DESCRIPTION FOR THE GENERAL PUBLIC

Lightweight metallic materials such as titanium alloys are increasingly used in various applications, including vehicles, wind turbines, sports equipment, aircraft and biomedical devices [1]. Continuous research to improve the properties of these materials aims to improve living standards and play a key role in shaping environmental sustainability. They help reduce the overall carbon footprint by reducing the weight of means of transport and, consequently, fuel consumption [2]. In addition, the development of Additive Manufacturing (AM) technologies (aka 3D printing) has opened up innovative possibilities for designing and processing Ti alloys into objects that were often difficult or even impossible to achieve using traditional production methods[3]. The freedom of shapes offered by AM enables the creation of complex geometries and tailored material properties, systematically increasing the group of recipients of Ti alloys. Metastable β-Ti alloys are of increasing interest to the aerospace and biomedical industries due to their high tensile strength and ductility, high corrosion resistance, low density, low modulus of elasticity and good biocompatibility. Metastable β-Ti alloys exhibiting Twinning Induced Plasticity (TWIP) and Transformation Induced Plasticity (TWIP) generally have excellent ductility, but usually at the cost of relatively low yield strength, which limits their widespread use [4]. On the other hand, research conducted on conventionally produced castings has shown the possibility of improving the yield strength by 30-50% [5]. Furthermore, preliminary research conducted by the Applicant has shown that it is possible to strengthen single-phase (α) and two-phase (α+β) Ti alloys by oxygen addition during the Laser Beam Powder Bed Fusion (PBF-LB) process [6–8]. However, precise oxygen *in situ* alloying during the PBF-LB process, resulting in specific oxygen content in the material after production, has not yet been implemented. The project aims to investigate the possibility of using oxygen as an interstitial element to regulate the stability of the β phase in order to significantly increase both the strength and ductility of TWIP/TRIP β-Ti alloys (including Ti-Mo and Ti-Nb). Microdosing of selected TWIN/TRIP alloys with oxygen will be carried out on a PBF-LB device, which allows for control of the oxygen content during the process. The project plans to produce selected alloys by casting them in an arc furnace, using ultrasonic atomization to produce powders, selecting PBF-LB process parameters using machine learning approaches, and characterization of the produced materials. As part of the characterization of the produced objects, analyses will be conducted for oxygen content, phase composition, and defects presence (i.e., cracks and porosity). Additionally, microstructure observations will be performed through microscopic methods, including SEM/TEM/EBSD, while hardness measurements and static tensile tests will evaluate mechanical strength. The knowledge gained from these analyses will enhance the application potential of TWIP and TRIP alloys manufactured using the PBF-LB process in industries such as medicine, aviation and aerospace, automotive and defence. The primary objective of this project is to investigate how to modify the mechanical properties of selected metastable alloys, specifically β-Ti Ti-12Mo-xO and Ti-32Nb-xO, focusing on yield strength, tensile strength, ductility, and hardness. Advancements in processing lightweight and strong titanium alloys are essential for promoting sustainable development.

1. Leyens, C. & Peters, M. *Titanium and Titanium Alloys: Fundamentals and Applications*. (Wiley Online Library, 2006).
2. Léonard, P. L. Y. & Nylander, J. W. Sustainability assessment of composites in aero-engine components. *Proceedings of the Design Society: DESIGN Conference* **1**, 1989–1998 (2020).
3. Yadroitsev, I., Yadroitsava, I., Du Plessis, A. & MacDonald, E. *Fundamentals of Laser Powder Bed Fusion of Metals*. (Elsevier, 2021).
4. Gao, Y. *et al.* Manipulating TWIP/TRIP via oxygen-doping to synergistically enhance strength and ductility of metastable beta titanium alloys. *J Mater Sci Technol* **215**, 58–70 (2025).
5. Wang, J., Xiao, W., Ren, L., Fu, Y. & Ma, C. The roles of oxygen content on microstructural transformation, mechanical properties and corrosion resistance of Ti-Nb-based biomedical alloys with different β stabilities. *Mater Charact* **176**, 111122 (2021).
6. Wysocki, B. *et al.* Microstructure and mechanical properties investigation of CP titanium processed by selective laser melting (SLM). *J Mater Process Technol* **241**, 13–23 (2017).
7. Wysocki, B. *et al.* Laser and Electron Beam Additive Manufacturing Methods of Fabricating Titanium Bone Implants. *Applied Sciences* **7**, 657 (2017).
8. Wysocki, B. A. *et al.* Mechanical Properties of Ti Grade 2 Manufactured Using Laser Beam Powder Bed Fusion (PBF-LB) with Checkerboard Laser Scanning and In Situ Oxygen Strengthening. *Crystals (Basel)* **14**, (2024).