Printability of pharmaceutical polymers in FDM 3D printers

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Background

3D printing (3DP) of pharmaceutical formulations via commercially available FDM printers has gained interested in recent years, enabling personalisation of medicines. It also facilitates advanced control of the micro-structure of the tablet core, permitting fine tuning of product release characteristics with a single formulation. In addition, the technology also offers a platform for Dose escalation studies employing a single formulation and single manufacturing step.

Objectives

The objective of this study was to develop a printability map of pharmaceutically relevant feedstock material for FDM.

Methods

Hot-Melt-Extrusion (HME): 5-50 % (w/w) Paracetamol (PCM) in Affinisol 15LV™ were extruded on an 16mm Hot-Melt-Extruder (Eurolab 16, Thermofisher, Karlsruhe, Germany) equipped with a 1.6 mm die [1].

Mechanical properties of filaments were tested on a Texture Analyser TA-XT (Stable Micro Systems, Godalming, UK) equipped with a mini 3-point bend rig and the flexural modulus determined [1].

Complex viscosity of drug loaded extrudates was measured by performing an oscillatory temperature sweep from 160°C to 110 °C temperature, with a constant deformation of 0.5 % at a frequency of 1Hz. The gap setting was normal force controlled at 0.1 N. Oscillatory frequency sweeps – Samples were loaded at test temperature (190°C and 160°C, respectively) and equilibrated for 2 minutes prior to analysis. Frequency sweeps were performed with a constant deformation of 0.5 % across a frequency range from 0.1 — 100 Hz.

Printability of filaments was assessed using a modified Startt printer [1] equipped with an 0.4mm nozzle at 190°C and 160°C for 50PCM only.

Results and Discussion

Filaments failure was observed for the 30 % (w/w) drug loaded filaments due to the filament buckling in the hot end and drive gear [1] (at 190°C, 0.4mm diameter nozzle) (Figure 1).

A printability map was established based on calculating the buckling ratio [2] of the flexural modulus (derived from the stress train graph of the material (Figure 2) and the complex viscosity (Figure 3) plotted against the angular frequency. By applying the Cox-Merz-Rule the shear rate ranges for different print speed and nozzle combinations were overlaid, indicating printability of material with different nozzle geometries and print speeds (linear speed 0.5 – 2 mm/s).

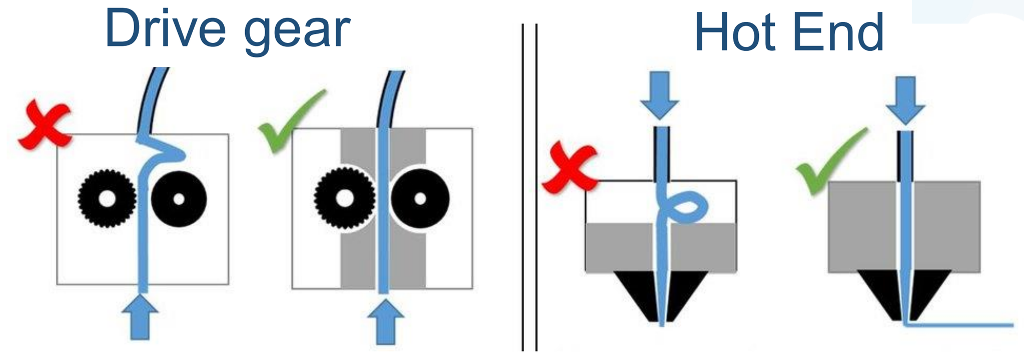

Figure 1: Failure mode of feed stock material in drive gear or hot end of an FDM printer.

