Effects of CUSP magnetic field on heat and oxygen transport during continues-feeding CZ processs

CHUN-HUNG CHEN1，YE TIAN1, He Li1

1.Xinxin Semiconductor （Group）Co., Ltd., Xuzhou, Jiangsu, China

Introduction

- The quality of silicon crystals is strongly influenced by the turbulent melt in the high-purity quartz crucible, especially near the crystallization interface.
- In order to produce higher quality wafers, it is necessary to further improve the crystal growth process to increase yields.
- As the size of silicon crystals gradually increases, control of the turbulent melt is particularly critical for producing high-quality crystals.
- Magnetic fields are an important technique for regulating the convection of conductive melts as well as impurity transport and crystallization interface shapes.

Model Description

- The geometry or the furnace in Basic CGSim for global heat transfer computations with the photo of the grown crystal are illustrated in Fig. 1.

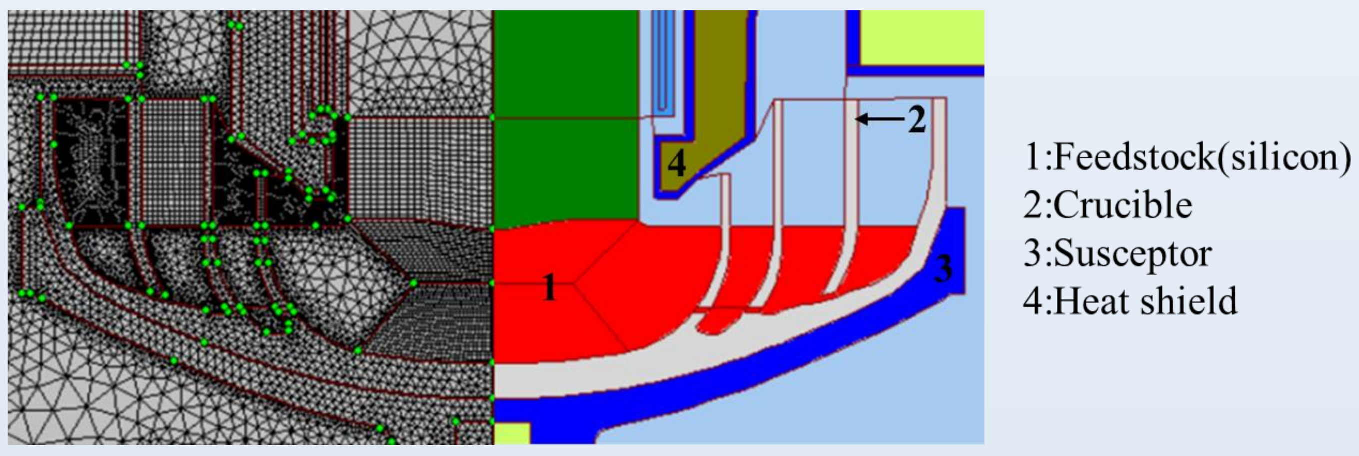


Fig. 1. Geometry of the CCZ-Si crystal growth in Basic CGSim

- Figure 1 includes feedstock (1) ,the quartz crucible (2) ,the suscepter (3). The figure also includes heat shields (4), as shown in Figure 1.

Design and Experiment Result

- After the simulation results converge, it is necessary to first confirm whether the magnetic field strength at the target position reaches the required value.

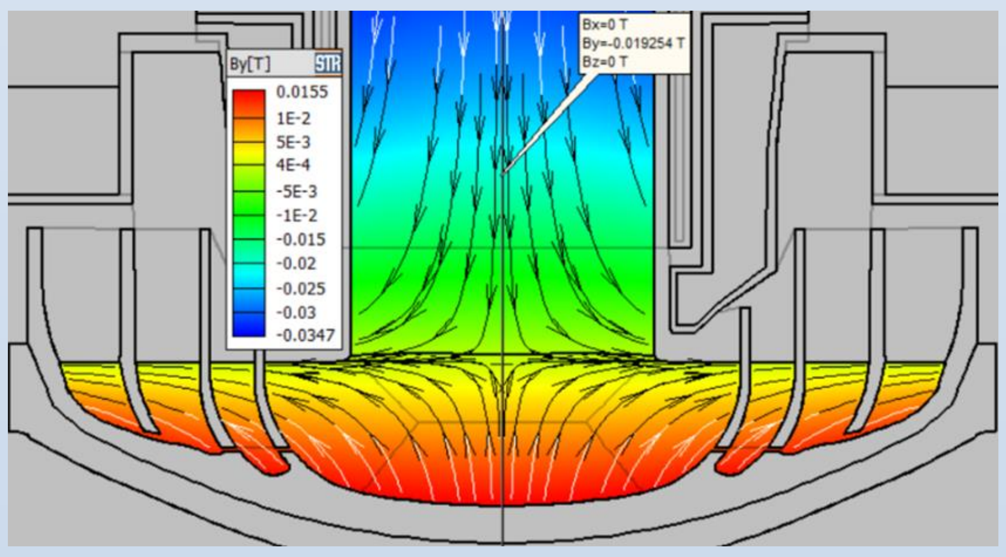


Fig. 2. Magnetic field strength at the target location in the simulation results

- Figure 2 shows the magnetic field strength at the target position in the simulation results when the reference magnetic field position is 1150mm, which is approximately equal to 0.02T.

