SEBM microstructure regulation of Fe-Cr-Mo amorphous alloys based on melt pool characterization

Introductory part, Abstract: Fabricating large-scale Fe-based bulk metallic glasses via electron beam additive manufacturing (EBM) is challenged by uncontrolled crystallization. This study investigates the process for $Fe_{55}Cr_{25}Mo_{16}B_2C_2$ using experiments and simulation. Results show substrate segregation affects melt pool homogeneity, and a quantitative correlation exists between parameters and pool geometry. Simulations identify a critical cooling rate (~10^3 K/s) for amorphous formation. Marangoni convection transports Mo/Cr, delaying homogenization and retarding amorphous formation by 15-20%. These findings provide a basis for tailoring EBM parameters.

Electron beam additive manufacturing (EBM) offers a promising route to fabricate large-scale Fe-based bulk metallic glasses (BMGs), yet crystallization control remains a key challenge . This work focuses on the $Fe_{55}Cr_{25}Mo_{16}B_2C_2$ alloy[1][2][3][4].

Fig.1 shows the substrate, prepared by spark plasma sintering, exhibited significant Cr segregation which persisted into the melt pool. Single-track experiments established clear quantitative relationships between process parameters (beam current, scan speed) and melt pool dimensions .

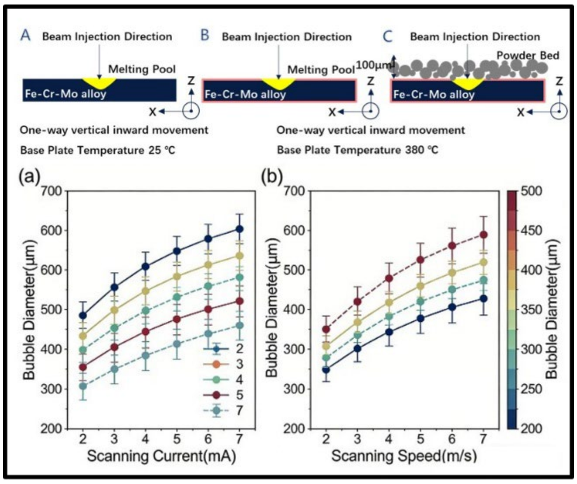

Fig. 1 The Relationship Between Melt Pool Geometry and Parameters

Fig. 2 showed the amorphous microstructural characterization which revealed that a critical cooling rate on the order of 10^3 K/s is required for amorphous phase formation, with the pool center being more favorable. However, intense Marangoni convection within the melt pool preferentially transports Mo and Cr elements towards the pool rear.

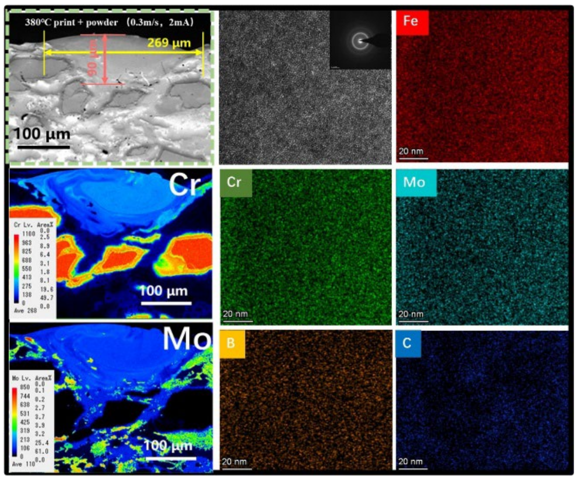

Fig. 2 Characterization of the microstructure and compositional distribution of the melt pool

Consequently, a strategic balance between achieving high cooling rates and minimizing convective solute disturbance is crucial for maximizing the amorphous fraction.

This solute transport delays compositional homogenization and retards amorphous phase formation in the central region by an estimated 15-20% compared to static conditions. The study elucidates the coupled thermal-fluid-solute mechanisms governing crystallization during EBM, providing a quantitative basis for process optimization to achieve high-performance, bulk amorphous components.

References

[1] Inoue A., Takeuchi A., MATER. TRANS. 46, 22-39 (2005)
[2] Wang W. H., Dong C., Shek C. H., Mater. Sci. Eng. R Rep. 44, 194-207 (2004)
[3] Galati M., Lanzetta M., Addit. Manuf. 41, 198324 (2021)
[4] Galati M., Iuliano L. , Addit. Manuf. 23, 123889 (2018)

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