SELECTIVE LASER MELTING FOR Nb-BASED POWDER ALLOY

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Abstract

The powder of Nb-25Ti-2Cr-2Al-16Si (at%) was obtained by mechanical alloying and plasma spheroidization from elemental powders. The building was performed by SLM 280HL machine on the titanium substrate. The microstructure was analyzed by MIRA Tescan scanning electronic microscope. The XRD was performed by BRUKER D8. The microstructure consists of Nbss+Nb_3Si eutectic with several areas of coarse dendrites, corresponds to the Nb_{ss}. The microstructure is greatly refined in comparison with casting technologies like VIM.

Keywords: Nb-Si, selective laser melting, additive manufacturing, powder metallurgy

1. INTRODUCTION

Niobium silicide-based alloys have been extensively studied as high-temperature structural materials [1-3]. Nb_5Si_3 has high melting point (2515 °C), low density (7.16 g/cm3) and excellent specific mechanical properties at high temperature [4,5], but Nb_5Si_3 has low fracture toughness at room temperature and poor deformability at high temperature. The Nb has high melting point (2472 °C), excellent fracture toughness and good deformability. According to Nb-Si binary phase diagram, Nb and Nb_5Si_3 coexist in wide range of temperature and silicon content. These features of the phase diagram allow us to fabricate Nb/Nb_5Si_3 in situ composites with desirable mechanical properties and excellent thermo-chemical stability [6-8]. However, Nb-Si based alloys are still limited by their poor room-temperature fracture toughness and insufficient high-temperature oxidation resistance [9-11]. Improvement in mechanical and environmental properties will be achieved by alloying with several elements and the development of advanced processing and production technologies. One of the advanced powder-based production processes are selective laser melting [12-14] and direct energy deposition additive manufacturing technologies [15]. In present work, a selective laser melting of Nb-25Ti-2Cr-2Al-16Si (at%) alloy is investigated.

2. MATERIALS AND METHODS

The powder of chemical composition Nb-25Ti-2Cr-2Al-16Si (at%) obtained by mechanical alloying with subsequent plasma spheroidization was used as a raw material for the SLM process. The powder was sieved into a fraction of 10-63 µm (d_{10}-d_{90}). The selective laser melting was performed on the SLM 280HL machine with following parameters: 375 W laser power, 1000 mm/s scanning speed, 0.1 mm hatch distance and 30 µm layer thickness. The phases were analyzed by XRD Bruker D8 ADVANCE. The microstructure of samples was characterized using SEM Mira3 Tescan in BSE mode.

3. RESULT AND DISCUSSION

The microstructure of the powder used for SLM process is shown in **Figure 1**. It consists of three contrasting phases of black, gray, and white corresponding to Nb_5Si_3, Nb_3Si, and Nb_{ss} respectively. All of the phases are uniformly distributed across the powder particle and size less than 1 µm. However, during the solidification process, phases are growing up to 5 µm at the center of the particle. The synthesis of the powder was studied in previous works [16,17].

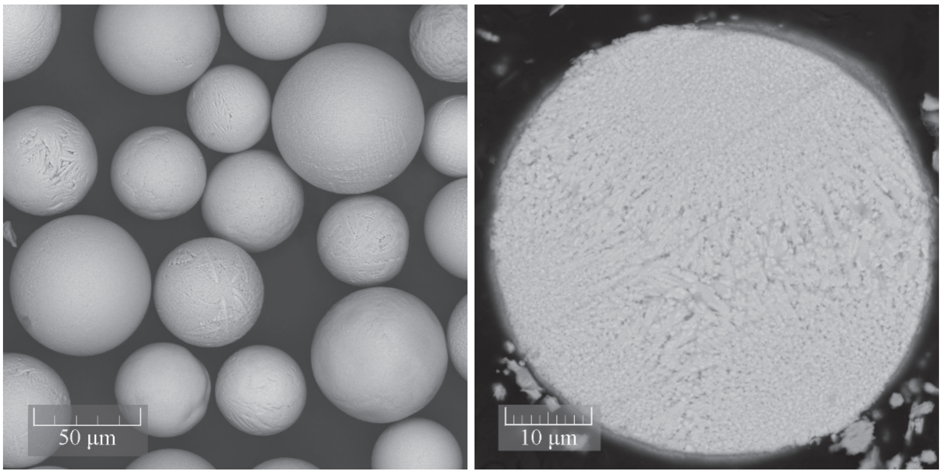

Figure 1 The microstructure of the Nb-25Ti-2Cr-2Al-16Si powder after mechanical alloying and after plasma spheroidization [16]

