**EUROPEAN JOURNAL OF MATERIALS SCIENCE AND ENGINEERING**
Volume 4, Issue 1, 2019: 44-50 | www.ejmse.tuiasi.ro | ISSN: 2537-4338

DOI: 10.36868/ejmse.2019.04.01.044

# STRUCTURAL ANALYSIS OF Ti-Mo ALLOYS

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**Abstract**

*In the last decade, many researchers have demonstrated that Ti-based alloys for implants, with different biocompatible elements (Zr, Ta, Mo, Si, Nb etc.) have positive responses interaction with bone tissues, promoting an adequate osseointegration. An ideal biomaterial, possesses an ideal combination of microstructure, mechanical properties and corrosion resistance. Ti-Mo are promising biomaterials candidates because presents specific advantages (mechanical properties, biocompatibility, corrosion resistance etc.) without affecting the health of the patient. In the current investigation is presented the correlation of β Ti alloys effect on the microstructure and micro-hardness properties. The samples were produced by argon arc-melting method. In connection with the researches reported in the field of biomaterials, Ti-Mo group are good candidates to orthopedic applications, thus aiming to replacing existing ones.*

**Keywords:** *Ti-Mo alloys, orthopedic implants, biomaterials, structural characterization.*

## Introduction

Importance to develop new materials with enhanced properties, biocompatible and long-term viability as an implant material, it comes from the request of market biomaterials, which has more and more requirements. Biomaterials the most common used in many applications from implants to devices are the titanium alloys (Ti6Al4V), cobalt alloys (CoCrMo) and stainless steels [1-4].

Titanium alloys are used for the high requirements compared to classical alloys due to: low elasticity (close to bone), strength and density low, corrosion resistance and biocompatibility interaction [5-7].

Song et all [8] have been highlighted that niobium, zirconium, molybdenum and tantalum are best suited as alloying elements in order to reduce the modulus of elasticity of cubic titanium without change mechanical strength. Also, an important aspect is that these alloying elements are in the category of non-toxic elements, giving them the advantage of being used for applications in implantology [9]. Based on these issues, researchers have developed and researched the second generation of biomaterials [10, 11], focusing on the development of biocompatible titanium alloys, improved alloys with non-toxic elements to the human body (Mo, Zr, Ta) by developing materials such as metastable beta alloys: Ti15Mo, Ti15Mo5Zr3Al, Ti10Mo1,2Si13Zr, etc.

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Baltatu and collaborators have been developed, new Ti alloys using Ta, Zr, and Mo as alloying elements (β -stabilizer elements) achieving a new titanium system (TiMoZrTa) with low elastic modulus, high strength, and corrosion resistance [12].

Many studies confirmed that some alloys have negative influence on human, like aluminium and others, because of this, researchers are aimed to improve alloys properties by introducing non-toxic elements, for enhaning surface characteristics, mechanical properties, corrosion resistance, biocompatibility etc [13-15]. On the opposite side is molibdenum which are nontoxic and present excellent biocompatibility, favoring vascularization in the tissue.

The current paper presents properties of two Ti-Mo alloys, with proper properties for medical applications.

## Experimental Procedure

For elaborate Ti-Mo alloys were selected proper elements, with high purity (Ti - 99.8%, Mo - 99.7%), in order to avoid unintended reactions. The samples were obtained in argon arc-melting method. The process of melting charge, occurs in high vacuum conditions (Fig. 1) achieved by pumping the working chamber with the pump system. During the melting of the samples, presence of oxygen, provides a significant reduction vacuum in the working chamber. After the recovery of the high vacuum, the argon is pumped into the working chamber in the atmosphere where the samples is melted. The proper temperature and easy sample handling, ensures a high homogeneity of the chemical composition of the samples. Typically, the homogeneity of the samples is obtained after seven times remelting.

