Properties of NiTi-structures fabricated by selective laser melting

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INTRODUCTION: Shape memory alloys (SMA) have exceptional properties as they can change their shape as the result of thermal or mechanical stimuli. Due to their biocompatibility, NiTi-SMAs are successfully used in the field of biomedical engineering.[1] We demonstrate that selective laser melting (SLM) permits producing NiTi structures with the typical material properties of SMAs. Designing and optimizing SMA bone scaffolds, implants with advanced performance will be realized.

METHODS: For the preliminary study, pre-alloyed NiTi-powder (MEMRY GmbH) with a d50 value of 60 µm served for specimen fabrication. Differently designed test objects such as spiral springs were built by means of the SLM Realizer 100 (MTT Technologies) operated with a power of 100 W and a continuous wave Ytterbium fibre laser with a wavelength between 1068 and 1095 nm. The melting process was carried out in a highly pure argon atmosphere. Differential scanning calorimetry (DSC) and energy dispersive X-ray spectroscopy (EDX) were accomplished with both the NiTi-powder and the SLM-structures. DSC measurements were performed between -50 and +150 °C using the DSC 30 (Mettler-Toledo). The SwiftED-TM EDX spectrometer dedicated for the TM-1000 tabletop microscope (Hitachi) provided the chemical composition. The shape memory effect of the SLM structures was verified using the thermo-mechanical system TMA 40 (Mettler-Toledo) measuring the length of a deformed SLM spring as the function of temperature.

RESULTS & DISCUSSION: The NiTi-powder and the SLM-structures do show a phase transition in the related DSC measurements, see figure 1. The austenite peak temperature A_p of the powder corresponds to 19 °C, whereas the SLM-objects exhibit a value of 40 °C. The martensite peak temperature M_p lies at -4 °C for the powder and -13 °C for the SLM-structure. The EDX measurements reveal a loss of Ni up to 2%w/w in the SLM processed samples compared to the powder. As expected from the lower vapour pressure of Ti, the Ni-content of the alloy decreases during processing. The shift of the phase transition temperatures, as summarized above can be referred to this composition change, since the phase transition temperatures strongly depend on the Ni/Ti ratio.[2] TMA-measurements (data not shown) demonstrate the pseudo-plastic behaviour of the SLM materials as the one-way effect could be clearly identified.

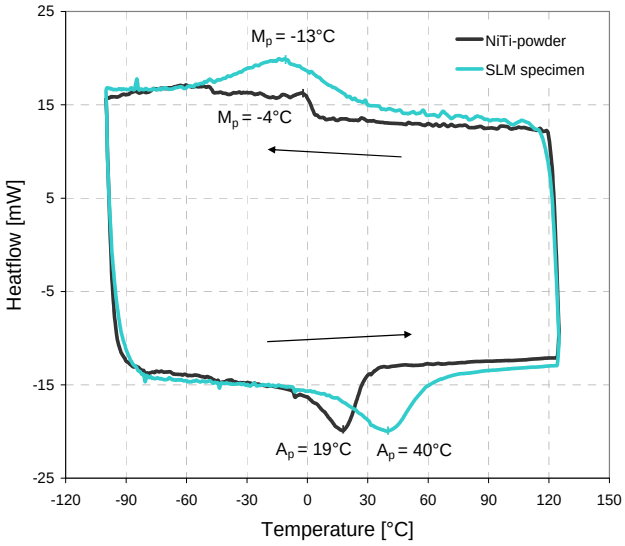

Fig. 1: DSC measurements of NiTi-powder and a selected SLM specimen.

CONCLUSIONS: The preliminary experiments reveal that SLM is an appropriate method for the fabrication of constructs with shape memory phenomena. Optimizing this process, bone scaffolds and implants of complex morphology can be realized. The final aim is the production of SMA-implants for a great variety of applications and for the benefit of patients.

REFERENCES: [1] ASTM International, F 2063 - 05. [2] W. Tang et al., (1999) *Acta Mater* **47**:3457-3468.

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