

## Abstract

# The effect of thermal cycles on the mechanical longevity of selectively laser melted metallic implants

S. Pal\*, T. Brajljih, N. Gubelj, and I. Drstvenšek

Faculty of Mechanical Engineering, University of Maribor, Maribor, Slovenia

\* Corresponding author, email: snehashis.pal@um.si

© 2026 S. Pal; 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>).

This study investigated the effects of thermal cycles and effective thermal spreading depth on crystallisation and microstructure evolution during the fabrication of parts by laser powder bed fusion. These thermomechanical factors significantly influence the mechanical properties of the parts. To examine this relationship, a range of pure metals and alloys, namely Mg, Zn, Ti-6Al-4V, and Co-Cr-Mo alloys, were considered to analyse their microstructural properties and their correlation with mechanical performance. Significant differences in grain size, grain shape, crystal orientation, and crystal ordering were observed as a function of the number of thermal cycles. These microstructural features are critical in determining the suitability of such materials for biomedical implant applications [1].

Crystal size and crystallographic orientation in pure metals varied significantly with the number of effective thermal cycles and thermal spreading depth. A hierarchy in  $\alpha'$ -martensitic size with a particular orientation was observed in Ti-6Al-4V. Grains ranged from smaller to larger, shapes varied from irregular to classically hexagonal, and  $\alpha'$ -martensitic structures ranged from larger to smaller as the number of thermal cycles increased [2]. As a consequence of this microstructural evolution, the yield strength varied from 1200 MPa to 600 MPa, elongation decreased from 8% to 2%, and hardness ranged from 350 HV to 400 HV in Ti-6Al-4V.

Discontinuous dynamic recrystallisation was promoted by repeated thermal cycling, while directional solidification facilitated the formation of coincidence site lattice boundaries in the Co-Cr-Mo alloy [3,4]. Furthermore, multiple thermal cycles prolonged the martensitic transformation process, reflecting its inherently sluggish kinetics in this alloy system [5]. Consequently, the yield strength in Co-Cr-Mo improved from 700 MPa to 860 MPa, and ductility increased markedly from 8% to 23%, which is particularly desirable for dental prosthesis applications.

## AUTHOR'S STATEMENT

Conflict of interest: Authors state no conflict of interest. Informed consent: Informed consent has been obtained from all individuals included in this study. Acknowledgments: This research is co-financed by the Slovenian Research Agency, with grant numbers P2-0137 and P2-0157.

## REFERENCES

- [1] Pal S, Finšgar M, Bončina T, Lojen G, Brajljih T, Drstvenšek I. Effect of surface powder particles and morphologies on corrosion of Ti-6Al-4 V fabricated with different energy densities in selective laser melting. *Mater Des* 2021;211:110184.
- [2] Pal S, Lojen G, Kokol V, Drstvenšek I. Evolution of metallurgical properties of Ti-6Al-4V alloy fabricated in different energy densities in the Selective Laser Melting technique. *J Manuf Process* 2018;35:538–46.
- [3] Chuang LC, Maeda K, Shiga K, Morito H, Fujiwara K. A  $\{112\}\Sigma 3$  grain boundary generated from the decomposition of a  $\Sigma 9$  grain boundary in multicrystalline silicon during directional solidification. *Scr Mater* 2019;167:46–50.
- [4] Lin F, Zhang Y, Godfrey A, Juul Jensen D. Twinning during recrystallization and its correlation with the deformation microstructure. *Scr Mater* 2022;219:114852.
- [5] Estrada R.T, Rodriguez A. S, Lopez HF. FCC to HCP transformation kinetics in a Co-27Cr-5Mo-0.23C alloy. *J Mater Sci* 2011;46:254–62.