

## Abstract

# A novel single-step manufacturing platform for patient-specific PEEK implants via FFF and in situ plasma biofunctionalization

J. Phruekthayanon<sup>1\*</sup>, M. Kühn-Kuaffeldt<sup>1</sup>, and M. Kühn<sup>1</sup>

<sup>1</sup> Institute of High Voltage Technology, University of the Bundeswehr, Munich, Germany

\* Corresponding author, email: [jay.phruek@unibw.de](mailto:jay.phruek@unibw.de)

© 2026 Jay Phruekthayanon; licensee Infinite Science Publishing

This is an Open Access abstract distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited (<http://creativecommons.org/licenses/by/4.0>).

Additive manufacturing of high-performance materials such as polyetheretherketone (PEEK) has been gaining acceptance in reconstructive medicine, particularly in maxillofacial and cranial applications [1-3]. However, PEEK is inherently bioinert and susceptible to implant-associated infections, which may limit long-term clinical performance [4]. Conventional strategies to overcome these limitations typically rely on post-processing surface treatments, which increase manufacturing complexity, require additional handling steps, and add to the regulatory burden.

We present an integrated additive manufacturing platform that combines fused filament fabrication (FFF) with in situ plasma-based surface coating, enabling the simultaneous fabrication and biofunctionalization of polymer implants within a single, continuous process [5]. Metal-based coatings exhibit varying degrees of antimicrobial activity, while some metal-oxides such as TiO<sub>2</sub> can enhance the attachment of bone cells [6, 7]. In addition, the printed parts may benefit from the vacuum environment in terms of improved mechanical properties [8] and the cleanroom-like conditions provided by the vacuum.

Overall, this integrated printing-and-coating technology represents a versatile manufacturing paradigm for next-generation medical implants that require both customized geometry and tailored biological functionality, with potential applications in reconstructive medicine.

## AUTHOR'S STATEMENT

Conflict of interest: Authors state no conflict of interest. Acknowledgments: This research is funded by dtec.bw - Digitalization and Technology Research Center of the Bundeswehr. Dtec.bw is funded by the European Union NextGenerationEU. Authors also acknowledge the clinic for Orthopedics and Sports Orthopedic of the Klinikum rechts der Isar Munich for the support of biological investigations as well as Institute of Engineering Mechanics and Structural Analysis at the University of Bundeswehr Munich for providing mechanical testing equipment.

## REFERENCES

- [1] Sharma, N., et al., *Dimensional characteristics of FDM 3D printed PEEK implant for craniofacial reconstructions*. Transactions on Additive Manufacturing Meets Medicine, 2020. **2**(1).
- [2] Demirak, O., E. Tutsak, and H. Demirci, *Additive manufacturing of custom-made cranial PEEK implant and postoperative evaluation*. Transactions on Additive Manufacturing Meets Medicine, 2022. **4**(1): p. 647-647.
- [3] Ahmad, A.F., et al., *Evaluating patients' satisfaction level after using 3D printed PEEK facial implants in repairing maxillofacial deformities*. Annals of Medicine and Surgery, 2022. **79**: p. 104095.
- [4] Wei, Z., et al., *Polyetheretherketone development in bone tissue engineering and orthopedic surgery*. Frontiers in Bioengineering and Biotechnology, 2023. **Volume 11 - 2023**.
- [5] Kühn-Kuaffeldt, M., et al., *Vacuum Arc Plasma Coating for Polymer Surface Protection—A Plasma Enhanced In-Orbit Additive Manufacturing Concept*. Plasma, 2022. **5**(4): p. 470-481.
- [6] Phruekthayanon, J., et al., *Biofunctionalization of 3D printed PEEK using integrated cathodic arc plasma coating: a one-step solution to antimicrobial and bioactive PEEK Implant*. Journal of Materials Science: Materials in Medicine, 2025. **36**(1): p. 109.
- [7] Boudot, C., et al., *Vacuum arc plasma deposition of thin titanium dioxide films on silicone elastomer as a functional coating for medical applications*. Mater Sci Eng C Mater Biol Appl, 2017. **74**: p. 508-514.
- [8] Kühn-Kuaffeldt, M., et al., *Fused filament fabrication of polyetheretherketone in vacuum: the influence of high vacuum on layer adhesion in z-orientation*. Progress in Additive Manufacturing, 2025. **10**(8): p. 5205-5215.