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MODELING AND NUMERICAL SIMULATION OF SILICON DIRECTIONAL SOLIDIFICATION

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Abstract:

Multi-crystalline silicon technology is set to dominate PV modules in 2014, with 62% of market part [1]. Directional solidification is a preferred technique in solidifying silicon from the melt [2]. After melting the initial feedstock placed in a crucible, heat is extracted from the bottom in order to initiate the crystallization of liquid silicon. Thus, the L-S interface moves upwards. By carefully adjusting the position of the bottom insulation in the furnace and varying the heater power, the growth rate is controlled so as to favor the solidification of a highly oriented crystal. Due to complexity of the mechanisms involved, numerical simulation becomes an important tool to assist experiments to improve the process [3-7].

The present study focuses on the determination of the velocity field, temperature distribution and interface shape in the central part of the furnace, which includes the crucible containing silicon and graphite heaters. Solidification of the Silicon crystal from the melt is modeled using a definite temperature of fusion, implying that the solid and liquid phases are separated by a sharp interface. During the growth, the melt phase is in the top, thus minimizing the negative effects of convection. Compared to the high cost experimental runs, numerical simulation is definitely an effective tool to accurately predict and optimize the heat transfer in the HEM furnace, in order to improve the crystal quality. An open and closed heat insulation system with a heat exchanger was used to improve the solidification DS process. It was beneficial because of its small heat loss, short cycle time and efficient oriented solidification [5].

A detailed understanding of the process is important to produce high quality multi-crystalline Si wafers. DS process for Si growth is a highly nonlinear and coupled problem. Therefore, global modeling is required.

One of the most important challenges faced during the optimization of the process is the control of the radial thermal instabilities and consequently the buoyancy driven flows in the melt. These phenomena are related to heat and mass transfer during the

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solidification process and are important for controlling both the solid/liquid interface shape and the impurities distribution in the ingot.

In this paper, we present an axis symmetric model of the temperature distribution in the growth furnace and its numerical implementation. Evolution of thermal field, melt flow, and solid-liquid interface shape were predicted during the crystal growth process.

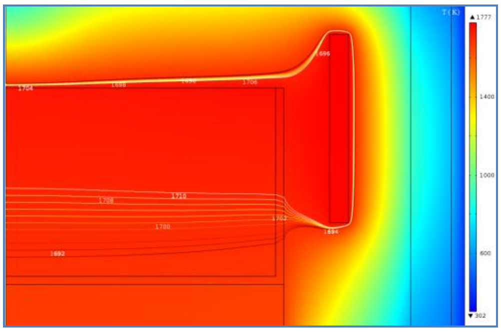

FIG. 1: Temperature distribution in the DS furnace

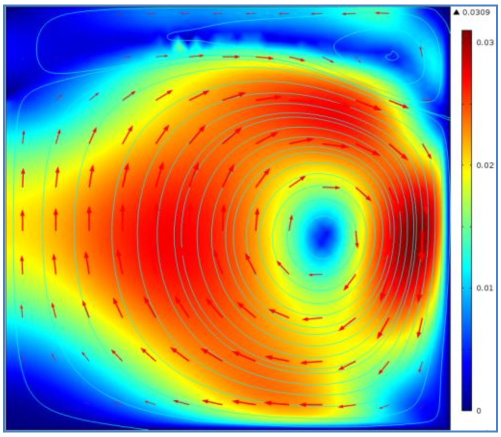

FIG. 2: Distribution of velocity in the melt (half- right hand side)

Keywords: Multi-crystalline silicon, Directional solidification, Modeling

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