Modification of heat exchanger block to enhance the quality of mc-Si ingot grown by DS process for solar cell application

Abstract No.: P32

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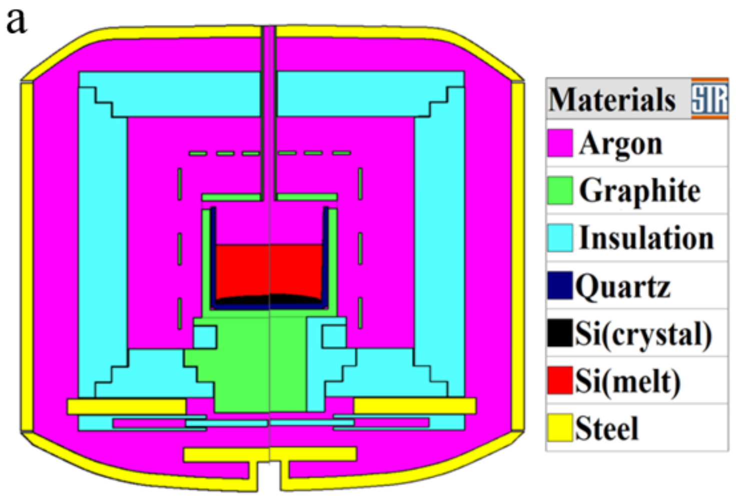
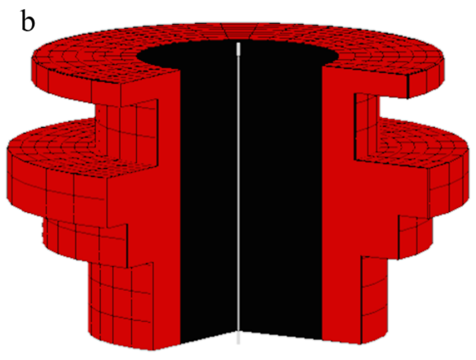
ABSTRACT: In the present work numerical investigation of thermal stress and dislocation density of the DS grown multi-crystalline silicon (mc-Si) ingot is carried out. The conventional furnace is modified to increase the quality of the mc-Si ingot. The heat exchanger block (HEB) plays the main role in the growth process, which decides the thermal stress and melt-crystal interface of the mc-Si ingot. In this modified furnace, 1/3rd part of the HEB is replaced by the insulation block. The purpose of the modification is to reduce heat extraction in the peripheral region during the growth process. By this, the homogeneity of the thermal stress is maintained. The modified HEB enhances the huge amount of heat extraction from the bottom center of the crucible. The von Mises stress, dislocation density and thermal gradient were analyzed. Conventional and modified mc-Si ingot results are compared. The modified furnace system results in better quality ingot. The result shows that the modified system grown mc-Si ingot can improve the efficiency of the solar cell.

Model Description

a



b



The heat exchanger block volume is reduced by 1/3 of its original size. This modification enhances the heat extraction from the bottom of the crucible. It reduces the wall growth and maintains the convexity of the melt-crystal interface.

Fig.1. a. 2-D view of Schematic diagram of DS furnace, and b. 3-D view of modified heat exchanger block

Introduction

- Nowadays, solar cell is one of the important sources for the electricity production. Around the world, many researchers are working in different types of solar cells in order to produce high conversion efficiency.
- There are three generations of solar cells available in the photovoltaic (PV) market. Silicon based solar cells are dominant in the PV market due to its efficiency with low manufacturing cost. Silicon based solar cells can be divided into two major parts known as mono-crystalline silicon (mono-Si, 25.6 ± 0.5%) solar cell and multi-crystalline silicon (21.25 ± 0.5%) [1].
- Directional solidification (DS) is a major technology for the production of mc-Si ingot in the photovoltaic (PV) industry and it attracts a lot of attention recently, because of its cost-effectiveness, ease of operation flexibility of feedstock material quality. In the DS growth, process various feedstock materials are used such as; MG silicon, solar grade silicon and the microelectronics industry waste. Hence the DS technology shows strong capability for further expansion in the market share compared with Cz technology [2].
- In the early days of the mc-Si growth process, ingots were harvested with larger grains to reduce the grain boundaries. It was considered the most straightforward approach to increasing crystal quality .
- Dislocations are well known as one of the most serious defects limiting the performance of mc-Si solar cells

RESULT & DISCUSSION

Temperature distribution

The heat extracted area of the conventional furnace grown ingot is high compared to the modified furnace grown ingot. In the modified furnace, in the peripheral region, the heat is extracted, avoiding the replacement of the insulation block at the heat exchanger block. The minimum depth of the temperature distribution is obtained in the conventional furnace grown ingot. At 100% solidified ingots the temperature distribution varies from 1343 to 1685 K and 1377to 1685 K in the order of bottom to the top of the grown ingot for conventional and modified furnaces respectively.

Dislocation density

There are two kinds of dislocation in the mc-Si ingot which are primary dislocation and multiplication of dislocation. During the growth process, the mismatched alignment of atom forms the primary dislocation forefront of the ingot. The movement of primary dislocation due to internal stress forms multiplication of dislocation. If thermal stress in the ingot is more than 10E6 Pa, then the primary dislocation is driven by the multiplication of dislocation [2]. The acceptable dislocation density range of the silicon is 10^3 to 10^4 cm-2 for the solar cell application [3]. The dislocation density varies from 9.7E6 to 1.5E10 Nm^{-2}

Von-Mises stress

The modified ingot obtains the minimum von Mises stress by maintaining the uniform thermal stress. In the conventionally grown mc-Si ingot, the stress level is below 6.5E5 Pa all over the ingot which is due to the different heat extraction paths. The minimum von Mises stress enhanced by the modified heat exchanger block furnace which maintains the homogeneous thermal gradient and the thermal stress. The modified heat exchanger block furnace gets the minimum dislocation density rate, less von Mises stress. It seems the better efficiency of the solar cell is given by the modified heat exchanger block ingot.

