Numerical Study Of The Free Surface In Silicon Melting By Cold Crucible Technique

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Abstract

Currently in the semiconductor industry more than 80% of silicon crystal are grown by the Czochralski (Cz) method. In this method, fused silica (SiO_2) crucibles and graphite heaters are used inside furnaces. The surface of the crucibles, which are in contact with the molten silicon, is gradually dissolved into the melt [1]. This reaction occurs during all the crystal growth process contributes to the presence of oxygen in silicon crystal and has a lot of consequence in the crystal quality (OSF, dislocation precipitation of impurities…).
In the eighties, wenkus & Menashi [2] and Ciszek [3] used a cold crucible in order to decrease the oxygen contamination level. They have shown that it was possible to get a small single crystal (2.5 cm in diameter) with a very low oxygen contamination. They concluded also that one of the major problems, as yet unresolved in the use of the cold crucible for the growth of single crystals, is related to the stabilization and precise control of the melt flow and the dome.

In this study, we present a concept of Cold Crucible for Czochralski technique (CZ). The fluid flow in the melt is due to many forces like: electromagnetic Lorenz forces, the viscous force, the force at the free surface by the argon gas flow, the thermo-capillary force and the buoyancy force driven by the temperature distribution. Therefore, the contribution of these forces on the free surface creates a resulting dome-shaped surface without talking into account the growth phenomena in a first state. So, we propose to model the shape of the free surface in the cold crucible.
Our numerical study is done with the COMSOL multiphysics coupling electromagnetics, laminar flow, heat transfer, ALE moving mesh. One of the advantages of the moving mesh which follows the free surface. We present a comparison of the 2D axisymmetric an 3D models

References:
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[2] J.F. Wenckus, W.P. Menashi: Growth of High Purity Oxygen-Free Silicon by Cold Crucible Techniques, Report of the US Air Force, RADC-TR-82-171 (1980).

[3] T.F. Ciszek, Growth and Properties of (100) and (111) dislocation free silicon crystals from a cold crucible, Journal of Crystal Growth 70 (1984), 324-329.

