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Selective laser melting of pure Fe and pure Zn for biodegradable implants

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INTRODUCTION: Laser based additive manufacturing processes have become an enabling technology for the production of customized biomedical implants in the past years. Selective laser melting (SLM) enables obtaining personalised products with complex shapes and controlled density and porosity, which are all advantageous for biomedical implants manufacturing [1]. Concerning metallic implants, titanium alloys and stainless steel have been by far the most widely studied with SLM. Although, the novel biodegradable metals are highly interesting for application requiring customized implants such as the orthopaedic ones, only few works on Mg and alloys are present in literature [2], whereas Fe and Zn have not been studied. In this work, SLM of Fe and Zn is presented. Manufacturability and mechanical properties of these materials were compared to a common bio-implant material AISI 316L.

METHODS: The used prototype SLM system consisted of a multimode 1 kW fibre laser equipped with a scan head generating 213 µm beam diameter at focal point. The powder grain sizes were 31±8µm, 41±19µm and 42±18µm for AISI 316L, Fe and Zn respectively. The powder bed was placed in a gas chamber with Ar flowing at 20Nl/min. Focal position was placed on powder surface. Laser power (P) was varied at two levels: 200 and 300 W, while scan speed (v) was varied between 150-1900 mm/s. The samples with minimum porosity (p) were characterized in terms of density (ρ), Vickers hardness (HV) and compression yield stress (CYS).

RESULTS: Figure 1 reports the optical microscopy images of the deposited materials with the lowest porosity achievable. Table 1 summarizes the processing conditions used with the resulting porosity and density levels. It can be seen that both AISI 316L and pure Fe allow complete melting of the powder and generate low levels of porosity. The porosity generated on Zn remains above 10%, due to its low vaporization point (907 K). As a matter of fact, with 300W laser power the process was unstable, as deposited Zn layers showed porosity levels higher than 20%. On the other hand, the deposited Zn was characterized by foam-like structure with high surface area. The Vickers hardness of AISI 316L and pure Fe was 245±8 and 157±5 respectively (pure Zn was not characterized due to high porosity). The CYS values of the laser melted materials are shown in Figure 2. High CYS was achieved with AISI 316L, whereas the CYS of laser melted Fe and Zn are very similar to the human bone.

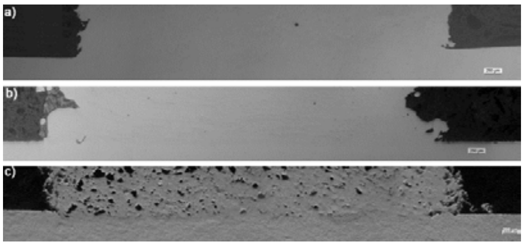

Fig. 1: Cross-sections of laser melted a) AISI 316L, b) pure Fe, and c) pure Zn.

Table 1. SLM conditions for the tested powders.

Material	P [W]	v [mm/s]	p [%]	ρ [g/cm³]
316L	300	150	1.5	7.87
Fe	300	150	1.1	7.82
Zn	200	600	14	6.1

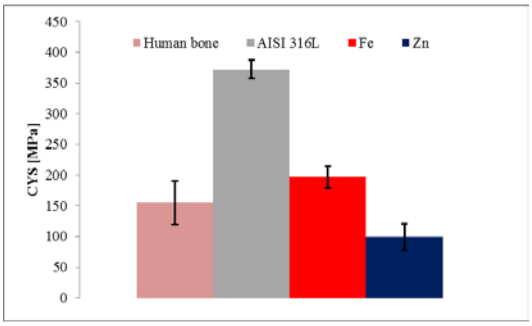

Fig. 2: CYS of the laser melted AISI 316L, pure Fe and Zn with comparison to human bone [3].

DISCUSSION & CONCLUSIONS: Both laser melted Fe and Zn appear to be highly appealing for biomedical applications such as orthopaedic implants, stents and scaffolds. The processability of pure Fe with the SLM is quite close to the widely used AISI 316L. Moreover the intrinsic foam-like porosity obtained in Zn can be also beneficial for cell integration and controlled biodegradation. On the other hand improving the controlled gas atmosphere can be solutions to obtain fully dense Zn.

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