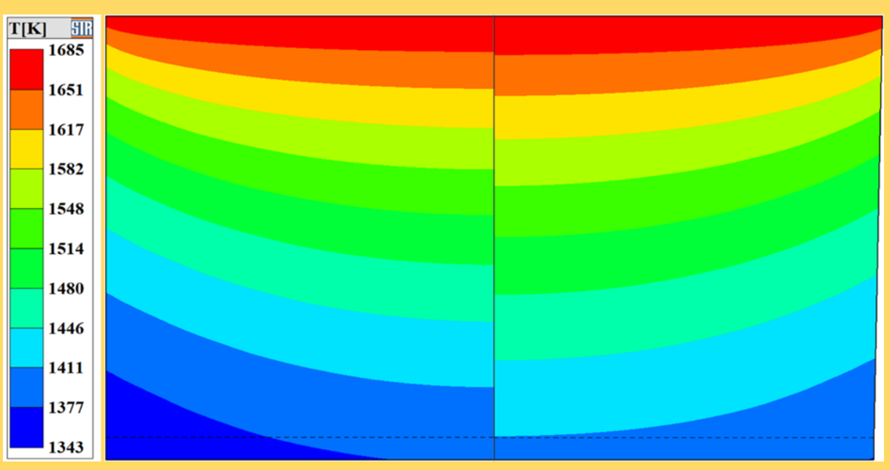


Fig.3 Temperature distribution

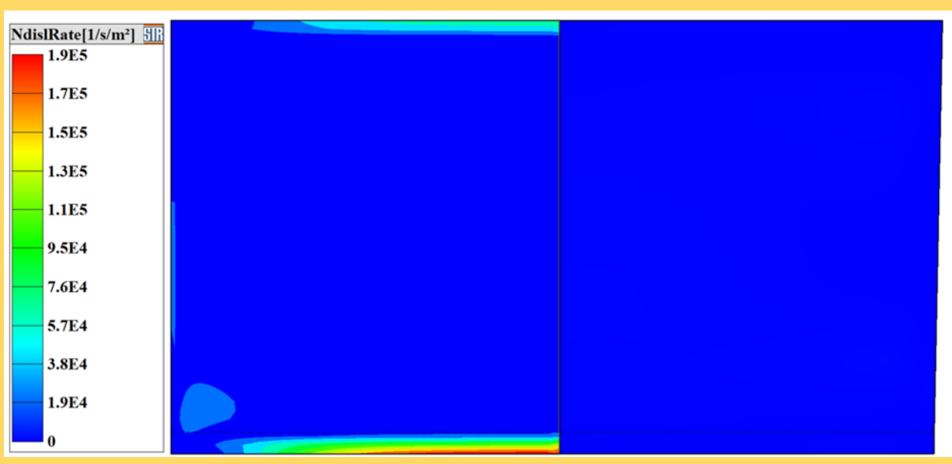


Fig.4 Dislocation density

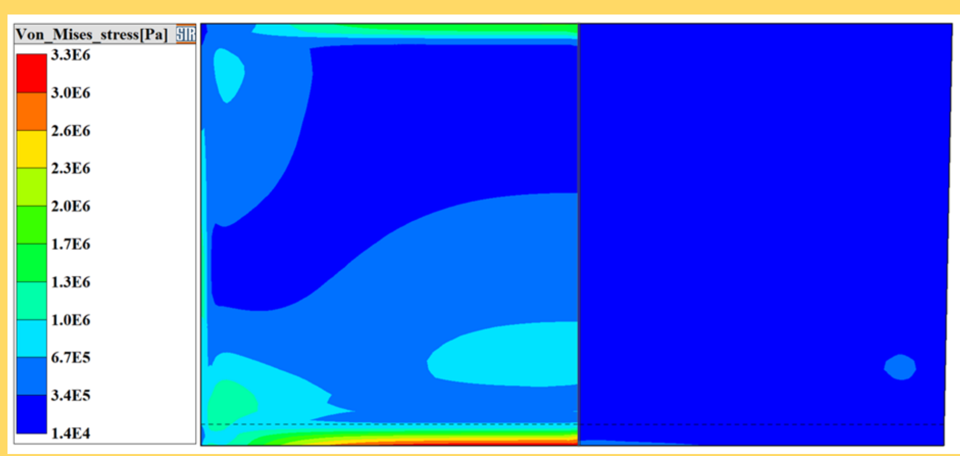


Fig.5 Von-Mises stress

CONCLUSION

Numerical simulation on the directional solidification process for the better mc-Si ingot growth has been carried out. The heat exchanger block has been modified and its effect on the mc-Si growth was analyzed. The von Mises stress, dislocation density and thermal gradient were compared with the conventional and modified mc-Si ingot. In thermal analysis, the heat extraction rate is increased by a modified furnace which enhances the fast growth during the growth process. In the crucible side wall heat extraction is reduced by the modified furnace.. The modified heat exchanger block furnace system results in better quality ingot. The result shows that the modified heat exchanger block furnace system grown mc-Si ingot can improve the efficiency of the solar cell.

Acknowledgement:
This work is supported by the Department of Science and Technology, Government of India (Order No. DST/TMD/CERI/RES/2020/7 dated on 31/12/2020).

Reference:

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