CAPE SIMULATIONS
6 Huron Drive
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Simulators

We develop a wide variety of comprehensive simulation tools. Our task-specific simulators integrate all of the factors that control the performance of the system into a user-friendly environment:

- Heat and Mass Transfer
- Fluid Flow
- Chemical Reactions
- Elastic and Plastic Deformations
- Electromagnetic Couplings
- Property-Processing Relationships

Our Simulators are used in hardware design, process optimization, and failure analysis. Each simulator is tailor-made to the client's specific configuration and materials application. Yet, it allows the user to change the system geometry as well as the operating conditions.

Below are three examples of our Simulators.

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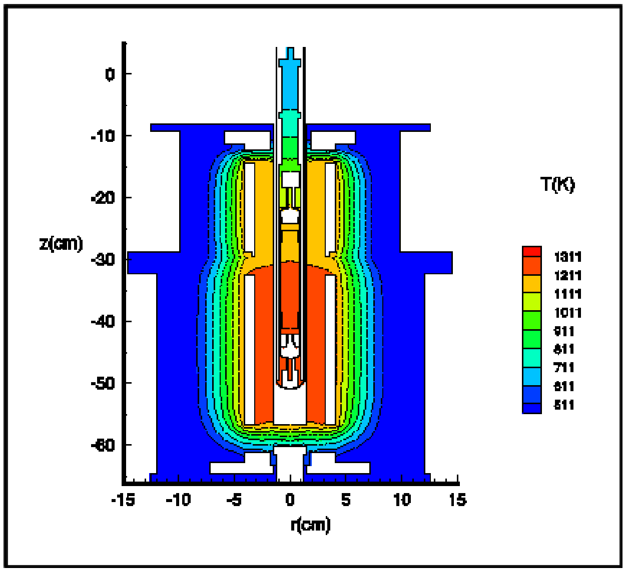
NASA Crystal Growth Furnace



The CGF simulator models melt growth of elemental and compound semiconductors in the NASA Crystal Growth Furnace deployed on board the Shuttle. It is based on detailed geometric representation of the furnace and experiment-specific cartridges and ampoules. The simulator tracks the solidification process as the furnace is translated relative to the cartridge. It provides highly accurate information needed for optimization of the experiments: influence of furnace parameters and ampoule geometry on the temperature field in the charge, shape of growth interface, convection intensity, and mass transfer and segregation in the melt. These calculations can be made for time-dependant and spatially varying gravity vector. The simulator predictions have been shown to be in excellent agreement with experimental results.

Features:

- Simulation of Entire Growth Run From Seeding to Termination and Cool-Down
- Detailed and Complete Geometry of Furnace, Cartridge, and Ampoule
- Radiation Between all Interacting Surfaces including Semi-Transparent Media
- Software Emulation of T/C Control of Furnace Heaters
- Convection in the Melt with:
- Thermo-Solutal Buoyancy Forces
- Magnetic Damping
- Magnetic Stirring
- Randomly Oriented Gravity Vector & Time-Dependant Gravity Field
- Mass Transfer and Segregation in the Melt
- Calculation of Instantaneous Growth Rate by Moving Boundary Simulations
- Thermo-Elastic and Spalling Stresses in the Crystal
- Electric Interface Demarcation: Joule Heating and Peltier Effects
- Residual Stresses in the Crystal

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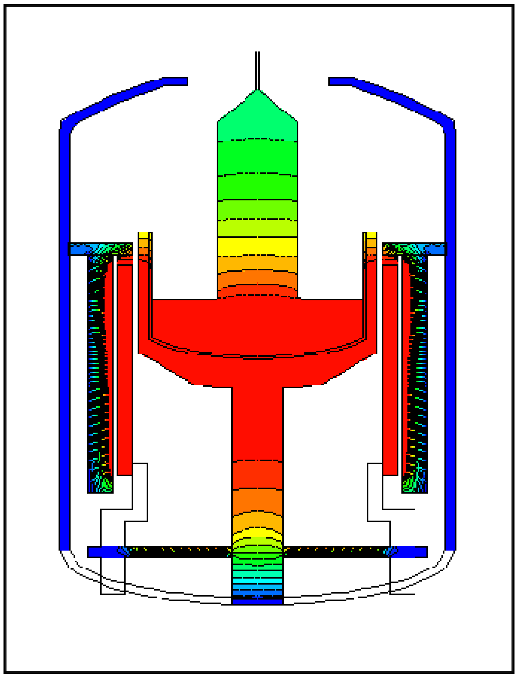
Czochralski Growth of Silicon



The Czochralski simulator models industrial-scale furnaces used for growth of large diameter Silicon, as well as other semiconductors and oxides. The model includes detailed geometry of the entire system, and captures all dominant thermo-fluid transport mechanisms, as well as radiative interactions in the growth system. It provides information on yield- and quality-critical parameters such as temperature and thermal strain fields in the crystal, shape of growth interface, and convection patterns in the melt.

The Czochralski simulator is used for design of large volume production furnaces, as well as exploration of design modifications in existing systems to control, for example, circulation pattern of SiO during crystal growth.