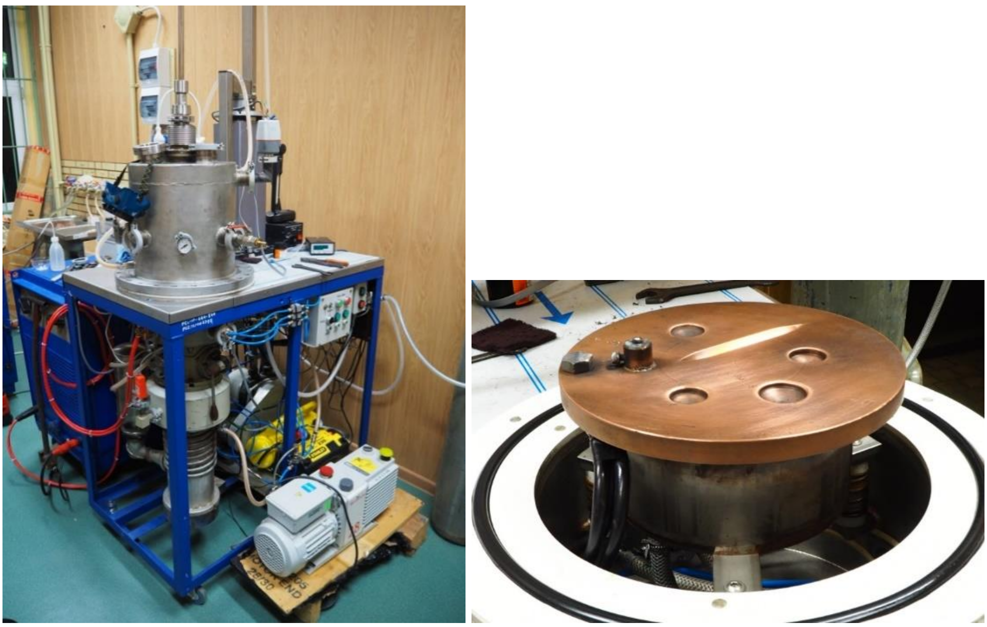


**Fig. 1.** Vacuum arc furnace

The preparation of Ti-Mo alloys in the vacuum arc remelting furnace comprised a succession of operations as described in Fig. 2.

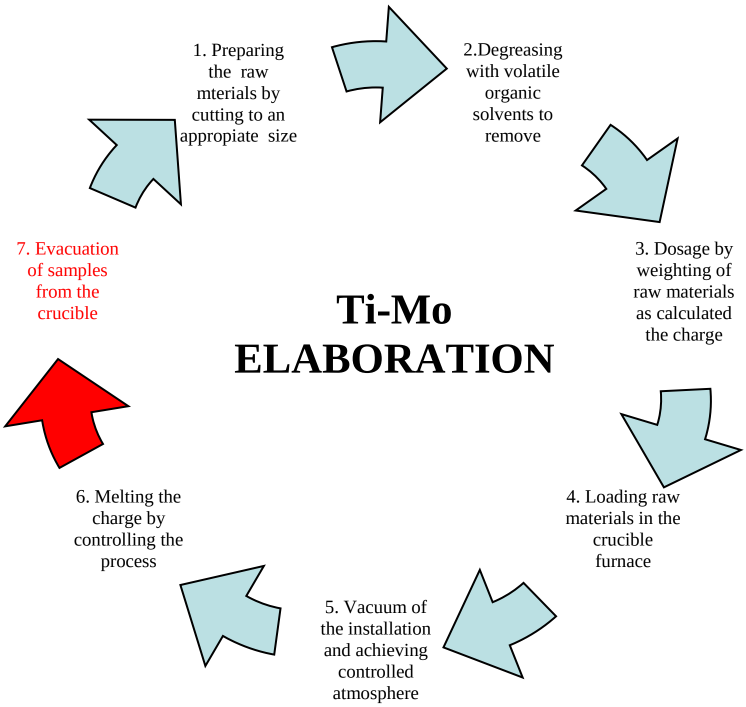



**Fig. 2.** Technological flow of Ti-Mo alloys

The chemical analyse of the alloy was done with help of EDX Bruker QUANTAX QX2 coupled to SEM VEGA II LSH scanning electron microscope manufactured by the TESCAN Co., the Czech Republic.

X'Pert Pro MPD diffractometer was used for identification of structural constituents. Parameters used for sample analysis are: range of angle θ-2θ between 20° - 80°; continuous scanning; step size 0,0131303; time per step 60 s; scan speed 0,054710 (°/s); number of steps 6093, use a copper X-ray tube. In order to determine the constituent phases, by X-ray diffractometry, from the Ti-Mo alloys developed, samples with size of 10 mm x 10 mm x 5 mm were cut and used after they had been polished.

