Study on the thermal field uniformity in the cast monocrystalline silicon furnace

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Introduction

➢ In recent years, the market share of cast monocrystalline silicon in the photovoltaic field has increased due to low cost and matching with new solar cell technology.

➢When the dimension of the cast furnace is continuously increased to meet the demand of large-size silicon wafers, the use of the traditional square heater in the near circular furnace will cause more severe nonuniform temperature distribution.

➢This study proposes a new method for improving the thermal field uniformity in the entire furnace. The square top heater is replaced by a round top heater, and an octagonal crucible is used.

Model description

➢ Governing equations

◆Melt area

$$\nabla \cdot \vec{u} = 0$$

$$\rho \frac{\partial \vec{u}}{\partial t} + \rho \vec{u} \cdot \nabla \vec{u} = -\nabla p + \nabla \cdot \left[\mu \left(\nabla \vec{u} + \nabla \vec{u}^{T} \right) \right] + \rho \vec{g} \beta (T - T_m)$$

$$\rho C_P \frac{\partial T}{\partial t} + \rho C_p \vec{u} \cdot \nabla T = \lambda \nabla \cdot (\nabla T)$$

◆Argon area

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{u}) = 0$$

$$\frac{\partial (\rho \vec{u})}{\partial t} + \nabla \cdot (\rho \vec{u} \vec{u}) = -\nabla p + \nabla \left(-\frac{2}{3} \mu \nabla \cdot \vec{u} \right) + \nabla \cdot (2 \mu S) + (\rho - \rho_0) \vec{g}$$

$$\frac{\partial (\rho C_p T)}{\partial t} + \nabla \cdot (\rho C_p \vec{u} T) = \Delta (\lambda T) \qquad \rho = \frac{p_0}{R_g T}$$

