PECULARITIES OF BIOMEDICAL TI-NB ALLOYS, PREPARED BY ELECTRON ARC MELTING AND SELECTIVE LASER MELTING

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ОСОБЕННОСТИ СТРОЕНИЯ БИОМЕДИЦИНСКИХ СПЛАВОВ Ti-Nb, ПОЛУЧЕННЫХ ЭЛЕКТРОДУГОВОЙ ПЛАВКОЙ И СЕЛЕКТИВНЫМ ЛАЗЕРНЫМ СПЛАВЛЕНИЕМ

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Аннотация. *Выявлено, что при электродуговой плавке и селективном лазерном сплавлении в сплаве Ti-Nb имеет место ликвация компонентов. На участках, обогащенных Nb образуется β-фаза, на участках, обедненных Nb – α''-фаза. Для устранения неоднородности фазового и элементного состава рекомендуется повысить содержание Nb в сплаве до 45 мас. %.*

The Ti-Nb alloys are used for the production of bioimplants due to their good mechanical properties and biocompatibility [1]. It was founded that alloys containing 40-45 mas % Nb have the lowest Young's modulus which is important for compatibility of implant and bone [2]. One of the modern methods of implants production is the method of selective laser melting (SLM). It is possible to obtain products with prescribed porosity by SLM method [2]. But high cooling rates during this process cause structural heterogeneity of obtained alloys. This heterogeneity may subsequently cause the rejection of the implant.

The aim of this investigation was to study conditions of the formation of the Ti-Nb alloy in different crystallization conditions.

Ingots produced by electron arc melting were investigated in this paper [3]. The mass of each ingot was 300 g. The structure of the ingot after melting was investigated.

SLM was carried out on "VARISKAF 100MV" installation. The composite powder material of Ti and Nb was applied on VT1-0 substrate. SLM conditions were as follows. Power of laser beam was 105 W, scanning speed of laser beam was 2000 mm/min, the spot diameter was 0.7 mm, scanning step was 0.05 mm and the substrate temperature at the beginning of melting was 200°C. Laser beam scan direction was changed by 90° for each subsequent layer. The specimens consisting of seven layers were investigated.

The investigations were carried out in shared use centers “NANOTECH”, ISPMS SB RAS Tomsk, “MIMAM”, NSTU, Novosibirsk and NR TPU, Tomsk on diffractometer DRON-7 (Burevestnik, Russia), SEM with energy dispersive microanalysis (EDMA) LEO EVO 50 (Zeiss, Germany) and metallographic microscope Carl Zeiss Axio Observer (Zeiss, Germany).

Primary dendritic-cell structure with secondary grain structure is observed on metallographic images of cast alloy (fig. 1a). The size of secondary grains is varied between 80 and 1000 µm [3]. Sizes of structural elements indicate that cooling rate of the alloy during ingot crystallization is about 100 deg/s.

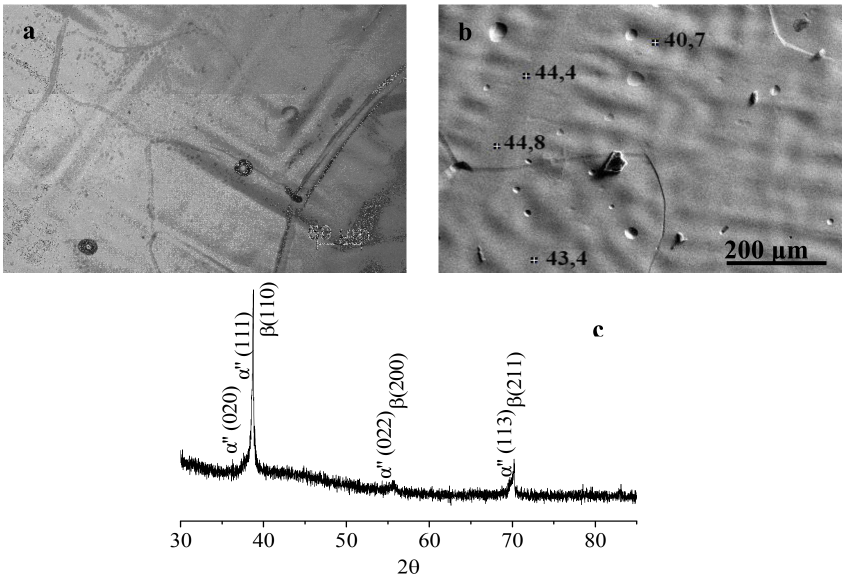

Fig. 1. The image of microstructure (a), concentration of Nb (mas %) in the elements of structure (b) and fragment of X-ray diffraction pattern (c) of the cast specimen

The dendritic structure in the ingot indicates presence of dendritic segregation in the alloy. Concentration of Nb in dendrites is greater than in interdendritic space (fig. 1b).

