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Structural and Nanomechanical Homogeneity of FDM 3D-Printed PVA Tablets: Drug Incorporation for Controlled Release

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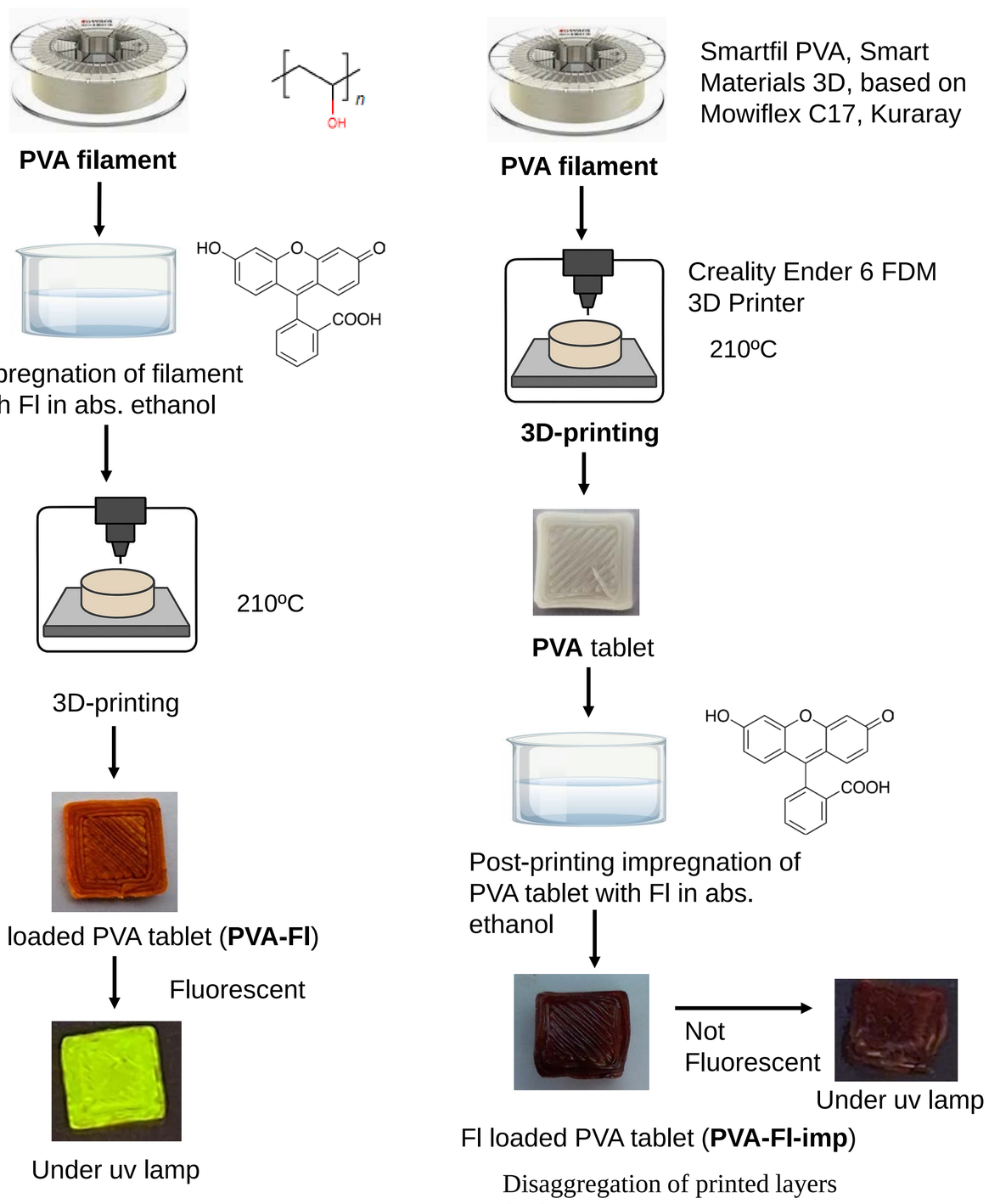
INTRODUCTION & AIM

Introduction: Fused Deposition Modeling (FDM) enables the fabrication of tailored drug delivery systems with controlled geometry and composition [1, 2]. Poly(vinyl alcohol) (PVA) is a biocompatible and water-soluble polymer commonly used as a matrix for controlled drug release. In this study, PVA and PVA–fluorescein tablets were fabricated to explore how both the method of drug incorporation and the presence of the model drug influence the polymer's structural and nanomechanical homogeneity. Fluorescein (Fl) was used as a model compound to visualize and compare drug incorporation behavior under different printing conditions.

Aim: To investigate the influence of drug incorporation route (direct printing from drug-loaded filament vs. post-printing impregnation) and fluorescein presence on the structural, thermal, and nanomechanical homogeneity of 3D-printed PVA tablets, using advanced characterization techniques.

