IOWA STATE UNIVERSITY
Department of Mechanical Engineering

Rapid Solidification of Undercooled Melts under Static Magnetic Fields

Jianrong Gao

Key Laboratory of Electromagnetic Processing of Materials (Ministry of Education)

Northeastern University, Shenyang, China

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Abstract

Rapid solidification has been increasingly used in modern metallurgy since its invention by Duwez in 1960's [1]. For example, nanocrystalline material of Fe-based soft magnetic alloys is now used for fabrication of thin tapes as magnetic cores in advanced electronic devices. In recent years, rapid solidification has attracted dual attention because of booming of the additive manufacturing technology for metals. On one hand, rapid solidification is often used for production of submillimeter-sized metal powers required in additive manufacturing. On the other hand, rapid solidification is involved in layering of additively manufactured products of metals owing to high cooling rates of millimeter-sized melt pools through rapid heat extraction to substrate material of alien or the same species. In this process, strong Marangoni convection often occurs on the surface of the melt pools. Thus, it is of great interest to understand the dynamics of the rapid solidification process with convection.

In fundamental studies, rapid solidification can be achieved by high undercooling of a bulk liquid at much lower cooling rates than those used in rapid quenching. Thus, numerous studies have been carried out using this alternative technique for understanding of kinetics and pattern formation in rapid solidification. Dendrites are the most popular growth morphology in rapid solidification of undercooled melts of pure substances and solid solutions. Although effects of melt convection on the kinetics and morphology of equiaxed dendrites were observed through many experiments, they were not well predicted by any theories until recently. In this work, I will give a short introduction to a recent theory proposed by Alexandrov and Galenko [2] and exemplify its excellent capability of predicting dendritic tip kinetics of succinonitrille under terrestrial and low gravity conditions [3]. Then, I will show measurements of dendritic growth velocities of glass-fluxed melts of pure Fe and Ni in the presence of static magnetic fields. In those measurements, melt convection is excited by the high magnetic fields due to Lorentz forces acting on thermoelectric currents from the dendritic tips and arms. This convection can alter heat transport in the undercooled melts and therefore the dendritic tip growth kinetics. In the last part of this talk, I will show a modeling of the magnetic field-induced melt convection by fitting the theory of the dendritic growth to the measured data of pure Ni and Fe. I will conclude my talk by commenting on further development of the theory of dendritic growth with convection and potential applications of static magnetic fields in additive manufacturing.

Bio

1996 Ph.D., Materials Science, Xi'an Jiaotong University, China 1991 B.Eng., Materials Science, Xi'an Jiaotong University, China. Research Interests: 1) Undercooling and solidification in high magnetic fields 2) Magnetically driven phase transitions in solids 3) Fundamentals of additive manufacturing of metals Professional Experience: 2003 – present Professor of Materials Science Key Laboratory of Electromagnetic Processing of Materials (MoE), Northeastern University, Shenyang, China 2001 – 2003 Long-Term Cooperation Alexander von Humboldt Research Fellow Institute of Space Simulation (currently Institute of Materials Physics in Space), German Aerospace Center (DLR), Germany 1999 – 2001 Alexander von Humboldt Research Fellow Institute of Space Simulation (currently Institute of Materials Physics in Space), German Aerospace Center (DLR), Germany 1998 – 1999 Associate Professor Deparment of Applied Physics, Northweastern University, Xi'an, China 1996 – 1998 Postdoc Research Fellow Deparment of Applied Physics, Northweastern University, Xi'an, China

This seminar counts towards the ME 600 seminar requirement for Mechanical Engineering graduate students.

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