Features:

- Simulation of Entire Growth Run From Seeding to Cool-Down
- High-Fidelity Representation of Furnace Geometry
- Electro-static Modeling of Power Distribution in the Heater
- Convection in the Gas Phase
- Convection in the Melt: Buoyancy- and Rotation-Induced
- Magnetic Damping of Convection in the Melt
- Diffuse Gray Radiation Between all Interacting Surfaces
- Thermo-Elastic Stresses in the Crystal
- Time Accurate Information on Temperature and Stress Fields for Control of Various
- Defect Formation Mechanisms
- Resolved Shear Stresses and Identification of Active Slip Systems
- Dislocation Multiplication Rates and Density at Various Stages of Growth
- Residual Stresses in the Crystal
- Magnetic Stirring

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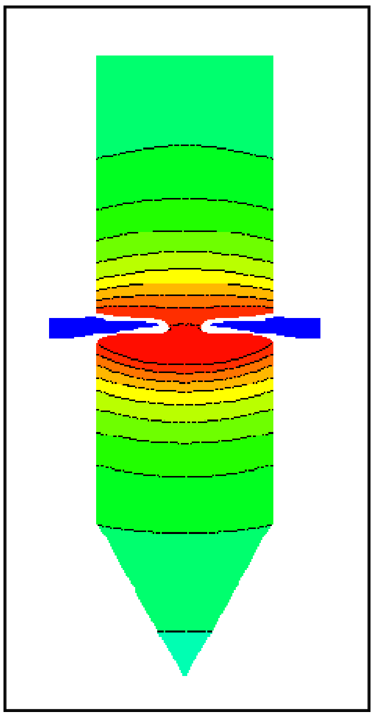
Float Zone Growth of Silicon



This simulator models the growth of Silicon by the Float-Zone technique. The Float-Zone simulator captures all phenomena controlling the growth process: Electro-magnetic heat input, Electro-magnetic free surface pressure field, Electro-magnetic stirring of the melt, coupled radiation/conduction/convection heat transfer in the charge, gas phase convection, and dopant mass transfer in the gas and in the melt. All of these features are integrated into one monolithic simulation tool. The Float-Zone simulator is based on a hybrid of finite-element and boundary-element techniques: the Electro-magnetic calculations are performed by the boundary-element methods, with results inputted directly into the finite-element model of momentum, heat, and mass transfer in the system. The Float-Zone simulator can be used to improve the quality and yield of growth process through optimization, for example, of the shape and location of the induction coil, or of gas-phase doping techniques.

Features:

- Simulation of Entire Growth Run From Seeding to Cool-Down
- High-Fidelity Representation of Furnace Geometry
- Electro-Magnetic Heating of the Charge
- Electro-Magnetic Pressure and Force Fields
- Calculation of Melt/Gas Free Surface
- Convection in the Gas Phase
- Convection in the Melt:
  - Buoyancy, Electro-Magnetic, and Surface Tension Forces; Rotation of Feed and Crystal
- Gas-Phase Doping
- Mass Transfer in the Gas and Melt
- Thermo-Elastic Stresses in the Crystal
- Time Accurate Information on Temperature and Stress Fields for Control of Various
- Defect Formation Mechanisms

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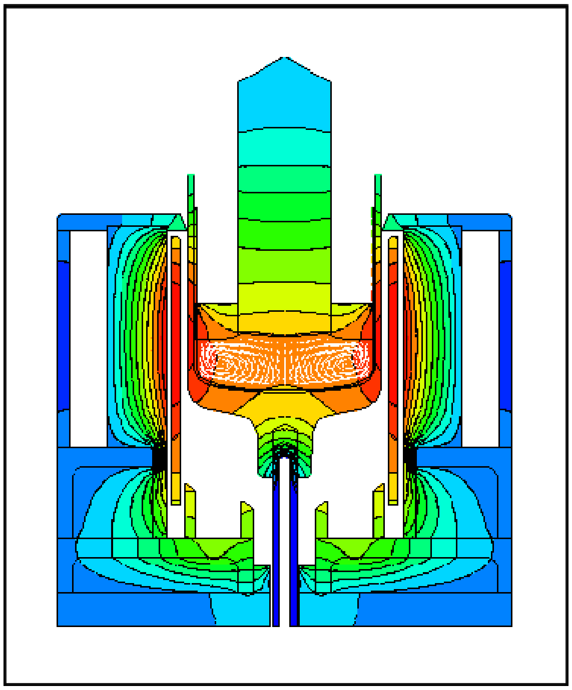
Czochralski Growth of Silicon



The simulator for the Liquid Encapsulated Czochralski (LEC) system has been developed to model industrial scale growth of GaAs and InP. It is based on pioneering work done at MIT, and can be adapted to geometric details of all commercial and custom furnaces. The simulation results have been extensively validated by experimental measurements.

The LEC simulator is used as a design and analysis tool to improve yield in ongoing operations and to design new growth hardware for scale up of boule diameter and length. The simulator reliably predicts the shape of the crystal-melt interface, the temperature distribution in the crystal, and the density of stress-induced dislocations in the crystal.

Features:

simulation of Entire Growth Run From Seeding to Cool-Down
High-Fidelity Representation of Furnace Geometry
Electro-Static Modeling of Power Distribution in the Heater
Convection in the Gas Phase
Convection in the Melt: Buoyancy- and Rotation-Induced
Magnetic Damping of Convection in the Melt
Diffuse Gray Radiation Between all Interacting Surfaces
Radiation Through the Semi-Transparent Encapsulant
Thermo-Elastic Stresses in the Crystal
Resolved Shear Stresses and Identification of Active Slip Systems
Dislocation Multiplication Rates and Density at Various Stages of Growth
Residual Stresses in the CrystAL