UNDERSTANDING FRACTURE IN LASER ADDITIVE MANUFACTURED BULK METALLIC GLASS THROUGH SMALL-SCALE MECHANICAL MEASUREMENT

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Bulk metallic glasses (BMGs) are amorphous metal alloys formed by fast cooling that display high strength and toughness with good resistance to corrosion and wear. One traditional limitation has been that BMG castings are often limited to <1 cm dimensions due to the high cooling rates needed. The recent development of selective laser melting (SLM) of metallic glasses opens up the possibility of creating large BMG components with complex geometries. However, we have recently shown that additive manufactured BMGs exhibit poor ductility and toughness when compared to their traditionally as-cast (AC) counterparts (Fig. 1 A-C).

Our work investigates how the processing route influences the structure of a Zr-based BMG, and how this is linked to mechanical performance. Evaluation at the micro-scale is critical, as thermal influences on the microstructure from laser-processing and melt-pool solidification exist at these length-scales. Experimental calorimetry results have shown enthalpic relaxation variation between cast Zr-based glasses and those manufactured with SLM-processing, suggesting differences in free volume for different processing routes. The effect on the fracture properties was studied using single edge notched beam bending tests: SLM-processed alloy showed significantly lower fracture toughness when compared with the as-cast alloy, and this was explained by energetic barriers for activating shear transformations in the glass, elucidated in detail using micro-pillar compression testing (Fig. 1 D/E). These results are further related to the glassy laser-processed structure through advanced structural analyses using synchrotron X-ray diffraction and nanoindentation.

While SLM-processing can effectively overcome critical casting thickness constraints in BMGs, significant issues persist regarding structure and consequently damage tolerance. Our results show that micro- and nano-mechanics is an effective tool for understanding material deformation of laser-processed amorphous alloys at critical length scales. Ongoing research in this area looks to harness small-scale testing as a structural optimisation tool for the development of such advanced alloys.

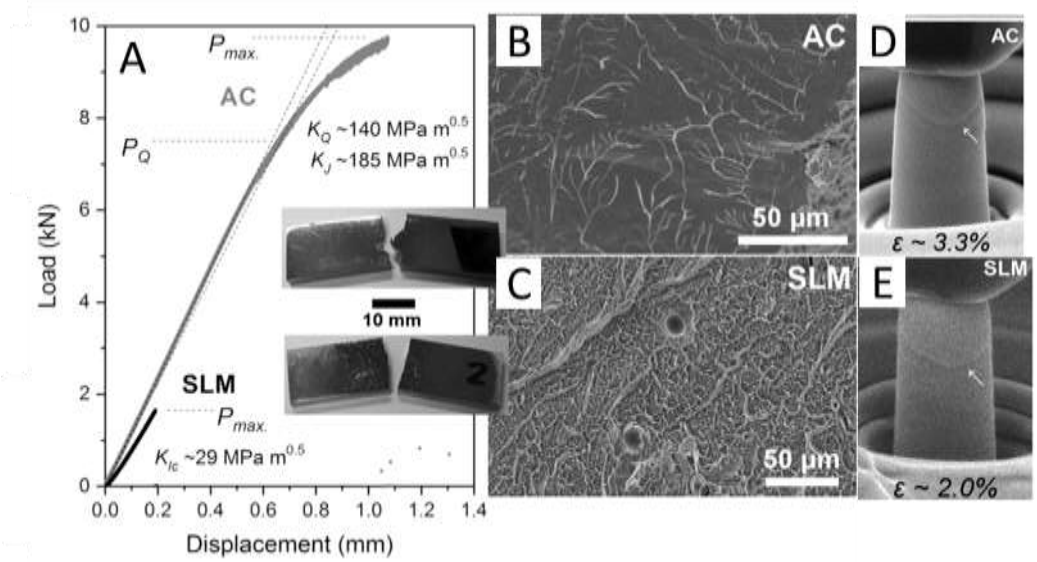

Figure 1 – Macro-scale fracture toughness measurements (A-C) and in situ micro-pillar compression (D/E) of a Zr-based BMG manufactured using casting (AC) and additive manufacturing (SLM).