

The influence of magnetic field on the heterogeneous nucleation behaviour of metals

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Nucleation plays important role in the solidification process of metals and largely determines the microstructure of metal solidification. As a non - contact physical field, the magnetic field has become one of the key technologies for regulating the preparation of metal materials. Research results show that the electromagnetic field can significantly affect the metal solidification process, including nucleation and grain growth. Based on the classical solidification theory, the melt structure and the solid - liquid interfacial energy are the key factors determining grain formation, and they significantly influence the thermodynamics and kinetics of metal nucleation and grain growth. Based on this, this paper carried out investigation from two aspects: the influence of the magnetic field on the metal melt structure and the solid - liquid interfacial energy. First, synchrotron radiation X - ray diffraction is used to study the structural transformation of the metal melt under the electromagnetic field. It is found that the electromagnetic field can change the short - range order structure (SRO) of the metal melt, resulting in a shortening of the average bond length, a decrease in the coordination number, and a decline in the local order degree of the SRO. Furthermore, by combining the machine - learning force field and the reinforcement - learning - weighted reverse Monte Carlo method, the three - dimensional atomic structures of the eutectic Ga85In15 liquid metal in a 0 T and a 0.2 T static magnetic field environment are reconstructed. The Voronoi geometry and the local bond - orientation order method is used to analyze the characteristic changes of the local short - range order (SRO) clusters in the sample with and without a magnetic field. The results of the cluster geometric configuration distribution show that the 0.2 T static magnetic field does not induce the formation of a new geometric structure of the SRO clusters but promotes the rearrangement of the configurations and tends to form low - coordination SRO clusters. In addition, the solid - liquid interfacial energy and its anisotropy under the electromagnetic field are measured through experiments, and the variation laws of the solid - liquid interfacial energy and its anisotropy of metal solidification under the magnetic field are explored. On this basis, a magnetic - coupled phase - field crystal model is developed to reveal the physical mechanism by which the electromagnetic field affects the solid - liquid interfacial energy and its anisotropy at the atomic scale.