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Dynamic elasticity modulus measured by mechanical spectroscopy of the Ti-Mo system

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Abstract – Titanium and its alloys have been very widely used as biomaterials due to their excellent biocompatibility, mechanical properties, corrosion resistance, high mechanical strength/density ratio, and low elasticity modulus. Metallic elements added to titanium can change the temperature and stability of allotropic transformation, modifying the temperature of phase transition, hardness, and strength. Mechanical spectroscopy constitutes a powerful tool for the dynamic elasticity modulus measures of materials. In this paper, a study of the effect of molybdenum quantity in the dynamic elasticity modulus of the Ti-Mo system is presented, using a torsion pendulum operating with a frequency between 3 and 30Hz and a temperature between 90 and 700 K.

With an excellent strength/density ratio, high corrosion resistance, and excellent biocompatibility, the titanium alloys are extremely attractive for applications in the aeronautical and automobile industry and also in the manufacture of orthopedic and dental prostheses [1, 2]. The Ti-6AL-4V alloy is the most widely used in orthopedic implants. However, it is known that aluminum ions cause neurological disorders and vanadium ions are associated with enzymatic disorders, among other problems [3]. The Ti-Mo (TM) system is part of a new class of alloys based on Ti without the presence of Al and V (showing cytotoxicity). These alloys have low values of elasticity modulus when compared to human bone (around 95 GPa), which is very attractive for use as biomaterials [4]. The elasticity modulus is an important property for applications in implants; therefore, the insufficient absorption of impacts can lead to erosion of bone and loss of the prosthesis. Metallic elements added to pure titanium cause change in the temperature and stability of the allotropic transformation, increasing or decreasing the temperature of the phase transition. Mechanical spectroscopy measurements are a powerful tool to study the interaction of interstitial and substitutional elements with the metallic matrix [5]. In this paper, a study of the effect of molybdenum concentration in the dynamic elasticity modulus of the Ti-Mo system is presented.

The used samples were polycrystals of the Ti-Mo system produced by arc-melting in an argon atmosphere in the UNESP, Faculty of Engineering, Guaratinguetá, Brazil. Chemical analysis showed the main elements that compose the alloy to be in good agreement with the stoichiometry (5, 10 and 15 wt% Mo). After melting, the samples were characterized by X-ray, optical microscopy, and scanning electron microscopy measurements. In order to study the effect of substitutional elements on the mechanical properties of the TM alloys, measurements of mechanical spectroscopy (internal friction and frequency) were made in a torsion pendulum in the temperature range of 90–700 K and a frequency between 3 and 30 Hz at a heating rate of approximately 1 K/min and under vacuum better greater than 10^{-6} Torr to avoid contamination of samples. In the internal friction measurements, the interaction of the substitional and interstitial elements present in the samples with the metallic matrix was obtained. The elasticity modulus was obtained by the oscillation frequency of the sample [5].

The results showed that there was a decrease of the elasticity modulus with increasing temperature, which is characteristic of most metals due to the natural softening of the material. The internal friction measurements showed complex relaxation spectra. With the decomposition of those relaxation spectra, it was possible to identify the interaction of substitutional and interstitial elements present in the alloys. The elasticity modulus results showed that this alloy is a promising material for use in orthopedic implants. In direct or indirect cytotoxicity tests, the studied alloys presented no cellular toxicity, indicating good in vitro biocompatibility.

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References

[1] M. Geetha, A. K. Singh, R. Asokamani, A. K. Gogia, Progress in Materials Science 54 (2009) 397-425.
[2] M. Niinomi, Materials Science and Engineering A 243 (1998) 231-236.
[3] J. Black, Biological performance of materials – Fundamentals of Biocompatibility, Marcel Dekker, New York, 1992.
[4] W.-F. Ho, Journal of Alloys and Compounds 464 (2008) 580-583.
[5] A. S. Nowick, B. S. Berry, Anelastic Relaxation in Crystalline Solids, Academic Press, New York, 1972.