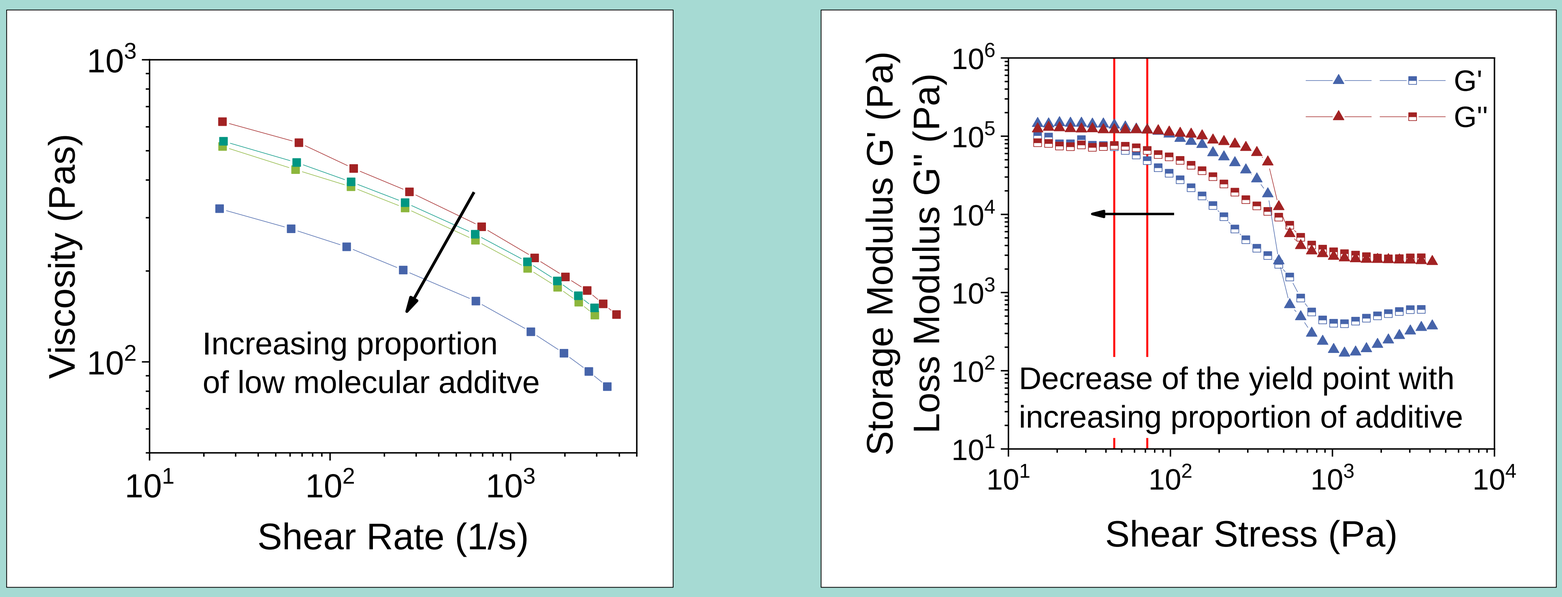
The feedstocks consist of minimum 60 vol.-% titanium (Ti-6Al-4V). The thermoplastic binder systems divide in high-viscosity backbone polymers, low molecular weight, water-soluble base polymers and additives.



