Numerical modelling of feed rod melting dynamics during floating zone silicon crystal growth

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The present study showcases a time-dependent model of the thin fluid film on the open melting front in the floating-zone single silicon crystal growth. The presence of thin fluid film allows for the continuous flow of molten silicon into the melt. It was shown before that the melting of polycrystalline feed rod by high frequency magnetic field is not uniform, and fine island and ring structures can appear on the melting front [1]. These structures can break the thin fluid film and interrupt the steady flow because their size is dependent on the process parameters. In extreme cases, these structures can reach the inductor coil surface, leading to system failure.

The previously considered model [2] was quasi-stationary and focused on determining the shape of the melting front structures and the resulting fluid film thickness. The present study investigates the time-dependent change of thin fluid film thickness including the breaking of this film and forming of solid islands. To achieve this, melt flow simulations are performed using volume of fluid method implemented in open-source software OpenFOAM and coupled with electromagnetic field and heat transfer simulations. Three phase environment is considered on a local scale near the melting front structures.

The effect of process parameters at different positions on the melting front on the stable or dynamic melting conditions is investigated. It is crucial to determine if and how the continuous flow can be re-established in such cases with large melting front structures.

One of the main results of open melting front modelling is the resulting effective thin fluid film thickness, which affects the average electrical conductivity of the melting front. In the case of breaking of the fluid film, the thickness of the remaining liquid layer increases due to the steady influx of molten silicon from the outer parts of the feed rod, resulting in a local change in the melting rate and possible instability of the overall growth process.

References

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