# Influence of selective laser melting mode on structure and phase composition of Ti-Nb alloy

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## Introduction

Physical mechanical and biocompatible properties of Ti-(40-45) wt. % Nb alloys make them applicable for bioimplants production. Selective laser melting (SLM) allows obtaining low-modulus Ti-Nb alloys and items of complex shape. Change of SLM parameters affects the size of structural elements and phase composition of resulting product. The purpose of the study was to investigate influence of SLM parameter change on the structure and phase composition of Ti-(40-45) wt.% Nb alloy.

## Materials and methods

Composite powder of titanium and niobium was obtained by mechanical activation of Ti and Nb powders mixture in AGO-2C ball mill (fig. 1). After activation composite powder was annealed in vacuum at 500°C during 1 hour.

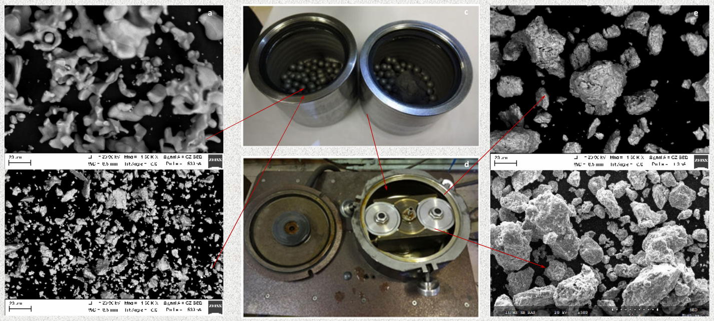


Fig. 1. Initial powders of titanium (a) and niobium (b), vials (c) and planetary ball mill AGO-2C (d), Ti-Nb composite powder (e, f)

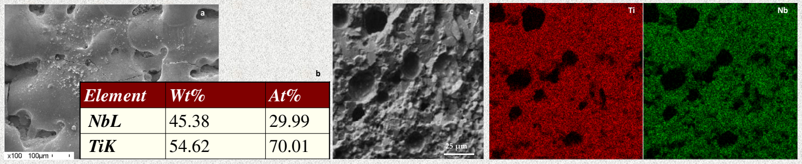
Then the composite powder was used for the production of 3-D specimens by SLM method using “VARISKAF-100MVS” installation (fig. 2). To produce 3-D specimens the composite powder was layered on Ti substrate in vacuum camera. The thickness of each layer was 0.05 mm. Than it was melted in Ar atmosphere. Specimens were formed with the laser beam of 80 W-power. The spot diameter was 150 µm, scanning step was 0.4 mm. Laser beam scanning velocity was varied in the range 40-70 mm/s with the step of 10 mm/s.

Fig. 2. “VARISKAF-100MVS” installation

Morphology of obtained specimens was investigated with scanning electron microscopy (SEM). Elemental composition was evaluated with energydispersive microanalysis (SEM 515 Philips, Zeiss LEO EVO 50 XVP). Phase composition was investigated with X-ray diffraction analysis (XRD) (Shimadzu XRD 6000 $CuK_{\alpha}$-radiation). Microstructure was investigated with transmission electron microscopy (TEM) (JEOL JEM-2100). Physical mechanical properties (Young’s modulus, nanohardness) were evaluated using Nanohardness Tester.

## Results and discussion

3-D specimen obtained on “VARISKAF-100MVS” installation is represented on fig. 3a. Each layer of the powder was completely melted and crystallized during SLM (fig. 3 a, c). The elemental composition of obtained specimens is represented by ~45wt.% Nb and ~55wt.% Ti. The elemental components are homogeneously distributed throughout the section of the specimen (fig. 3c).



| Element | Wt% | At% |
|---|---|---|
| NbL | 45.38 | 29.99 |
| TiK | 54.62 | 70.01 |

Fig. 3. SEM-image (a), results of energydispersive analysis (b) and elemental mapping (c) of 3-D specimens obtained on “VARISKAF-100MVS” installation

Phase composition is represented by β- and also TiO-phases (fig. 4a). The microstructure is represented by β-phase grains with the size of 5-7µm (fig. 4b). Martensitic α''-phase is located throughout β-phase boundaries and inside its grains. The size of α''-phase grains is 0.1-0.7 µm.

With laser beam scanning speed increasing from 40 to 70 mm/s the nanohardness changes in the range of 6500-6800 MPa and the Young’s modulus is in the range of 55-83 GPa. This indicates that there are strengthening phases and internal stresses in obtained alloy.

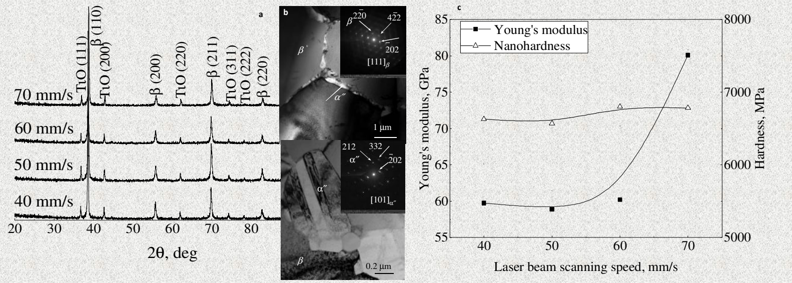



Fig. 4. Results of XRD analysis (a), TEM (b) and physical mechanical properties measurement (c) of investigated specimens

## Conclusions

- The obtained specimens had homogeneous elemental distribution with Nb concentration of 42-45 wt.%.
- The equiaxed grains and grains elongated towards the substrate are observed on TEM-images. These grains correspond to β-phase and α''-phase;
- XRD have shown presence of β-phase and TiO;
- Nanohardness is varied in the range of 6500-6800 MPa;
- The Young’s modulus is varied in the range of 55-83 GPa.

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## Literature Cited

- M. Niinomi, M. Nakai (2014) Biomedical implants devices fabricated from low Young’s modulus titanium alloys demonstrating high mechanical biocompatibility. Material Matters 9(2): 39–50.
- I. Yadroitsev, P. Krakhmalev, I. Yadroitsava (2015) Hierarchical design principles of Selective Laser Melting for high quality metallic objects. Additive Manufacturing 7: 45–56. doi:10.1016/j.addma.2014.12.007.
- C. Körner (2016) Additive manufacturing of metallic components by selective electron beam melting – a review. International Mater. Reviews 61 5: 361-377.