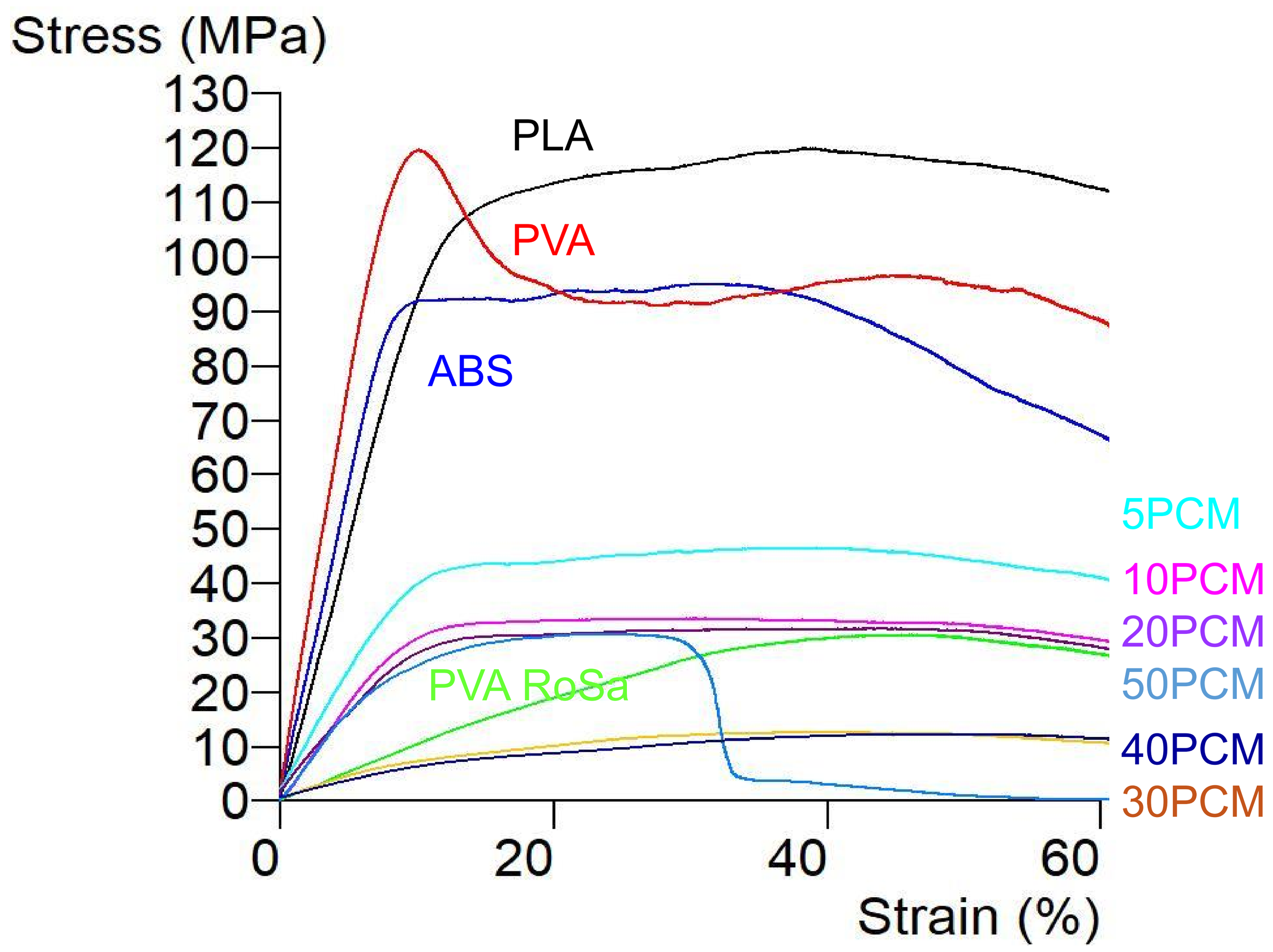

Figure 2: Stress-Strain graph of FDM feed stock material: commercial filaments PLA, PVA, ABS and 5-50% PCM-Affinisol [1].