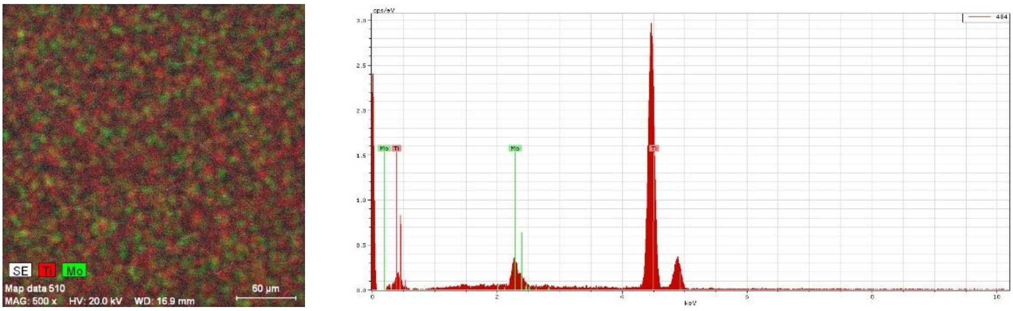
Wilson Wolpert universal hardness tester 751N model, were used for the Vickers hardness measurements, with a load of 9,807 N during 12 s. Hardness measurements were performed on samples obtained of Ti-based alloys of dimensions 10mm x 10mm x 3mm, the surface of the samples being prepared by metallographic grinding on abrasive paper. Experimental tests consisted of three determinations in different areas on the surface of each sample, using a 9.81 N pressure force and a 12 second measurement time.

## Result and Discussion

In table 1 is presented the chemical composition of the two elaborated alloys, which is the average value for multiple measurements and in the Fig. 3 and Fig. 4 are the EDX spetrum and mapping elements of Ti-Mo alloys. The structure is uniform and homogenous.

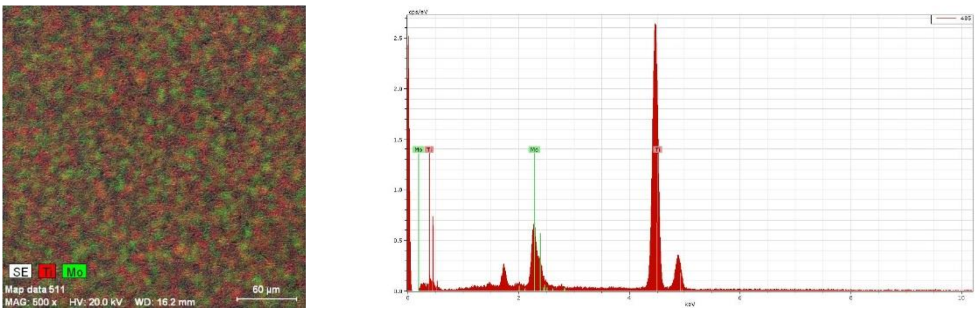
**Table 1.** Chemical composition of the Ti-Mo samples after melting

| Element | Mo | Ti |
|---|---|---|
| wt.(%) | 9,56 | Balance |
| | 19,91 | Balance |




(a) (b)

**Fig. 3.** a) EDX spectrum and b) mapping the elements for Ti15Mo alloy



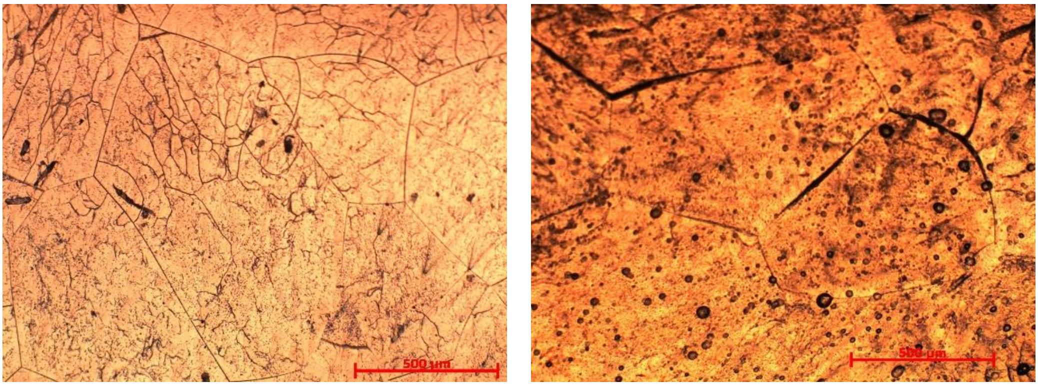

(a) (b)

**Fig. 4.** a) EDX spectrum and b) mapping the elements for Ti20Mo alloy

For the determination of the chemical composition of alloys obtained from the Ti-Mo alloys, samples having dimensions of 10 mm x 10 mm x 5 mm were used. Before being examined, the samples were metallographic grinding on abrasive paper to remove impurities and titanium oxide film on the surface of the alloy.