The main phase in the alloy is β-phase (fig. 1c). Furthermore, the α''-phase peaks can be identified on diffraction patterns. This phase is nonequilibrium and it forms in conditions of quenching from liquid state. Consequently, the process of the ingot formation occurs in nonequilibrium conditions. Only β-phase grains are observed on metallographic image of the ingot (fig. 1a).

The structure of the alloy during SLM is formed in completely different temperature and rate conditions. The high cooling rates about 105 deg/s could ensure the formation of fine grain structure and nonequilibrium phases.

The process of layers stacking of SLM-specimens is accompanied by the formation of macrodeffects such as interlayer boundaries, large drawholes, etc. Each layer has nondendritic grain structure with average grain size about 8 µm (fig. 2a).

Nondendrtitc grain grows in the alloy during the process of crystallization. High cooling rates facilitate this process. It can be concluded that cooling rate of the alloy during SLM is 104 deg/s. The quantitative ratio of min components of the alloy ranges from 36 to 38 mas % Nb (fig. 2b). The Nb concentration is varied between 15 and 42 mas %. Consequently, heterogeneity of components distribution is retained in Ti-Nb alloy.

The reflections from the β- and α''-phase planes are identified on diffraction patterns of investigated specimens (fig. 2c). Exclusion of presence of nonequilibrium α''-phase is possible by long annealing but it may lead to the growth of grain.

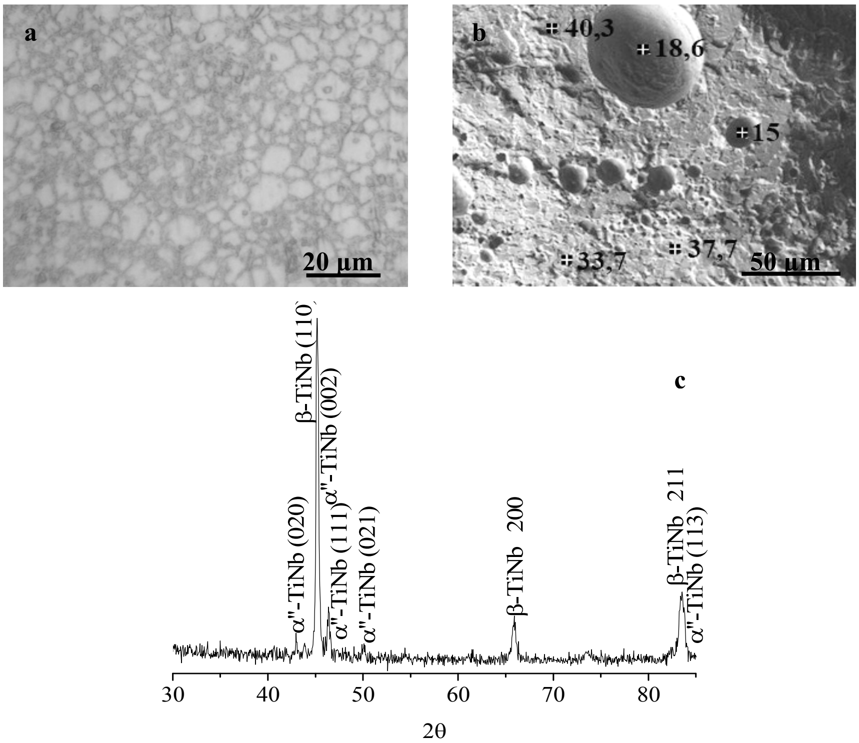

Fig. 2. The image of microstructure (a), concentration of Nb (mas %) in the elements of structure (b) and fragment of X-ray diffraction pattern (c) of the specimen obtained by SLM

Conclusion

1. During crystallization in Ti-Nb alloy with 40 mas % of Nb primary dendritic structure is formed throughout the whole bulk of the ingot. There is dendritic segregation in the alloy. The secondary structure is large polyhedral β-phase grains.
2. The structure consisting of fine grains is formed after SLM. The two-phase composition indicates that the alloy heterogeneity retains at high cooling rates.
3. It is recommended to increase Nb concentration in the alloy up to 45 mas %.

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