Effects of Water-cooled Jacket on the Oxygen Distribution during the Czochralski Silicon Crystal Growth Process

Xiaofang Qi [1,2,3], Junlei Wang[3], Wencheng Ma*[1]

[1]Institute of Functional Crystal, Tianjin University of Technology, Tianjin 300384, China

[2] School of Energy and Power Engineering, Jiangsu University, Zhenjiang, Jiangsu 212013, China

[3] Jiangsu Huantai Group Co., Ltd., Yangzhong, Jiangsu 212200, China

Email: wenchengma2012@gmail.com; xiaofangqi19@163.com

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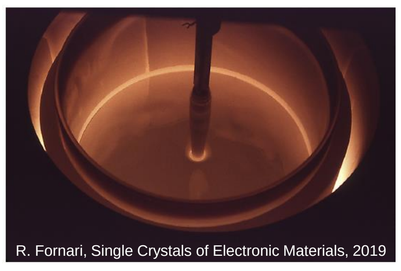
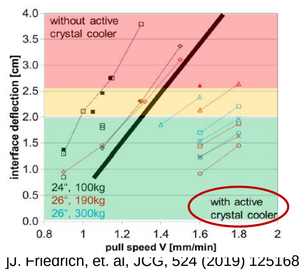
Motivation

Effects of water-cooled jacket on CZ-Si growth

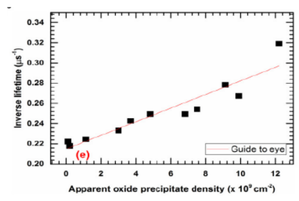


R. Fornari, Single Crystals of Electronic Materials, 2019



J. Friedrich, et. al, JCG, 524 (2019) 125168

Heat transfer was **enhanced significantly** with the water-cooled jacket.



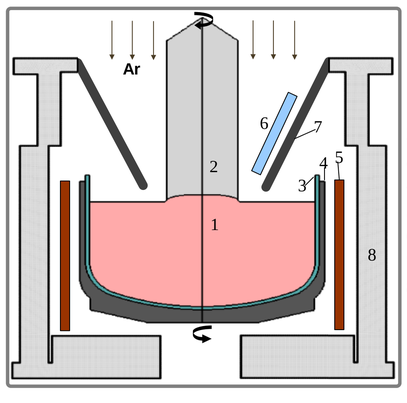
J. Appl. Phys. 124, 243101 (2018)

Oxygen affects the minority carrier lifetime, solar cell efficiency

To learn effects of water-cooled jacket on oxygen distribution

Numerical Model

CZ furnace and growth parameters



1:Melt
2:Crystal
3:Crucible
4:Susceptor
5:Heater
6:Water-cooled jacket
7:Heat shield
8:Insulation

Hot zone: 28 in.

Crystal diameter: 215 mm

Initial charge : 390 kg

Crystal rotation rate : 9 rpm

Crucible rotation rate : -8 rpm

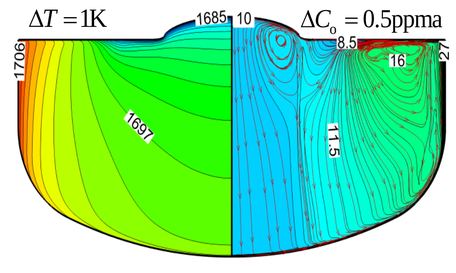
Pulling rate : 1.0 mm/min (without)

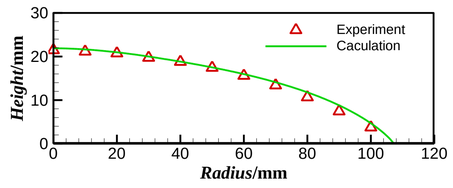
1.8 mm/min (with)

2D global heat and mass transfer model

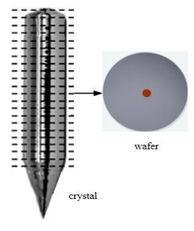
In-house software (CGeMoS)

