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# Optimization of a Harmonic Structured Ti-24Nb-4Zr-8Sn Alloy through Combined Microstructural and Mechanical Investigations

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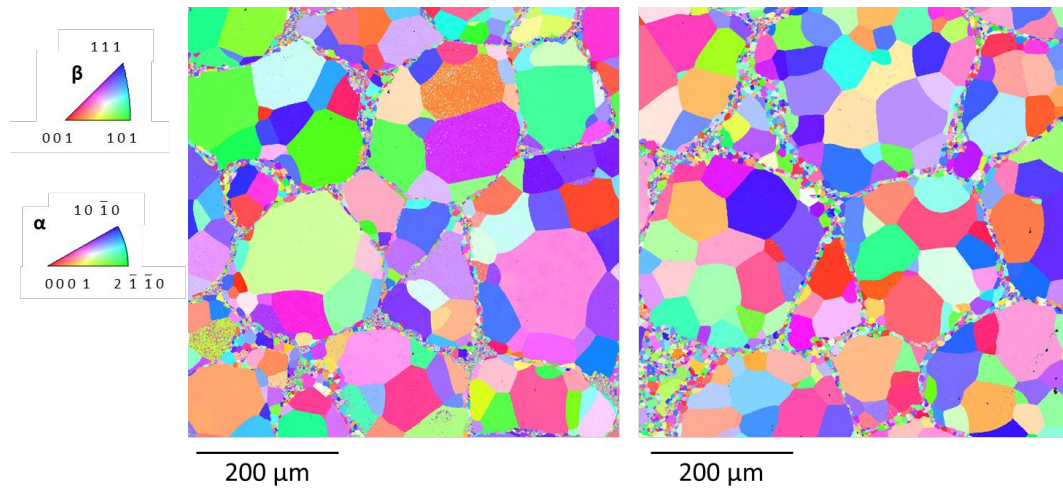
**Keywords:** Harmonic structure, Powder Metallurgy, Spark Plasma Sintering, Mechanical properties, Plastic deformation mechanisms

**Abstract.** Heterogeneously structured materials have benefited many recent developments because of their potential to reach a good compromise between strength and ductility. Among them, this work focuses on harmonic-structured materials, which consist of a volume network of soft core and hard shell regions in the material [1]. Such a design was applied on a Ti-24Nb-4Zr-8Sn alloy - which belongs to the  $\beta$ -metastable titanium alloys family. The aim is to master the processing route and investigate a possible improvement of mechanical properties induced by the harmonic design, for a use of Ti-24Nb-4Zr-8Sn alloy as a hip implant constituent.

The powder metallurgy (PM) processing route includes a Ball Milling stage of spherical and pre-alloyed powder particles, followed by a consolidation step using Spark Plasma Sintering. An oxygen contamination could occur during the fabrication route, and the consequences of such enrichment were first evaluated on the microstructure. Then, an optimization of harmonic-structured Ti-24Nb-4Zr-8Sn was performed by combining specific fabrications together with complete microstructural characterizations and mechanical testings of the obtained samples. Typical Ti-24Nb-4Zr-8Sn harmonic microstructures are shown in Figure 1. It proved a significant contribution of the harmonic design on yield strength of the alloy without a drastic loss of ductility, if the shell fraction does not exceed a threshold value. Grain size differences between core and shell can also be controlled during the process and high differences are required for an improved mechanical behaviour.

Besides, interrupted quasi-static compression tests were performed to observe the microstructure evolution by ex-situ Scanning Electron Microscopy, Electron BackScatter Diffraction (EBSD) and X-Ray Diffraction (XRD). It highlights the formation and propagation of dislocations during plastic deformation: a very high density was detected with XRD after compression deformation. Some of them are Geometrically Necessary Dislocations which pile up at core-shell interfaces, as highlighted by EBSD results at intermediate strain percentages. Pile-ups of dislocations create at this location a misoriented area thereafter called Interface Affected Zone. It contributes to increase the value of the hetero-deformation induced stress – or back stress - which appears during deformation and leads to the global hardening of the material [2].

Finally, these experiments allow to optimize the PM processing route, discuss the mechanical properties of the harmonic-structured Ti-24Nb-4Zr-8Sn alloy, and understand the corresponding plastic deformation mechanisms.



**Fig. 1.** EBSD Inverse Pole Figure maps of harmonic-structured Ti-24Nb-4Zr-8Sn obtained by varying Ball Milling parameters.

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