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EFFECT OF ELECTRON BEAM MELTING PROCESSING PARAMETERS ON PROPERTIES OF Ti-42Nb ALLOY PARTS

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Additive Manufacturing (AM) techniques allow producing metal implants with the suitable porosity, size, and complex geometric design. One of the most perspective powder bed AM techniques is Selective Electron Beam Melting (SEBM). Titanium and its alloys are widely used in bone replacement surgery due to their low weight, high strength, reduced elastic modulus and good biocompatibility [1]. However, the elastic modulus of most commonly used titanium alloys is still much higher than that of bone tissues causing a stress-shielding phenomenon, which can lead to implant loosening [2]. Niobium is a β-stabilizer of titanium and its addition reduces the elastic modulus of the alloys [3]. Compared to nickel Nb is a non-toxic biocompatible metal [3]. However, there are no established process settings for SEBM of Ti-Nb alloys, and corresponding parameters leading to adequate quality material should be selected for each material.

In this study several samples were manufactured using a pre-alloyed Ti-42 wt.% Nb powder in ARCAM A2 EBM machine (GE Additive, Mölndal, Sweden) to find a suitable processing parameter window. Processing regimes with raster type scanning, different currents and scanning speeds with the same target layer thickness of 100 μm and surface energy between 2.40 and 5.15 J/mm^2 were used (Tab.1).

Tab. 1. The EBM processing parameters for Ti-42 wt.% Nb alloy (Taniobis GmbH)

Sample Nr	Beam current, mA	Scanning speed, mm/s	Beam track spacing, L_{off}, mm		Beam power, W	Surface energy, E_{area}, J/mm^2
1	3.5	700	0.125		210	2.40
2	4	700	0.100		240	3.43
3	4	800	0.100		240	3.00
4	4	900	0.100		240	2.67
5	4-5	800	0.100		270	3.38
6	5	700	0.100		300	4.29
7	5	900	0.100		300	3.33
8	7.5	700	0.125		450	5.14

Regimes № 1, 4, 5, 6, 7 result in a lack of fusion between some of the consecutive layers, while regimes № 2, 3, 8 yielded samples with good layer-to-layer fusion. The presence of pores with 2-15 μm size is typical for all samples. Optical microphotographs after chemical etching in Kroll's solution at room temperature (1 ml 45 % HF, 3 ml 65 % HNO_3 and 46 ml H_2O) showed grains with 50-150 μm size. The shape of the grains corresponds to the β-phase [4]. Elongated grains of the lath α-phase were not detected.

The XRD patterns of the pre-alloyed Ti-42Nb precursor powder identified only the β-phase peaks (BCC structure, space group $Im\overline{3}m$). However, the XRD analysis of the samples as-manufactured by SEBM reveals that the alloys consist mainly of β-phase and a small amount of metastable α″-phase (orthorhombic structure, space group *Cmcm*). The martensitic α″-phase transformation has been identified in some previous studies of Ti-Nb alloys [4–6]. The α″-phase was most clearly detected in two samples, produced with a scanning speed of 700 mm/s and current of 4 and 7.5 mA. The appearance of the α-phase can be resulting from a slower cooling rate. The low scanning speed together with high surface energy results in a longer time melt-pool stays 'open' and a decreased cooling rate [5].

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