Ultrasonic Processing of Materials

Benefits

Development of core principles and quantitative bases for nucleation, growth, and fragmentation processes during degassing and alloy solidification in an acoustic field. Development of tools for production of novel and fine-grained alloy microstructures.

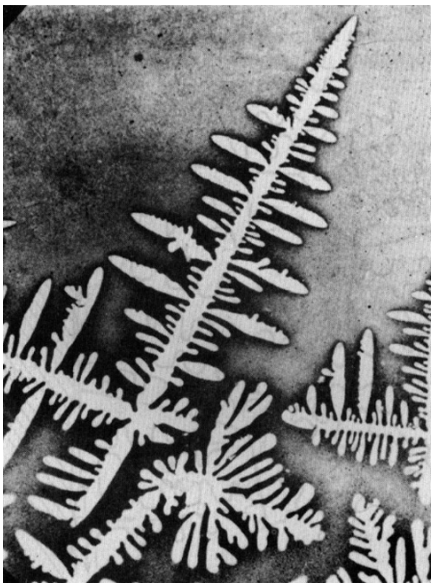
Applications

Implementation opportunities exist in a wide range of materials and processes:

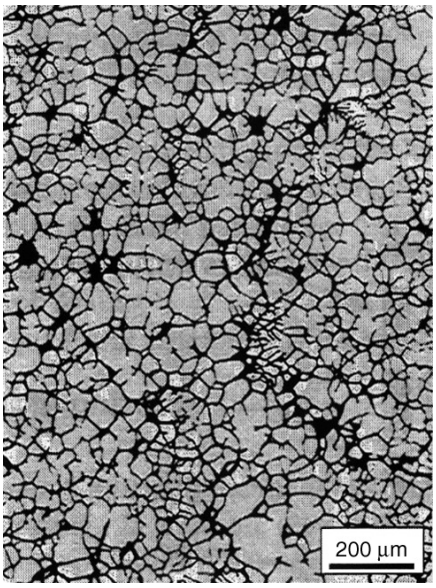
- **Aluminum:** Direct chill casting for the aluminum industry.
- **High-Temperature Alloy:** Vacuum arc remelting for the high-temperature alloy industry.
- **Metalcasting:** Degassing and grain refinement for the metalcasting industry.
- **Steel:** Continuous casting for the steel industry.

Ultrasonics will enhance degassing during casting and grain refinement during solidification for optimized microstructures

Ultrasonic effects on the microstructure of alloys include a reduction in the grain size, control of columnar structure, formation of equiaxed grains, variation in the distribution and refinement of phases, improvement of material homogeneity, segregation control, and the uniform distribution of second phases and inclusions. Although many studies of the use of ultrasonic energy during solidification have been carried out in the laboratory, there is limited industrial-scale application. In addition, there have been no fundamental studies of the effects of ultrasonic vibration on the nucleation and growth of grains during solidification. This project will result in tools for producing novel and fine-grained alloy microstructures. It is expected that the results of the work will impact a wide range of alloy processing including direct chill (DC) casting, continuous casting, vacuum arc remelting, and foundry processing in the areas of degassing, grain refinement, and semi-solid metal casting (SSM).



Typical dendritic microstructure that forms early in solidification in the absence of grain refinement, showing 50-micron arm spacing.



Typical improved solidified structure that occurs after grain refinement.

Project Description

Goal: The goals of the project are to evaluate the core principles, establish a quantitative basis for the ultrasonic processing of materials, and to demonstrate key applications in the areas of (1) grain refinement of alloys during solidification, and (2) degassing of alloy melts.

Issues: Presently, many casting products have porosity and coarse grain size. Ultrasonic processing has been shown to reduce porosity and refine microstructures. Although many studies on the use of ultrasonic energy during solidification have been carried out in the laboratory, there has been limited industrial-scale application. In addition, there have been no fundamental studies of the effects of ultrasonic vibration on the nucleation and growth of grains during solidification.

Approach: This study will focus on two classes of materials, aluminum alloys and specialty steels, and will demonstrate the application of ultrasonic processing during ingot (and continuous) casting, foundry shape casting, and vacuum arc remelting. This investigation proposes to study the effects of acoustic energy of varying phonon energy and frequency introduced during the melting and solidification process. Acoustic frequencies from dc to 100 MHz, and continuous acoustic input power of up to 100 watts will be used. Variables will be input acoustic power, input acoustic frequency, and cooling rate.

Potential payoff: The results will provide core principles and will establish quantitative bases for nucleation, growth, and fragmentation processes during degassing and alloy solidification in an acoustic field, and will provide tools for producing novel and fine-grained alloy microstructures. It is expected that the results of the work will impact a wide range of alloy processing, including DC casting, continuous casting, vacuum arc remelting, and foundry processing in the areas of degassing, grain refinement, SSM, and the production of new microstructures.

Progress and Milestones

- Build apparatus for ultrasonic processing.
- Demonstrate grain refinement of aluminum alloys.
- Demonstrate degassing of aluminum alloys using ultrasonic energy.
- Demonstrate grain refinement of 4340 steel.
- Develop procedures for industrial applications of ultrasonic processing.

Primary

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Project Partners

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