Composition of a feedstock containing 60 vol.% titanium

Rheology

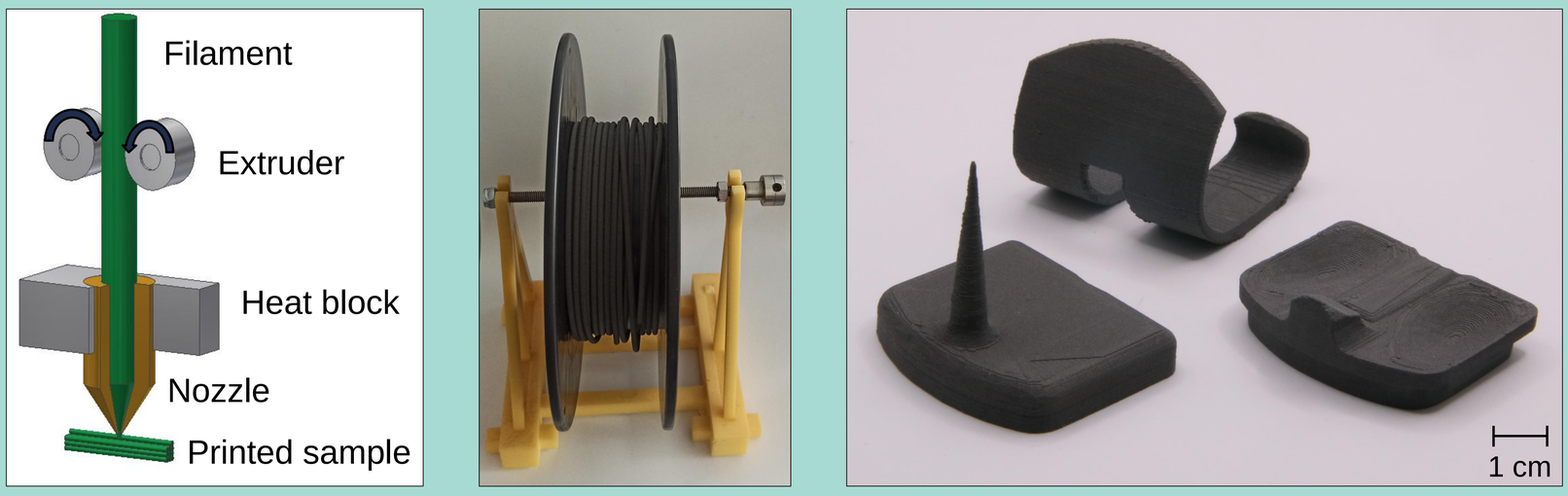
For good processing properties and to achieve a high level of detail during printing, special focus was set on the rheological behaviour of the feedstocks. The composition of the binder and, in particular, the type and the proportion of additives showed a significant influence on the flexibility of the filaments and the viscosity of the feedstocks.



Capillary rheology (left) and oscillation rheology (right) at 160 °C for feedstocks with 60 vol.-% filler content and different proportions of additive

3D printing

For use in commercial FFF printers, the feedstocks must be formed into filaments. These are melted in the hotend of the printer, extruded through the nozzle and deposited on the print bed or on previous layers. After a layer is finished, the print bed lowers by the set layer thickness and the next layer is printed.



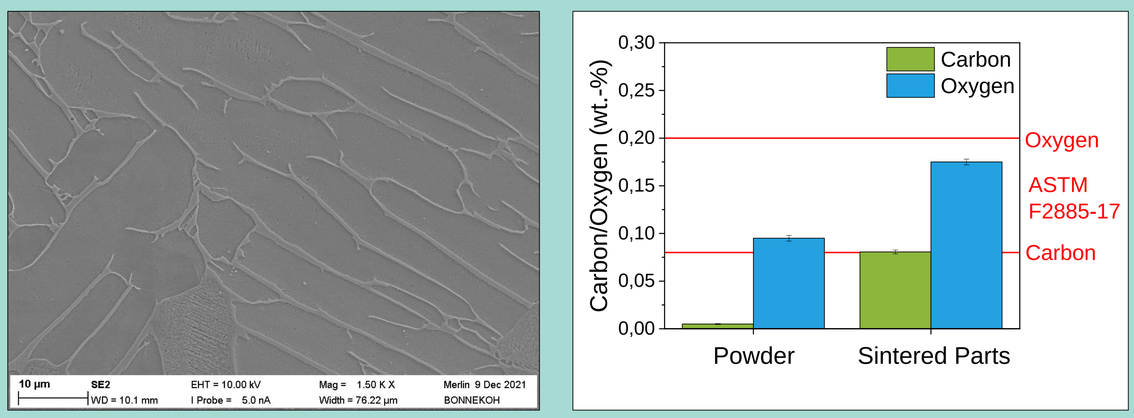
Schematic illustration of the FFF process (left), winded filament (center) and printed knee implant (right)

Post processing

- **Debinding** in two steps for the removal of the binder
  - Chemically in water
  - Thermally
- **Sintering** in argon atmosphere for densification (1350 °C, 4 h)
- **Hot isostatic pressing (HIP)** for further densification

Properties of the final parts

- Production of defect-free and dense parts after sintering and HIP
- Contamination with oxygen and carbon below the critical level for medical products (ASTM F2885-17)



Microstructure of an etched cross section and impurities of sintered parts

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