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Elastic anisotropy in additive-manufactured titanium alloys studied by resonant ultrasound spectroscopy

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Extended Abstract

Abstract

Titanium alloys offer a remarkable combination of high strength and toughness, along with excellent fatigue and corrosion resistance while maintaining low density and low elastic moduli. Their favourable strength-to-density ratio makes them attractive for a wide range of industrial applications, whereas the combination of low elastic modulus and biocompatibility is particularly promising for biomedical uses, such as hip implants. Among Ti alloys, metastable alloys exhibit the lowest elastic moduli, while possessing complex multiphase microstructures comprising alpha, beta or omega-Ti phases. The phase composition and the resulting elastic properties are strongly influenced by various alloying elements, where even minor variations in elemental combinations can lead to significant changes in alloy properties. Additive manufacturing (AM) is particularly advantageous in this context, as it enables the fabrication of a wide variety of alloy compositions directly from elemental powders. In this study, the elastic properties of various additively manufactured titanium alloys were investigated by resonant ultrasound spectroscopy (RUS). This technique allows determination of the complete set of elastic coefficients from the resonant spectrum of a freely vibrating millimetre-sized sample. The investigated materials included pure alpha-Ti, an alpha+beta Ti6A4lV alloy, and TiNb-based beta-Ti alloys fabricated by different additive manufacturing techniques, namely cold spraying, directed energy deposition, and laser powder bed fusion. As the AM processing often induces a substantial crystallographic texture, particular attention was paid to its influence on the elastic anisotropy. A clear correlation between the texture and the elastic anisotropy was observed; for example, some TiNb-based alloys exhibited Young’s modulus values below 60 GPa along specific AM processing orientations. In such alloys, the presence of crystallographic texture can be beneficial, as it would enable the directions with the lowest Young’s modulus to be aligned with the principal loading direction of the implants, thereby limiting stress shielding caused by mismatch of elastic properties between the bone and the implant. The authors acknowledge the assistance provided by the Ferroic Multifunctionalities project no. CZ.02.01.01/00/22_008/0004591, supported by the Ministry of Education, Youth, and Sports of the Czech Republic, co-funded by the European Union, and by the Czech Science Foundation project no. GC24-11074J.

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