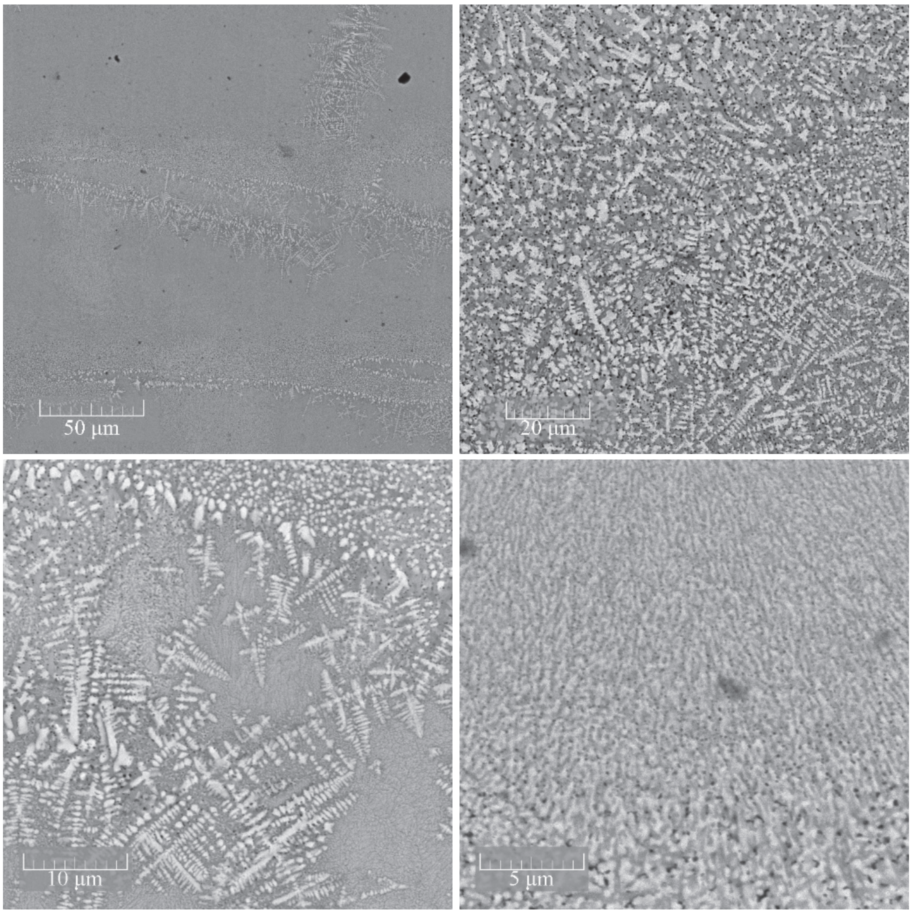

Figure 2 The microstructure of the Nb-25Ti-2Cr-2Al-16Si sample after selective laser melting a longitudinal section

The microstructure of the longitudinal section of the sample after selective laser melting is presented in **Figure 2**. It consists of the fine eutectic and coarse dendrites. According to XRD patterns (**Figure 4**), the bright phase corresponds to Nb_{ss} and eutectic correspond to Nb_{ss}+Nb_3Si. With a higher SEM magnification dispersed black phase also noticed. This phase was not detected by XRD due to its submicron scale. However, it can be determined as Ti in accordance with the chemical composition of the raw powder.