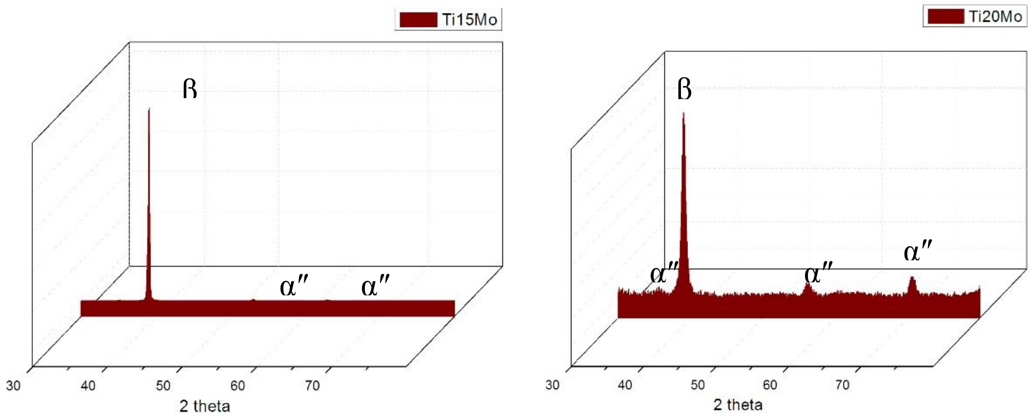
Table 1 shows the mass percentages of the elements identified in the alloy composition, the percentages of the elements varying slightly with the theoretical batch calculation. The analysis bulletins on the chemical composition obtained revealed that the main elements identified in the alloys elaborated are titanium and molybdenum, without the presence of alloy inclusions. In Figures 3 and 4 are presented EDX spectrum and the mapping elements for Ti-Mo alloys.

Microstructure and mechanical properties of Ti-Mo alloys depending on the amount of stabilizing elements α or β added in the chemical composition. Fig. 5 illustrates the microstructure of beta-type Ti-Mo alloys. By elaborating of the two Ti15Mo and Ti20Mo alloys, the formation of beta-equiaxial grains having different dimensions was emphasized, highlighting that the 20% Mo alloy has grains higher than the 15% Mo alloy.



(a) (b)

**Fig. 5.** Optical microstructure(100X) for Ti-Mo alloys: a) Ti15Mo, b)Ti20Mo




(a) (b)

**Fig. 6.** XRD paterns: a)Ti-15Mo, b) Ti-20Mo

The diffractograms obtained of Ti-Mo processed alloys (Fig. 6) confirm the β-type structures identified by optical microscopy. It can be seen that all samples illustrate a mixture phases of hcp α-Ti and bbc β-Ti, in which the β-Ti is more acquainted at higher intensity. It can be seen that with the increase of Mo content from 15% to 20% appear more peaks of orthorhombic α″.

The hardness measurements highlights the resistance to the penetration action of an external body and provide information on the behavior of the studied materials. In this way, we can analyze the Ti-based alloys developed for the purpose of fitting them into the specific medical application. The hardness measurements made on the titanium alloys developed by the Vickers method are a general method for determining the hardness of metallic materials, very used in biomaterial testing.

**Table 2.** Hardness values of titanium samples

| **Alloy** | Hardness (HV) |
|---|---|
| Ti15Mo | 361,28 |
| Ti20Mo | 411,48 |

Hardness values of Ti-Mo alloys are presented in Table 2. When the Mo content reached 5 wt%., an increase in hardness was observed. This high hardness is attributed to orthorhombic α″ phase, observed in diffractograms obtained. For high-Mo-content alloys, the stabilization of β phase resulted in a decrease in hardness.

## Conclusions

For obtaining and improving new Ti-based alloys for medical applications is very important to study all mechanical properties, but an important thing it has correlation between mechanical properties and composition microstructural of β Ti alloys, so the current paper were investigated two Ti-Mo alloys from this from these points of view.

Two alloys of Ti-based alloys were elaborated in vacuum arc furnace. Alloys obtained (Ti15Mo and Ti20Mo) were structural investigated for mapping, chemical composition and XRD patterns. As the molibdenum content was increased, all properties are changed, grains having different dimensions, more peaks of orthorhombic α″ apperead an increase in hardness were observed.

## Acknowledgement

This work was supported by a grant of the Romanian Ministry of Research and Innovation, CCCDI – UEFISCDI, project number PN-III-P1-1.2-PCCDI-2017-0239 / 60PCCDI 2018, with in PNCDI III.

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*Received: January 6, 2019*
*Accepted: January 10, 2019*