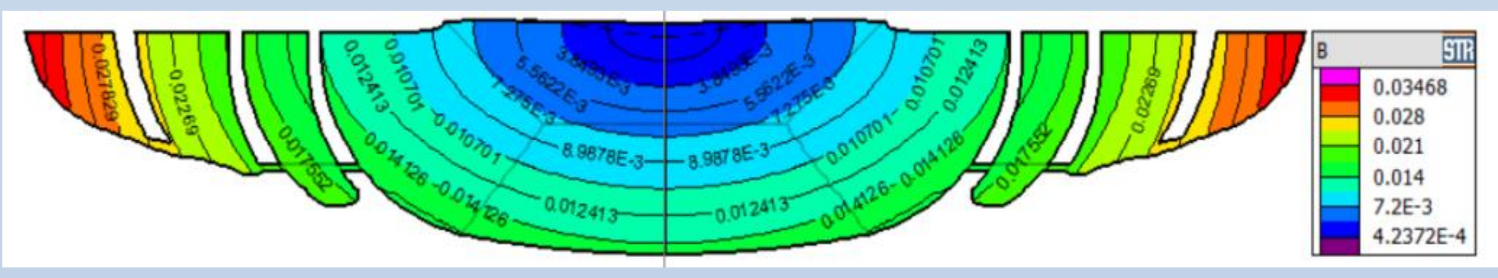


Fig. 3. Magnetic field distribution inside the crucible

- FIG. 3 shows the magnetic field distribution in the crucible under different crystallization conditions when the magnetic field reference position is 750mm.

