Laser Surface Alloying for Enhanced Antibacterial Performance by Copper Surface Alloying of Titanium Ti6Al4V Alloy

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Abstract

Statement of the Problem: Titanium alloys, particularly Ti6Al4V, are exceptional biomedical materials renowned for their strength, corrosion resistance, and biocompatibility, making them ideal for various medical implants and devices. Despite the exceptional properties of the alloy for medical implants, bacterial colonization remains a significant concern post-surgery, attributed largely to contamination during implantation procedures. This colonization, seen especially after dental and cardiovascular implant placements, poses risks to patient health and implant longevity. Integrating copper (Cu) into titanium alloys to form a copper-enriched phase **(Ti_2Cu)** shows promise for combating bacterial colonization due to the antibacterial properties of released Cu^{2+} ions. The objective of this research is to investigate the feasibility of forming an intermetallic phase (Ti_2Cu) through laser surface alloying using the TruDisk 3302, a Ytterbium-doped Yttrium Aluminum Garnet (Yb: YAG) disk laser system capable of delivering continuous wave (CW) output power up to 3.3 kilowatts (KW). The study includes microstructural analysis and microbiological investigations.

Conclusion & Significance: The study successfully demonstrated the feasibility of forming the Ti2Cu intermetallic phase on titanium alloys using the TruDisk 3302 Yb: YAG laser system. Laser surface alloying at specific power and scan speed parameters enabled the creation of this desired intermetallic structure. Microstructural examination revealed the formation and distribution of the Ti_2Cu intermetallic phase within the alloy matrix. This analysis provided insights into the structural changes induced by laser surface alloying and the potential implications for the alloy's properties.

The integration of copper into titanium alloys to form Ti_2Cu showed promise for combating bacterial colonization. The antibacterial efficacy of Ti_2Cu, attributed to the release of Cu^{2+} ions, was assessed through microbiological investigations.

The successful formation of the Ti_2Cu intermetallic phase via laser surface alloying opens avenues for enhancing the antibacterial properties of titanium alloys used in medical implants. This advancement could contribute to reducing the risks associated with post-surgical infections and improving the longevity of biomedical devices.

Image

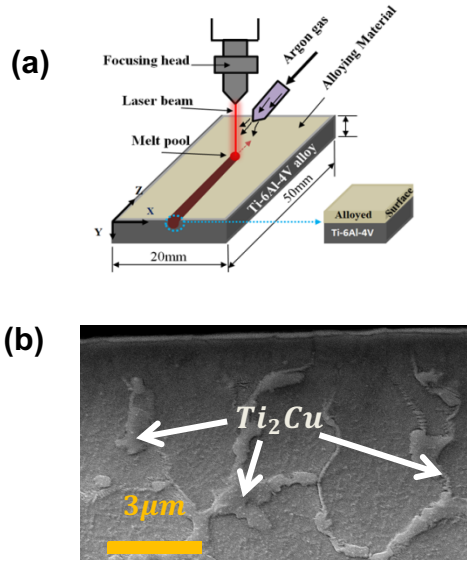

Figure 1 (a) Laser surface alloying system (b) SEM micrograph of Ti-Al-V-Cu

Recent Publications

1. Hana Beyene Mamo, Marcin Adamiak, Anil Kunwar, 3D printed biomedical devices and their applications: A review on state-of-the-art technologies, existing challenges, and future perspectives (2023),Elsevier,https://doi.org/10.1016/j.jmbbm.2023.105930.
2. Marcin Adamiak, Augustine NS Appiah, Anna Woźniak, Oktawian Bialas, Surface Modification of Metallic Materials Using Laser and Plasma Technologies (2022), Springer Nature Switzerland, https://link.springer.com/chapter/10.1007/978-3-031-47990-8_8
3. Xiangshuo Li, Zhengjun Yao , Xuewei Tao , Mengxin Yao , Shasha Zhang ,Developing Cu modified Ti6Al4V alloys with a combination of high strength and ductility by electron beam freeformfabrication,(2021), Elsevier https://doi.org/10.1016/j.vacuum.2021.110638.
4. Valerie Sue Goettgens , Lukas Kaserer , Jakob Braun , Richard Busch , Lutz Berthold ,Christian Patzig, Gerhard Leichtfried , Microstructural evolution and mechanical properties of Ti-6Al-4V *in situ* alloyed with 3.5 wt.% Cu by laser powder bed fusion, Elsevier, https://doi.org/10.1016/j.mtla.2023.101928
5. Erlin Zhang, Xiaotong Zhao, Jiali Hu,a Ruoxian Wang, Shan Fu, and Gaowu Qina,b,Antibacterial metals and alloys for potential biomedical implants.Elsevier, https://doi.org/10.1016%2Fj.bioactmat.2021.01.030

Photograph

Biography

Mrs. Hana Mamo is currently pursuing a PhD at the Silesian University of Technology in Materials Engineering, focusing on additive manufacturing technologies. Specifically, her research explores the use of 3D printing to develop custom metal alloys for biomedical purposes.

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