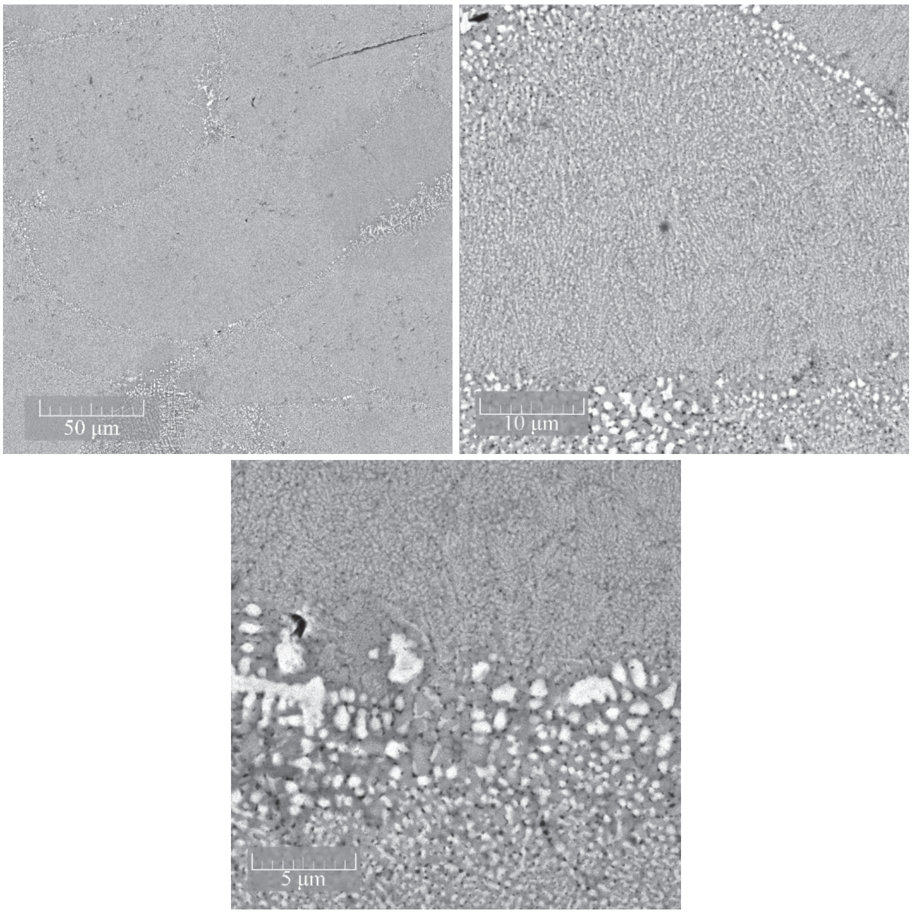

Figure 3 The microstructure of the Nb-25Ti-2Cr-2Al-16Si sample after selective laser melting a cross section

The cross-section (**Figure 3**) is presented by a similar microstructure except for the direction of growth of the Nb solid solution dendrites. According to XRD patterns (**Figure 4**), the bright phase corresponds to Nb_{ss} and eutectic correspond to Nb_{ss}+Nb_3Si. Based on repetitive of the coarse dendritic areas, it can be concluded that coarsening of the microstructure may be caused by remelting by laser during SLM process. For longitudinal section, it corresponds to the hatch distance (0.1 mm) and for cross-section - to the remelting between the layers of 30 µm. Despite the presence of the coarse dendrites, the microstructure is significantly finer and more homogeneous compared to casting technologies [18]. That fact makes selective laser melting the promising production technology of the Nb-based high-temperature alloys.

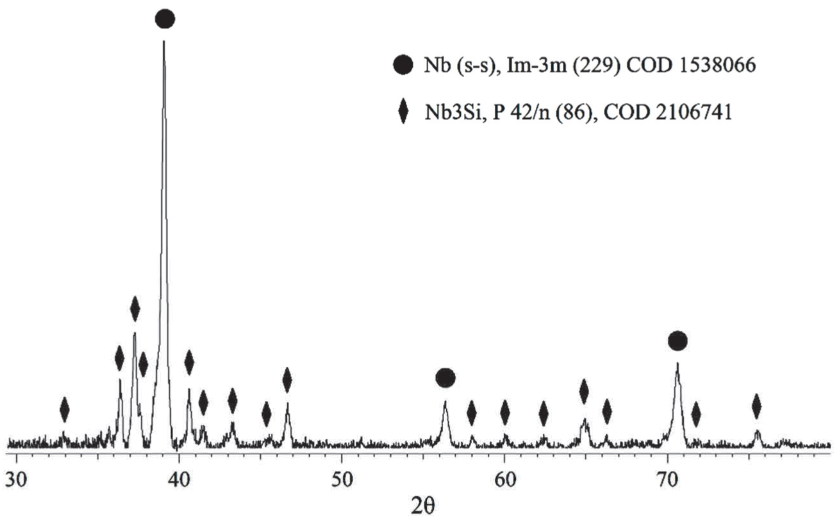

Figure 4 XRD patterns of Nb-25Ti-2Cr-2Al-16Si sample after selective laser melting

According to the XRD patterns, presented in **Figure 4**, the microstructure consists of two phases: Nb and Nb_3Si. An equilibrium phase Nb_5Si_3 was not detected. It can be explained by the rapid quenching of the melted powder layer, forming in SLM process. The diffraction peaks of Ti, Al, and Cr are not detected, due to their high solubility in Nb and forming Nb_{ss}, and Ti also alloying Nb_3Si by replacing Nb atoms with Ti.

4. CONCLUSION

In the present work, the sample of the Nb-based alloy with the chemical composition of Nb-25Ti-2Cr-2Al-16Si (at%) was obtained by selective laser melting from mechanically alloyed and plasma spheroidized powder.

The microstructure of the sample after selective laser melting consist of three fine Nbss+Nb3Si eutectic, the coarse dendrites of the Nb_{ss}, which coarsening in tracks of laser remelting due to the hatch distance or interlayer interactions, and dispersed black submicron phases, that presumably can be identified as Ti. An equilibrium phase Nb_5Si_3 was not detected due to the rapid quenching of the melted powder layer, forming in SLM process.

The microstructure is significantly finer and more homogeneous compared to the casting technologies, which makes selective laser melting the promising production technology of the Nb-based high-temperature alloys.

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