Model verification-with water-cooled jacket





Oxygen
FTIR spectrometry



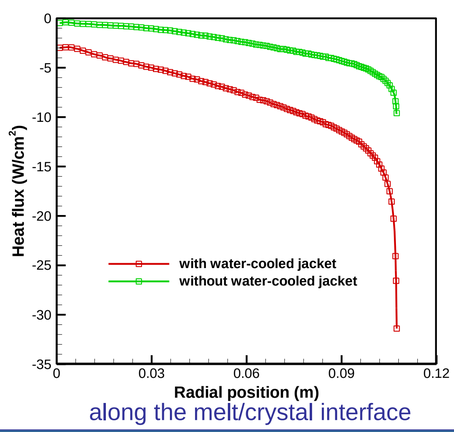
Quick pulling separation method

The simulation results and experimental data agree reasonably well

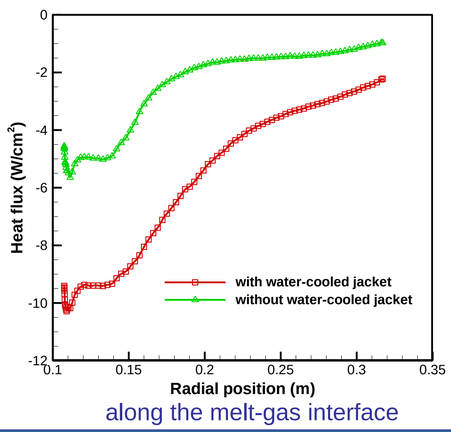
Numerical Results

Effects of water-cooled jacket on heat transfer

Heat flux profiles distribution



along the melt/crystal interface

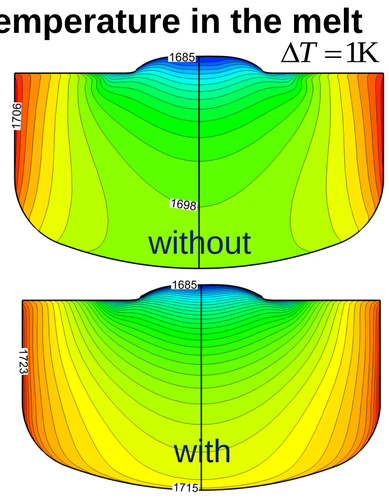


along the melt-gas interface

	along the m-c interface (melt side)/kW	along the melt-gas interface/kW
Without	1.39	5.76
With	3.86	13.68

With the water-cooled jacket, **heat flux &temperature increased**

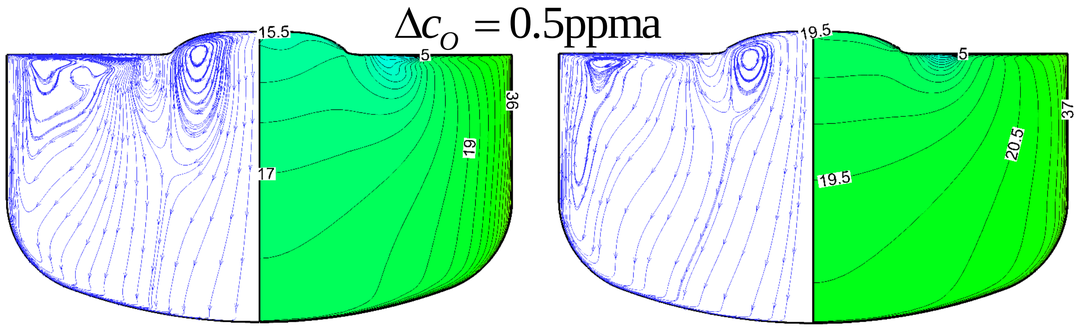
Temperature in the melt



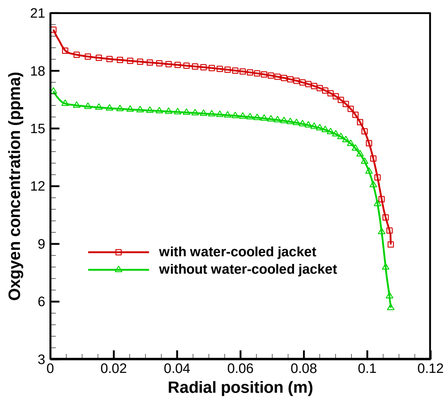
Effects of water-cooled jacket on oxygen distribution

1ppma ≈0.56×10^{17} atoms/cm^3

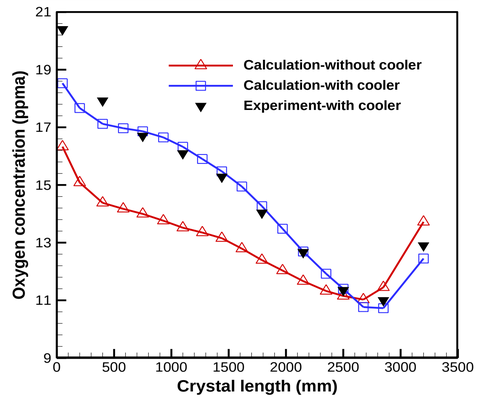
Oxygen and streamlines distribution in the melt



Oxygen distribution along the melt/crystal interface



Oxygen distribution along the centerline



With water-cooled jacket，both oxygen along the centerline of the solidified ingot & along the melt/crystal interface increased

Conclusions

- **By using the water-cooled jacket, heat transfer in the growth crystal was significantly enhanced.**
- **Oxygen concentration along the centerline of the solidified ingot was about 3 ppma higher than that without the water-cooled jacket.**
- **The simulation results were in good agreement with experimental data.**