Fabricating NiTi shape memory scaffolds by selective laser melting

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INTRODUCTION: Shape memory alloys (SMAs) like NiTi can change their form as a result of thermal or mechanical stimuli. Due to these properties, FDA-approved NiTi is successfully applied in the field of biomedical engineering [1]. The layer-wise additive manufacturing process of Selective Laser Melting (SLM) enables the build-up of complex three-dimensional geometries, see Fig.1. In this study we investigate the influence of SLM process parameters and following heat treatments on properties of SMA NiTi-structures.

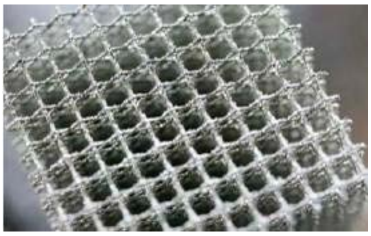

Fig. 1: Open porous NiTi lattice with 200 µm struts produced by SLM.

METHODS: SLM (Realizer 100, SLM Solutions, Lübeck) served for fabrication of complex-shaped NiTi specimens with shape memory properties [2]. Starting material was pre-alloyed NiTi-powder (MEMRY GmbH, Weil am Rhein, Germany). Subsequent to fabrica-tion, heat treatments were carried out at 500 °C and 800 °C, respectively. All processing steps were accomplished under Ar atmosphere. Optical microscopy served for metallographic investigation. After each processing step, the oxygen content was determined by means of inert gas fusion method (Galileo G8, Bruker, Karlsruhe, Germany). Furthermore, X-ray diffraction and differential scanning calorimetry investigations were conducted to examine the present crystallographic phases as well as the related phase transition temperatures.

RESULTS & DISCUSSION: The SLM fabricated NiTi-samples show a highly textured microstructure (see Fig. 2). The crystallites are elongated, whereas their orientation refers to the direction of heat transfer, which is equal to the building direction. In addition, the samples reveal the processing route, as the laser trajectories can clearly be identified as dark welding traces (see Fig. 2). Their perpendicular orientation refers to the scanning strategy of the laser, which hatches the slices alternating in x- and y-direction.

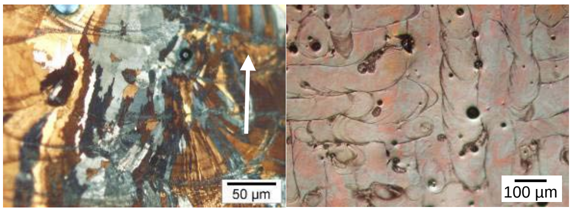

Fig. 2: Optical micrographs of a solid SLM NiTi-part. Left: Microstructure with elongated grains, arrow indicates building direction. Right: Traces of the laser in x-y-plane.

The SLM process leads to an increase of the oxygen content of about 0.025%, as shown in Table 1. Heat treatments at 500 °C don't lead to a further significant change of the oxygen content whereas heat treatments at 800 °C result in a slight increase of the oxygen content.

Table 1. Oxygen content of NiTi specimens after fabrication by SLM and heat treatments at 500 °C and 800 °C, respectively.

	Powder	SLM	500 °C	800 °C
O [%]	0.075	0.102	0.101	0.118
SD_O	0.004	0.019	0.005	0.003

CONCLUSIONS: SLM is a useful tool to fabricate complex-shaped NiTi micro-structures with shape-memory properties. The process can be qualified monitoring chemico-physical properties after the individual process steps. The fabrication process will be further optimized to create medical implants. Furthermore, the adaptation of our porous SMA-microstructures opens perspectives concerning the bio-functionality for the benefit of patients.

REFERENCES: [1] M.Es-Souni et al., Anal Bio-anal Chem, Vol. 381 (2005) 557-567. [2] T.Bormann et al., Proc. of SPIE, Vol. 7804 (2010) 78041.

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