A partial three-dimensional (3D) global model [1] was improved and applied to modeling the mixed heat transfer in a unidirectional solidification process for crystalline silicon solar cells. An efficient algorithm for the calculation of view factors, which is essential in the modeling of radiative heat transfer, was developed for complicated 3D configurations. Some 3D features of such a solidification process will numerically investigated.

1. Introduction : Unidirectional solidification method is an important method for large-scale production of multi-crystalline silicon material for solar cells in photovoltaic industries. Square crucibles are usually used in such a solidification process which has prominent 3D features. Since the thermal system is highly nonlinear, a 3D global analysis of heat transfer is therefore essential in optimization of the thermal management of a unidirectional solidification process for crystalline silicon solar cells.

2. Numerical Approach : Conductive heat transport in all solid components, radiative heat exchange between all radiative surfaces in a unidirectional solidification furnace and the Navier-Stokes equations for the melt flow were coupled and solved iteratively with a finite volume method together with a surface element method. A 2D/3D mixed discrete scheme was used. An efficient algorithm for the calculation of view factors was developed for the modeling of radiative heat transfer in a 3D-featured configuration utilizing such a discrete system. A partial 3D global modeling can therefore be carried out for a unidirectional solidification furnace with moderate requirement of computer resources.

3. Results : After the algorithm was first validated, a series of 3D global simulations were carried out for a unidirectional solidification process with a square crucible under different conditions. Fig. 1 shows the velocity field and temperature distribution of silicon melt in a square crucible. It was found that the melt flow structure is much more complex than those predicted with a 2D global model. The flow structure changes a lot at different stages of a solidification process. Though the magnitude of convection is small, we found it plays an important role in determining the solidification front shape when comparing to the results we obtained without melt convection.

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