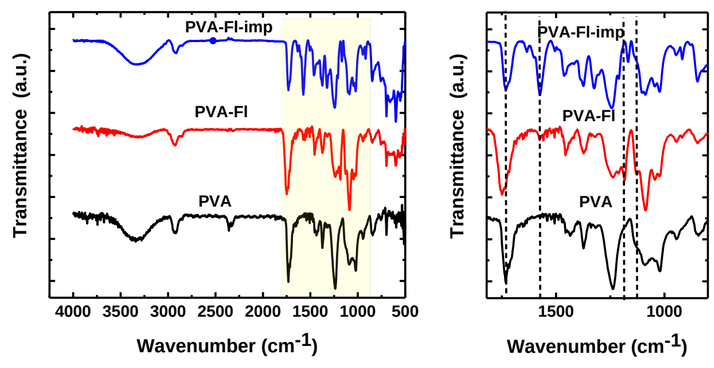
METHOD



Characterization: IR, TG/DSC, XRD, AFM/UFM, Biocompatibility assays

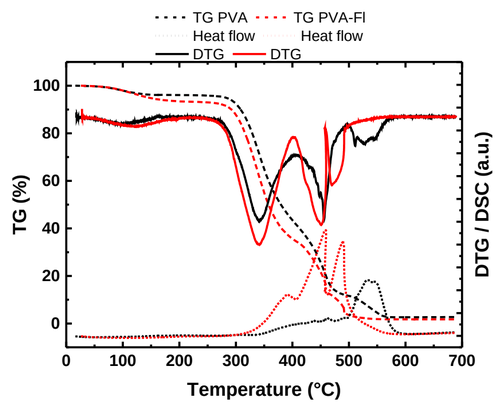
RESULTS & DISCUSSION

FT-Infrared Spectroscopy



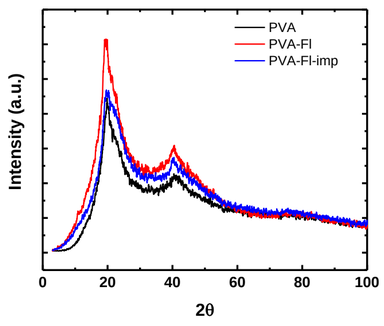
Appearance of fluorescein-related bands in modified samples. PVA–Fl: peak shifts indicate PVA–fluorescein interactions (hydrogen bonding)

TG / DSC



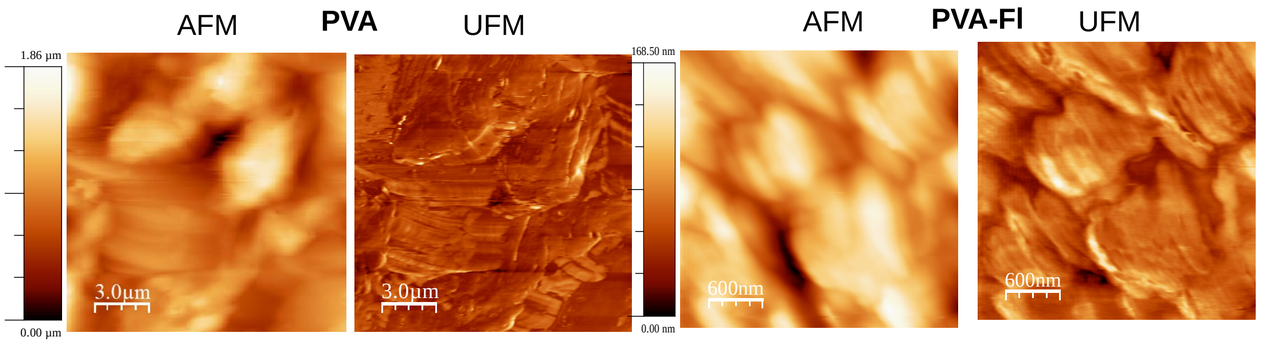
PVA–Fl: slightly reduced thermal stability, modified DSC transitions ⇒ Fluorescein alters PVA thermal degradation[3].

XRD



PVA–Fl –increased crystallinity compared to pure PVA, ⇒ fluorescein acting as a nucleation site for PVA chains during printing.

PVA–Fl-imp – broader main peak and lower crystallinity ⇒ fluorescein disruption of PVA crystalline domains during impregnation.



On both PVA and PVA-Fl samples the topography is characterized by a patch-liked layered texture typical of FDM. Smaller patches were better resolved in the PVA-Fl sample. On both samples, UFM reveals nanoscale elastic inhomogeneities, which may arise from local density variations and/or residual interfacial stresses, and in the case of PVA-Fl, also from fluorescein aggregates.

Biocompatibility: HaCaT cells were used to assess the non-toxic properties of the material (3D-printed PVA) via the MTS assay. Cell viability on the material surface was 80.96±5.13%, while cells treated with extracts from the material showed a viability of 102.57±5.23%, indicating that the material is non-cytotoxic.

CONCLUSION

Loading a commercial PVA filament, which proved to be non-cytotoxic, with fluorescein using a saturated ethanolic solution enabled the production of luminescent 3D printed tablets using FDM. The fluorescein-loaded samples exhibited higher crystallinity than pure PVA and showed smaller, better-resolved layered surface patches.

FUTURE WORK/ REFERENCES

Future work: explore additional procedures for filament modification.

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