Materials characterization and corrosion behaviour of additively manufactured titanium alloys for biomedical applications

Ingrid Milošev, Denis Sačer, Barbara Kapun, Terezija Poženel Kovačič, Peter Rodič
Jožef Stefan Institute, Department of Physical and Organic Chemistry, Jamova c. 39, 1000 Ljubljana, Slovenia

Development of new metallic materials for biomedical applications is a long-term and complex process due to a variety of requirements the materials have to fulfil, starting from appropriate mechanical properties including strength, hardness, elastic modulus and impact toughness, high corrosion resistance in the presence of chloride ions and biomolecules and biocompatibility with human body environment. Only several classes of metallic materials align with these requirements, including titanium alloys, cobalt alloys, and stainless steel. The manufacture of these alloys has been based exclusively on the metallurgical procedures to produce wrought or cast alloys. Ti-6Al-4V does not provoke allergic reactions, is biocompatible and exhibits a good balance of strength, ductility, fatigue, fracture properties, low Young elastic modulus, low density, hardness and excellent corrosion resistance based on the formation of TiO_2 passive layer. A specific property of Ti-based materials is their osseointegration capability to form bone cells and mineralised bone matrix on the Ti surface. Contemporary productions nowadays include another possibility, namely additive manufacturing. Additive manufacturing (AM) uses data computer-aided design software or 3D object scanners to direct hardware to deposit material, layer upon layer, in precise geometric shapes. Among different AM methods available for the production of alloys, direct energy deposition (DED) was employed in this study.

Materials characterisation was conducted using scanning electron microscopy combined with energy-dispersive X-ray spectroscopy (SEM/EDS). Electrochemical measurements were carried out at 37°C in three solutions: 0.9% NaCl as a first approximation of physiological conditions, Hanks physiological solution imitation serum plasma, and artificial saliva. The composition of AM Ti6Al4V alloy is aligned with that of the wrought Ti6Al4V alloy, which was used as a reference. The microstructure of wrought and AM alloys differs, with the former showing α-Ti phase and intergranular β-Ti phase and the latter with a lamellar widmanstatten pattern, Figure 1a. Both wrought and AM Ti6Al4V alloys passivate in simulated physiological solutions and show no susceptibility to localised corrosion, Figure 1b. These results confirmed that the properties of additively manufactured Ti alloy are comparable with commercial wrought alloy. Further advantages offered by additive manufacturing are the possibilities of designing material composition. We aim to produce the material with inherent antibacterial properties that do not jeopardise other biomaterial properties. The newest developments will be presented.

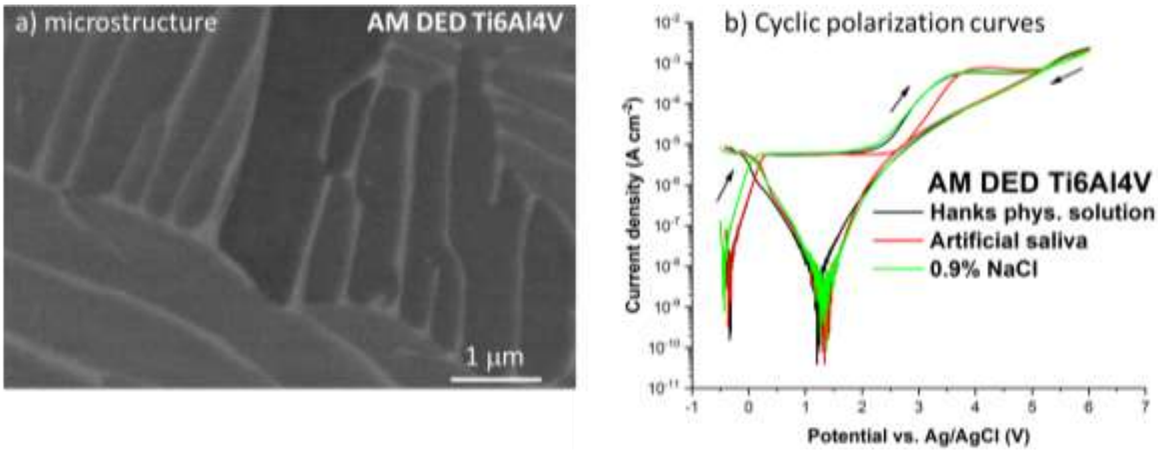

Figure 1. a) SEM backscattered image of the microstructure of additively manufactured Ti6Al4V alloy. b) Cyclic polarisation curves of additively manufactured Ti6Al4V alloys is three simulated physiological solutions.

Acknowledgement: The material was prepared at the Faculty of Mechanical Engineering of the University of Ljubljana. This study was financed by the Slovenian Research and Innovation Agency (grant BIOAD No. J7-4639).

References

1. G. Sander, J. Tan, P. Balan, O. Gharbi, D.R. Feenstra, L. Singer, S. Thomas, R.G. Kelly, J.R. Scully, N. Birbilis, *Corrosion.* **74** (2018) 1318 https://doi.org/10.5006/2926
2. J. Fojt, V. Hybášek, Z. Kačenka, E. Průcová, *Metals.* **10** (2022) 1547. https://doi.org/10.3390/met10111547
3. I. Milošev. A. Jeromen, P. Rodič, B. Kapun, D. Sačer, T. Poženel Kovačič, D. Kramar, F. Pušavec, E. Govekar, *Akademija s*trojništva **12(3/6)** (2023) 150 https://www.zveza-zsis.si/2023/11/22/akademija-strojnistva-2023-november-2023/