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Preparation, characterization, and biocompatibility of Ti-Zr alloys for biomedical applications

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Abstract - Titanium alloys are frequently used as biomaterials, mainly in orthopedic and dental implants, due to their properties as corrosion resistance, a smaller elasticity modulus in relation to other metals, and good biocompatibility. Samples of Ti-Zr alloys were prepared and structurally characterized by X-ray diffraction, optical microscopy, and scanning electron microscopy. Mechanical testing in a torsion pendulum were made and showed that the presence of interstitial elements changes the mechanical properties of the samples. Biocompatibility tests confirm that the material can be used in biomedical implants.

Ti-6AL-4V alloy is the main titanium alloy used as biomaterial in Brazil, but due to the detection of toxicity of Al and V, new alloys have been developed without the presence of these elements. Among the options, alloys with elements such as Nb, Ta, Zr, and Mo have gained importance, and consequently, it is necessary to understand the mechanical properties of binary systems, such as Ti-Zr (TZ) [1]. The presence of interstitial elements in TZ alloys causes changes in the mechanical characteristics of the material and can make the sample more viable for orthopedic implants [2]. Measures of mechanical spectroscopy are a powerful tool to evaluate the behavior of interstitial elements in the sample [3, 4].

Samples of Ti-Zr alloys (5 and 10 wt% of Zr) were produced from the melting of precursors Ti cp (99.7%) and Zr (99.8%) in an arc-melting furnace with an argon atmosphere. Chemical analysis showed the main elements that compose the alloy. Ingots were characterized by X-ray diffraction, optical microscopy, and scanning electron microscopy. Mechanical spectroscopy measurements were performed in a torsion pendulum in the temperature range between 100 and 700 K, with a frequency between 3 and 30 Hz, heating rate of approximately 1 K/min, and vacuum better than 10^{-5} mbar.

The X-ray pattern of the sample showed peaks in the same positions as Ti cp, indicating that the addition of zirconium did not change the crystalline structure of the material, corresponding to the alpha phase (hcp structure). The micrographs showed a microstructure that also characterized the alpha phase of the alloy. The mechanical spectroscopy measurements showed a spectra composed by several peaks (Fig. 1) that were attributed to the stress-induced ordering of interstitial atoms around atoms of the metallic matrix. The dynamic elasticity modulus of the material, obtained from frequency measurements (Fig. 2), showed that this alloy is a promising material for use as orthopedic implants. In direct or indirect cytotoxicity tests, the studied alloys presented no cellular toxicity, indicating good *in vitro* biocompatibility.

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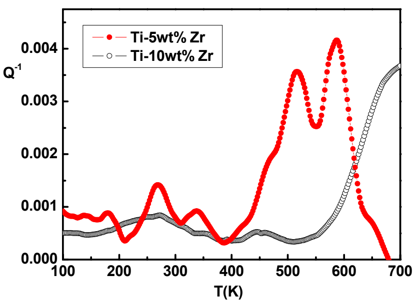

Figure 1: Mechanical spectroscopy of Ti-Zr alloys.

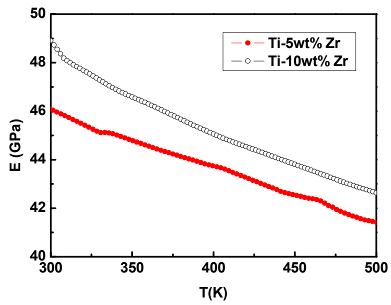

Figure 2: Dynamic elasticity modulus of Ti-Zr alloys.

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