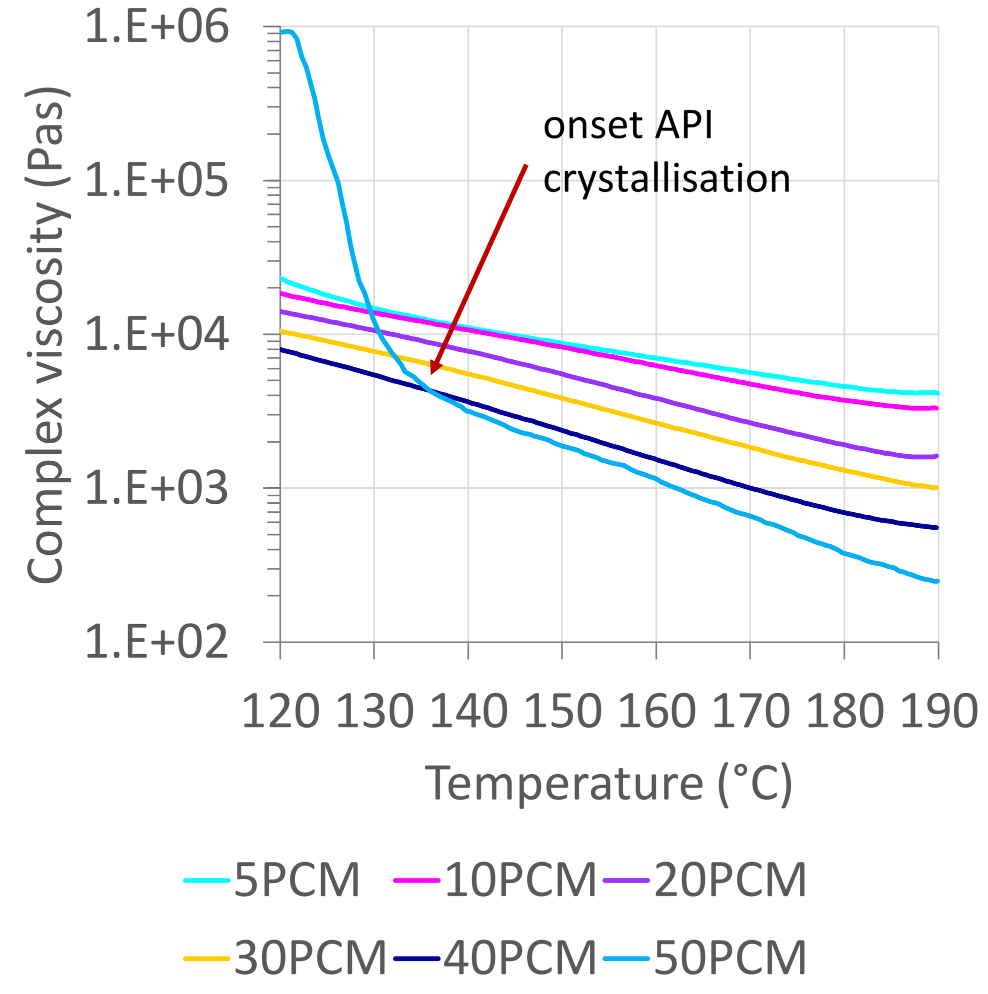

Figure 3: Oscillatory temperature sweep from 190-100°C: complex viscosity versus Temperature.

