Experimental study on the effect of magnetic field on the metal melt structure

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The formation of ordered structures within the melt can act as nucleation sites, thereby altering the nucleation pathway [1]. The magnetic fields, known to influence structure-sensitive properties of melts such as electrical resistivity [2], magnetic susceptibility [3], and diffusion coefficient [4, 5], could potentially modify the melt microstructure. However, direct experimental evidence supporting this hypothesis is currently lacking. Therefore, this study investigated the atomic-scale structural evolution of liquid zinc (Zn) and aluminum (Al) under the influence of a 0.3/0.4 T static magnetic field using in situ high-energy X-ray diffraction. Our results reveal distinct responses to the magnetic field: the first coordination shell of liquid Zn expands, while that of Al contracts, indicating that the magnetic field differentially affects atomic aggregation in these metals, which further influences the solid-liquid interfacial energy (γ) during the subsequent nucleation process. Specifically, the magnetic field increases γ in Zn, hindering nucleation, while decreasing γ in Al, thereby promoting nucleation. This contrasting behavior arises from the distinct magnetic properties of the two metals and their corresponding responses to the magnetic field, consistent with the magnetic dipole theory. By elucidating the atomic-scale mechanisms through which magnetic fields influence nucleation, this study provides a foundation for tailoring solidification microstructures through the controlled application of magnetic fields.

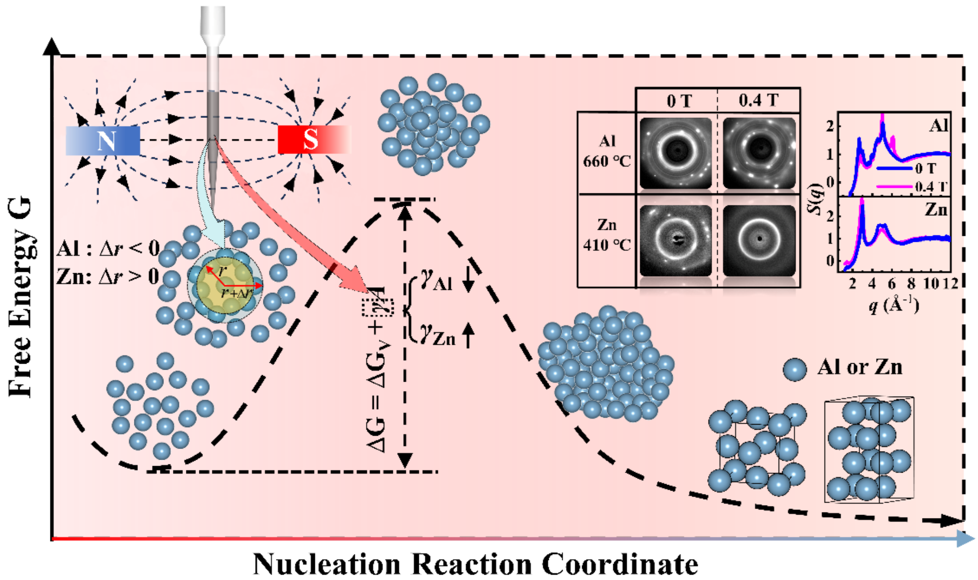

Fig.1 The schematic of the impact of magnetic field on the melt structure

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