◆Heater area

$$\rho C_P \frac{DT}{Dt} = \lambda \nabla \cdot (\nabla T) + Q$$

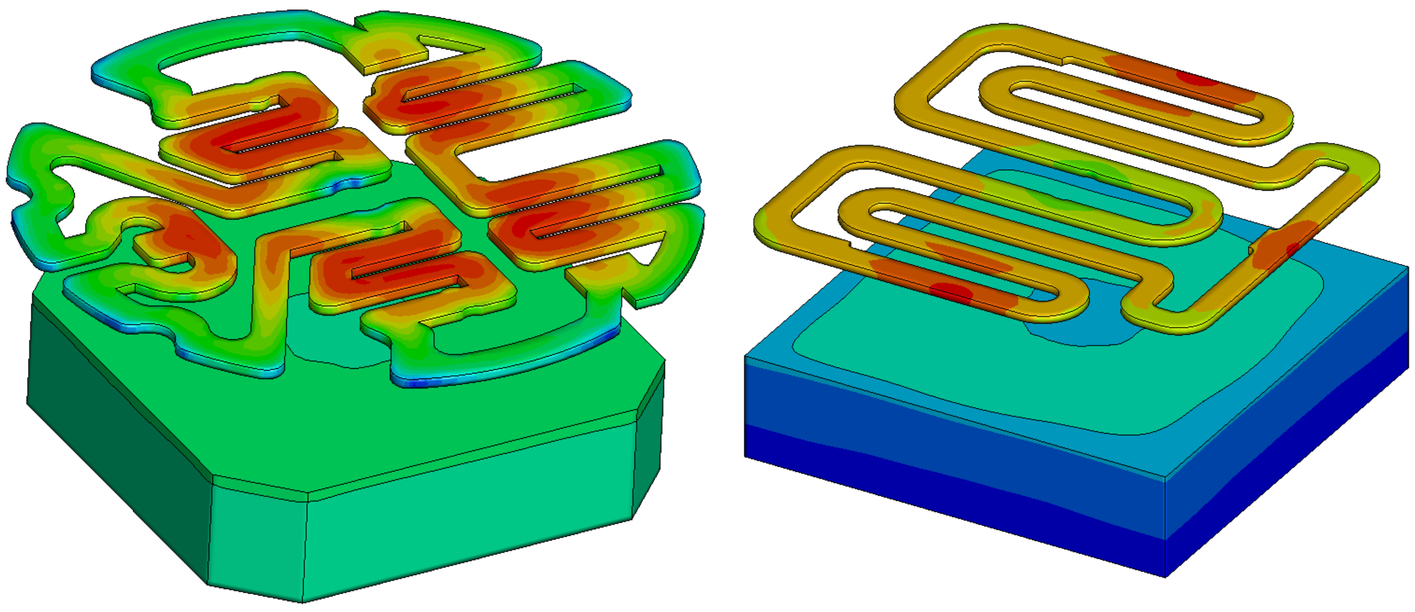
◆Other solid area

$$\rho C_P \frac{DT}{Dt} = \lambda \nabla \cdot (\nabla T)$$

3D global heat and mass transfer model In-house software (CGeMoS)

Results and Discussion

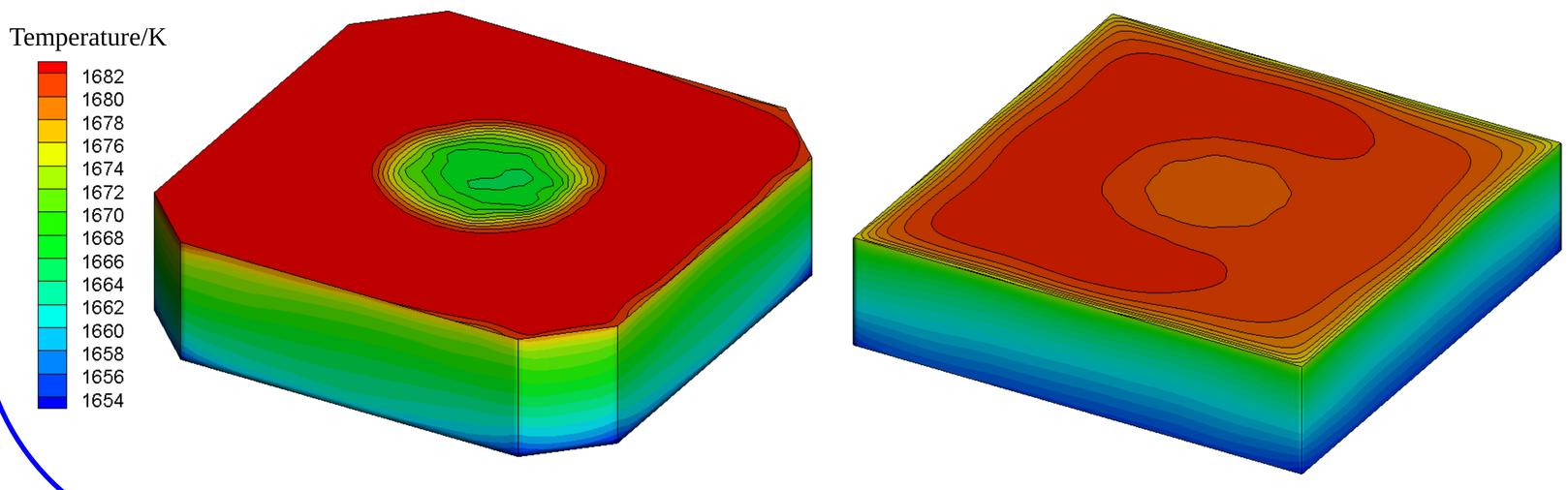
➢ Local temperature distribution



➢ The high temperature of the round top heater is concentrated in the center, and the temperature gradually decreases along the radial direction.

➢The temperature distribution of the square top heater is not uniform, and the high temperature area is scattered around.

➢ Temperature distribution in the melt



➢ More uniform melt temperature distribution can be obtained by the use of the round top heater rather than the square top heater.

Conclusions

1. The use of octagonal crucible with the round top heater is beneficial for obtaining high efficiency monocrystalline silicon ingots.
2. Moreover, the use of crucible rotation can also obtain a thermal field with more uniform temperature distribution.