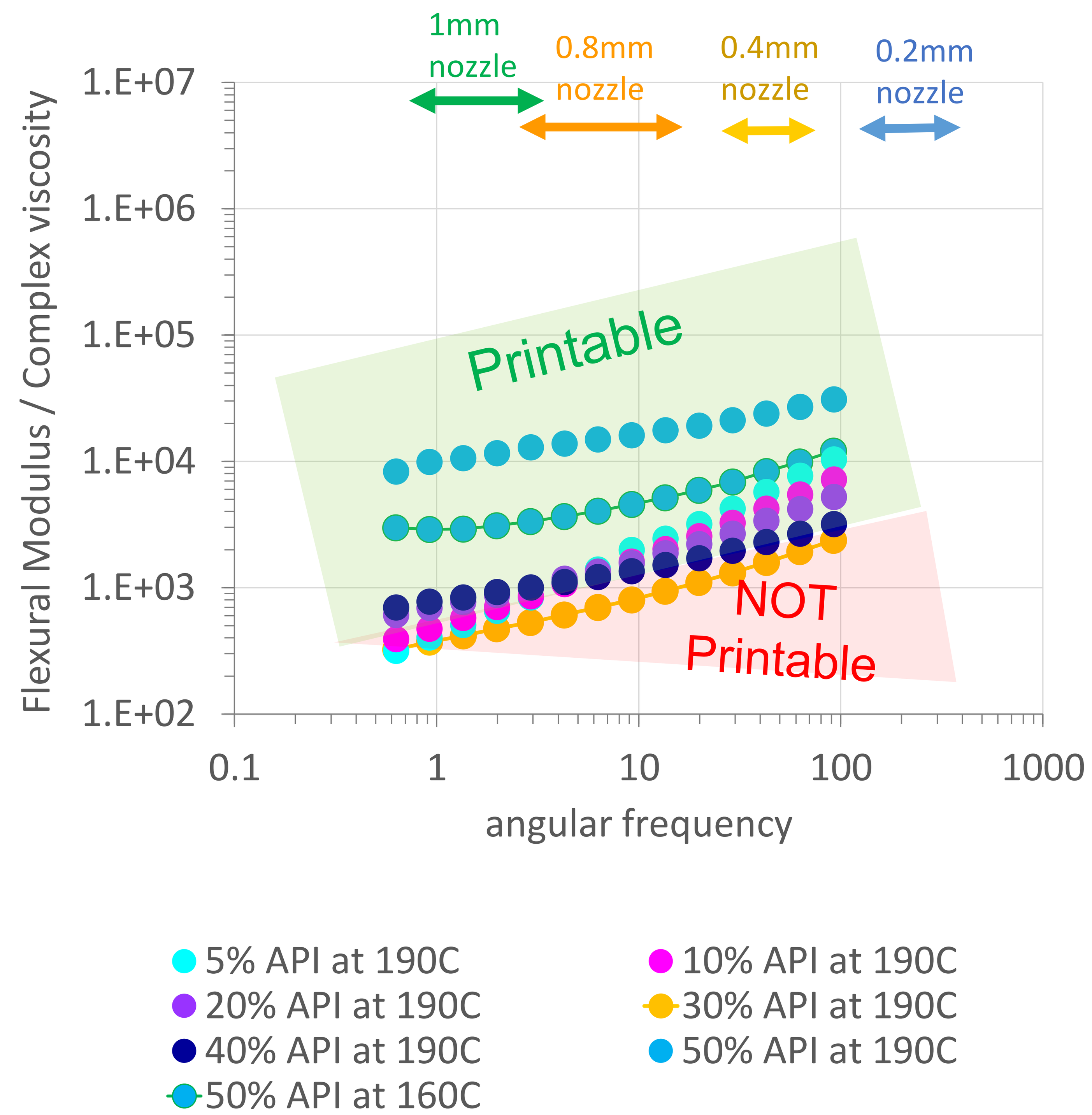

Figure 4: Printability map of 5-50% w/w PCM-Affinisol filaments.

Conclusion

A printability map was established based on the mechanical and rheological properties of the material, enabling identification of suitable (printable) material as well as printer configuration/printing condition selection for successful FDM.

References

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2. Venkataraman N, Rangarajan S, Matthewson MJ, Harper B, Safari A, Danforth SC, Wu G, Langrana N, Guceri S, Yardimci A 2000. Feedstock material property – process relationships in fused deposition of ceramics (FDC). Rapid Prototyping Journal 6(4):244-253.