- Case 1 with and without magnetic field

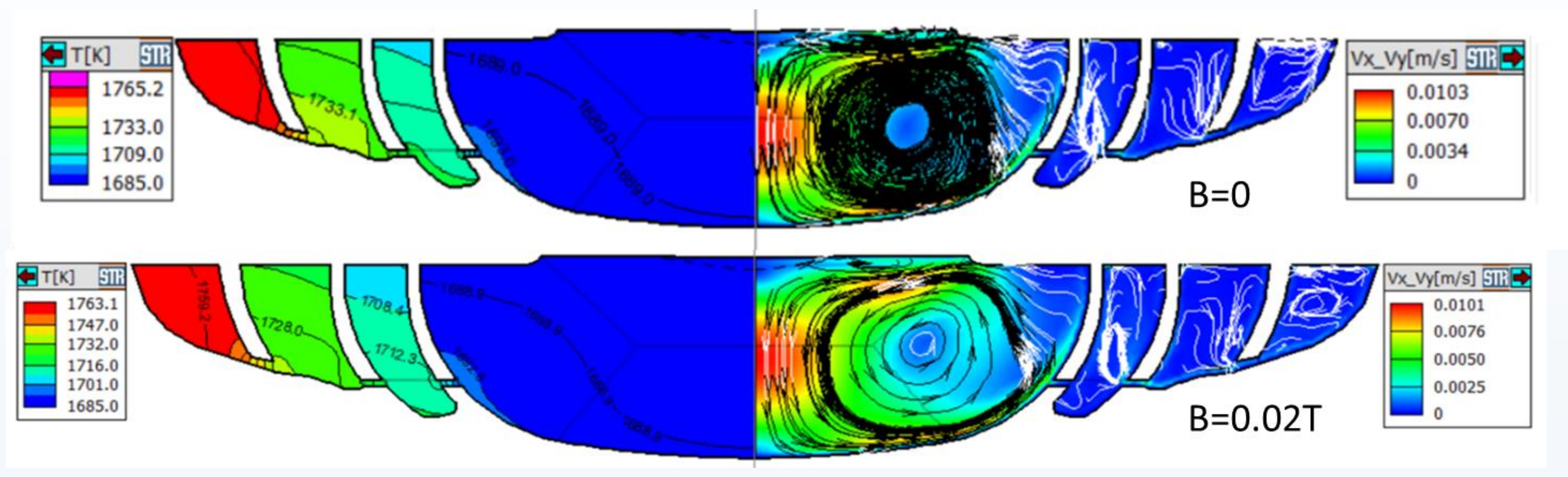
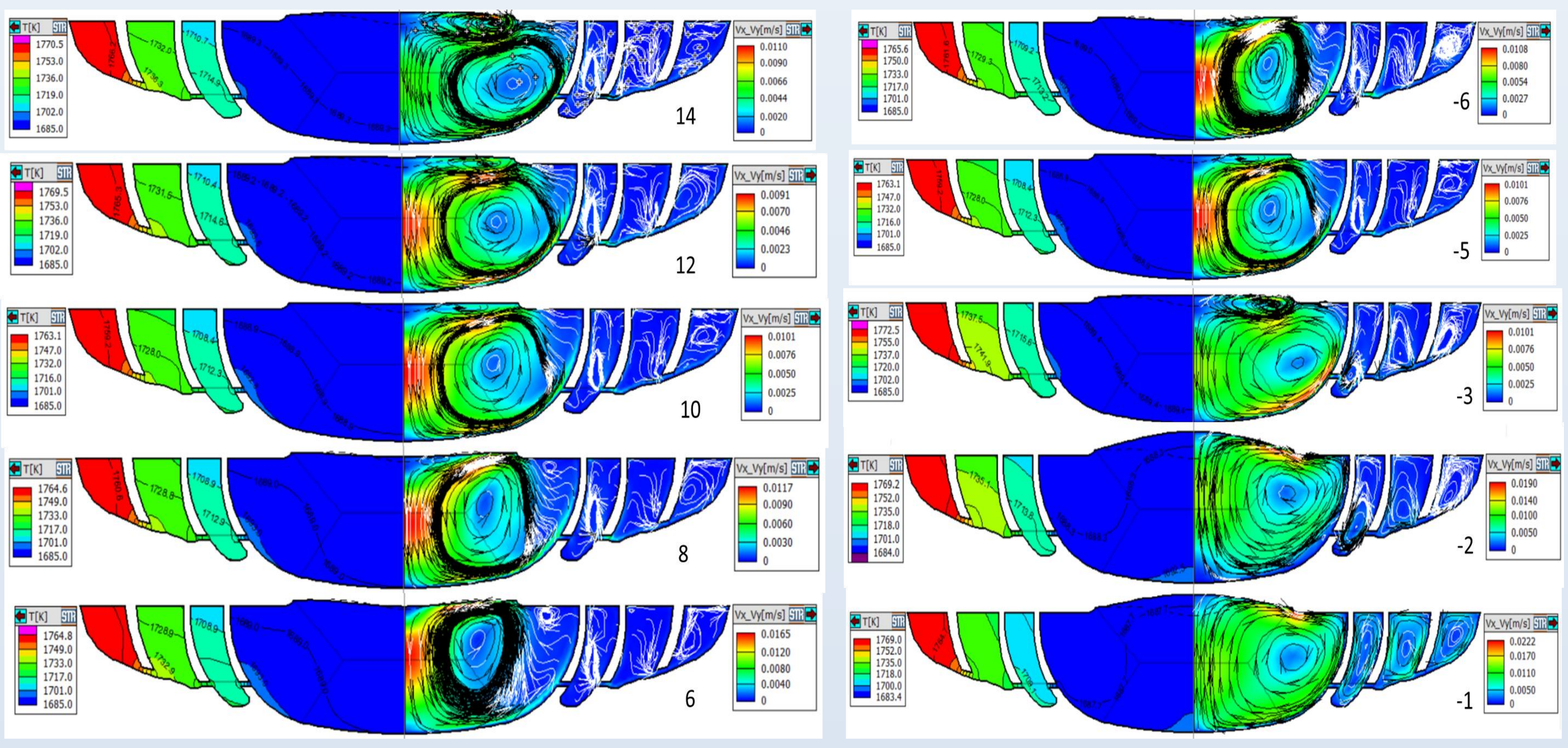


Fig. 4. Flow field diagram in the crucible

- The velocity of melt have decreased due to the magnetic field. The vortex center have moved up and more closed the crucible wall. The power is increased but the thermal gradient is decreased due to the Lorentz force suppress the energy. The flow distribution is very different from the 3 crucible system and the crystal-melt interface is more flatly.

- Case 2 different crystal rotation and crucible rotation



(a) (b)

Fig. 5. Flow field diagram in the crucible (a) different crystal rotation, (b) different crucible rotation

- With the decrease of crystal transition, it is clear that the vortex under the solid-liquid interface gradually disappears, resulting in the center velocity of Taylor flow getting faster and faster, so the solid-liquid interface is more and more convex to the molten soup. The vortex center moves from closer to the quartz crucible wall to the center and closer to the solid-liquid interface. There is a small transition flow in the upper right corner due to the energy being driven by the Taylor flow.
- As the pot turns from -6 to -3, the Taylor flow becomes more and more buoyant and the eddy is squeezed to occupy the entire right side of the soup. When the pot turns from -3 to -1, the Taylor flow almost disappears and the interface becomes more convex to the crystal. In the case of the pot turning -1, the whole inner crucible melting soup is dominated by buoyant eddy currents.

Conclusions

- According to the results of this study, it is found that the design of four crucibles can make the growth zone more stable and the interface is more flatly than other system.
- We can control the uniform distribution of the flow field in the melt by the design of thermal field and the adjustment of the cusp electromagnetic field. The optima process at 4 crucible system is SR10 and CR-5.