Figures used in the abstract

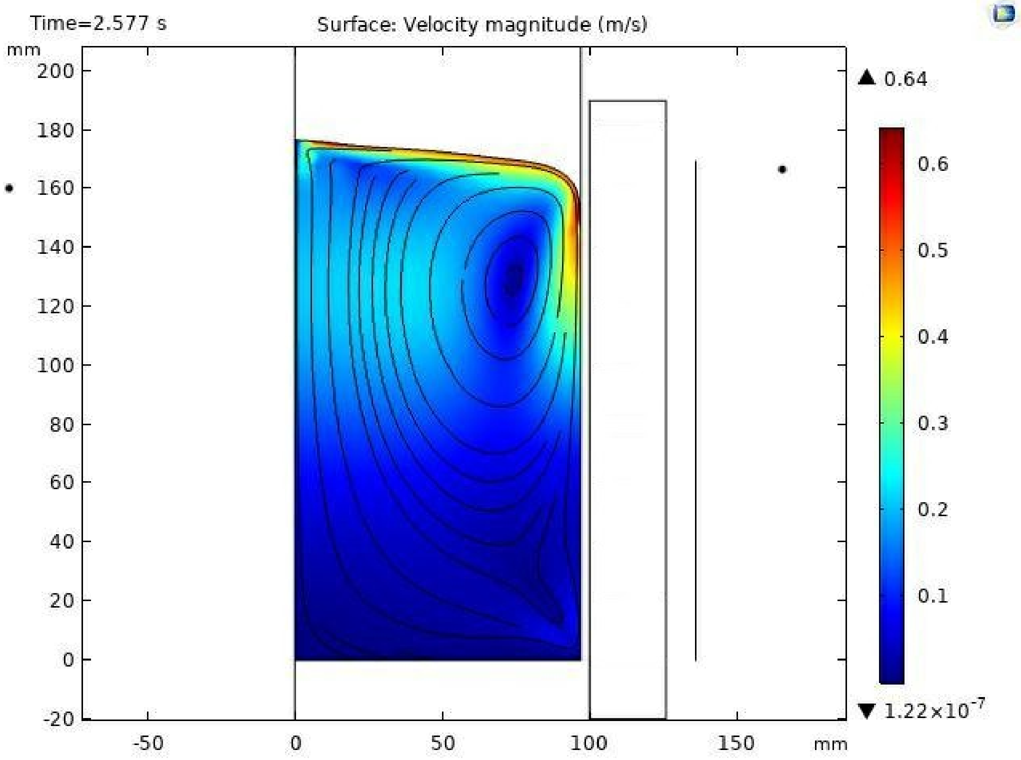

Figure 1

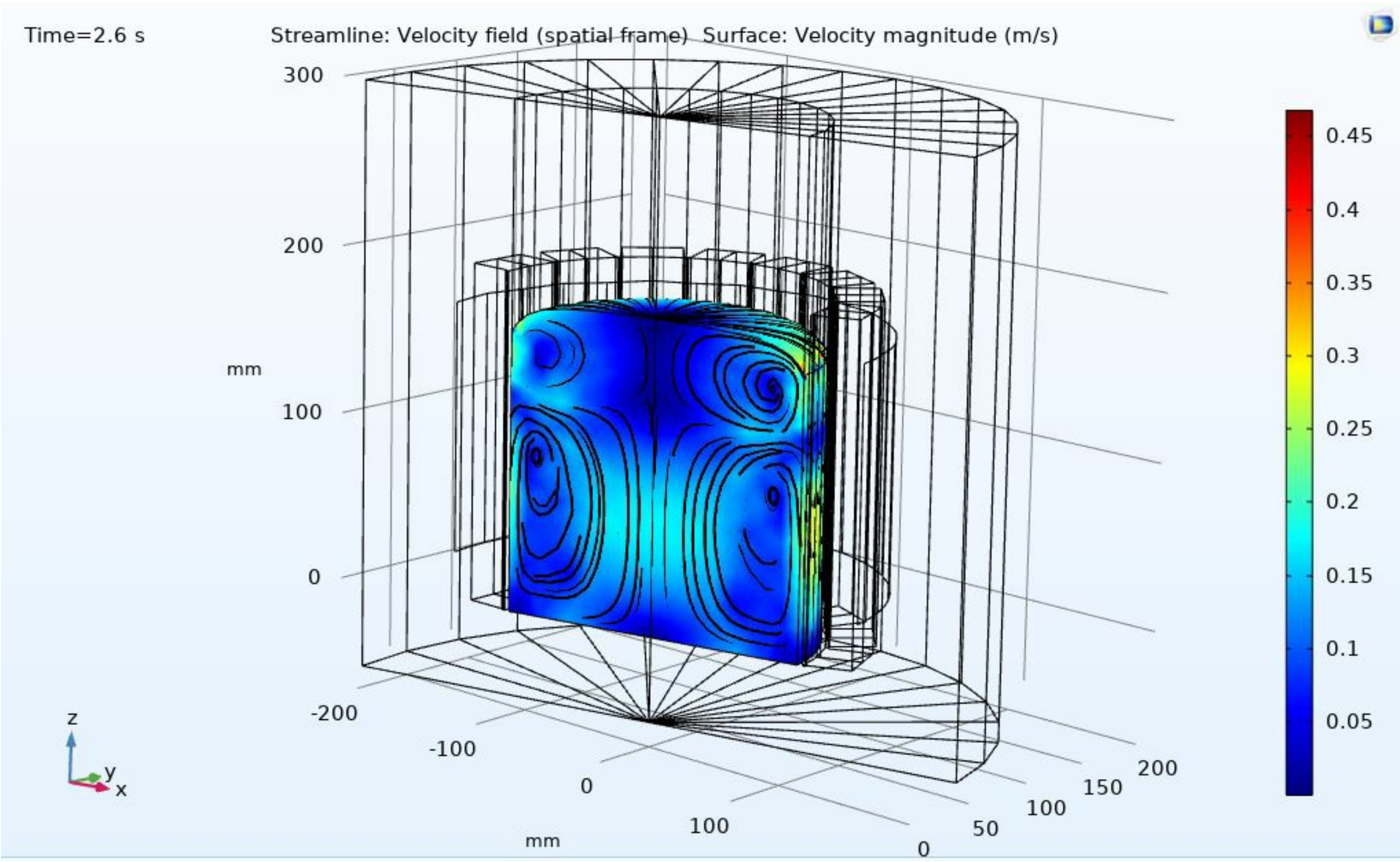

Figure 2