Silicon Melting in Cold Crucible Heated with Electron Beam; Modelling Using OpenFOAM

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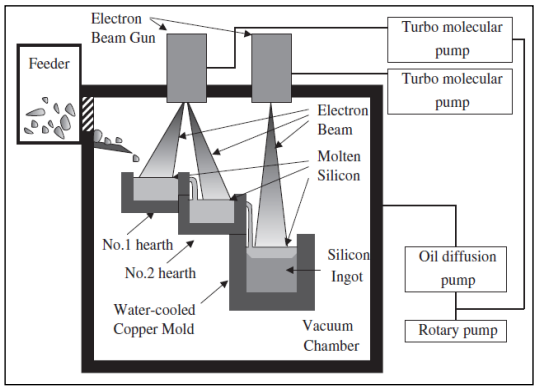
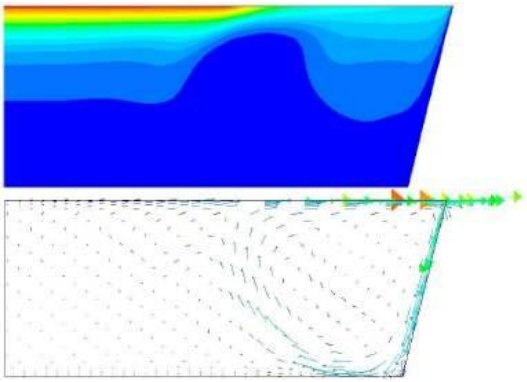
Because of the photovoltaic power industry's needs, intensive research is carried out nowadays for the development of economical mass production methods for manufacturing the solar-grade silicon (SOG-Si) from metallurgical-grade silicon (MG-Si).

One of such methods is the melting and purifying of MG-Si in a water-cooled copper crucible by using the electron beam technology [1]. Polycrystalline silicon in a crucible is melted by an electron beam which is directed vertically downwards to the free surface of silicon. High overheating temperatures (several hundreds of degrees) ensure effective evaporation of some impurities. In this way silicon could be purified relatively cheaply and in large quantities. Because of extremely high temperature gradients in the silicon, the process must be controlled with a great precision. Therefore it is important to develop adequate mathematical models which describe melt motion, temperature field in the molten silicon and solid silicon layers at the crucible wall.

In the present work, several axisymmetric mathematical models are proposed for the modelling of the considered system. The solid silicon layers at the crucible wall are analyzed with *FEMM* package; the turbulent melt flow is modeled using *ANSYS FLUENT*. The melt flow was also modeled with solver *buoyantBoussinesqSimpleFoam* from the open source library *OpenFOAM 2.0.1*., and SST k-omega turbulence model were used. Generally, the *OpenFOAM* solvers are based on the 3D modelling of the fluid flow. Therefore for axisymmetric calculations, a 3D grid is generated with one cell layer in the azimuthal direction, and the *wedge* boundary condition is used.

In the figure below (left), a general scheme of the silicon purifying system by using electron beams (picture from [1]) is shown on the left. On the right an example of calculations of melt motion in the cold crucible is shown: top - temperature distribution; bottom – velocity distribution.





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References

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