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# Numerical study of 12 inch silicon crystal growth by continuous-feeding Czochralski

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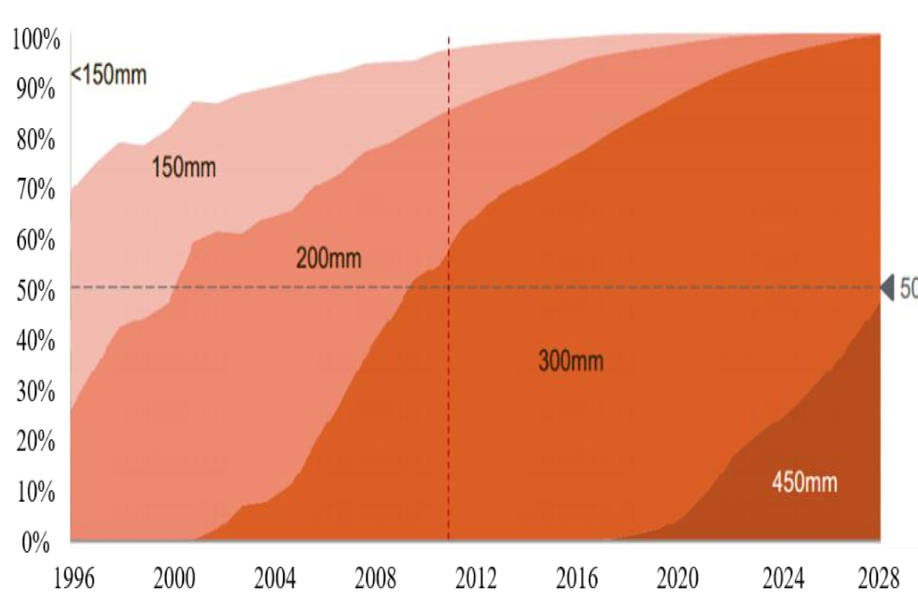
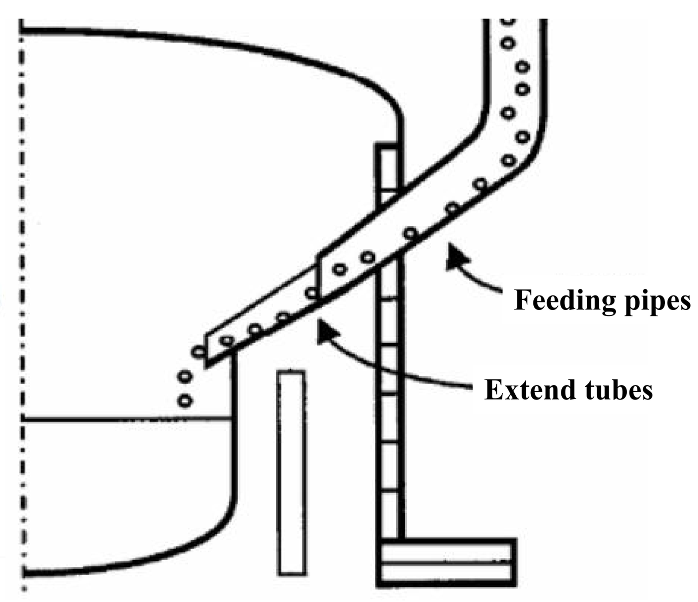
## Introduction




**a. Dimensions of electronic grade silicon wafers**

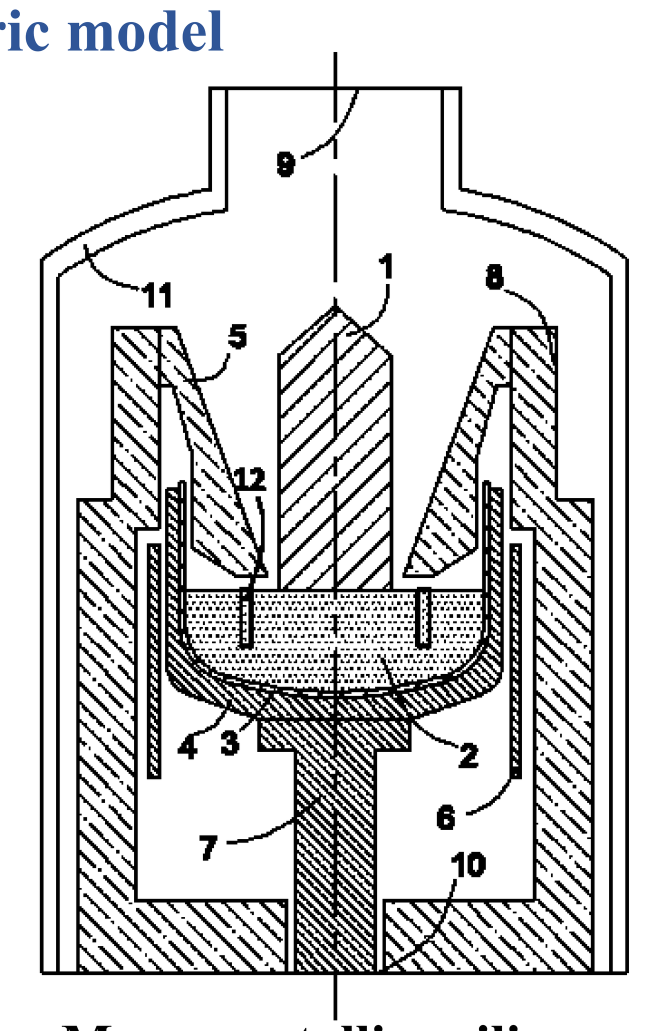



**b. Key process for CCZ**

Compared with the traditional Czochralski method (CZ), the continuous-feeding Czochralski (CCZ) can replenish silicon material into the crucible during the crystal growth continuously. Therefore, the output of monocrystalline silicon is no longer limited by the crucible size, and growing large diameter and long silicon crystal rods can be realized. Double crucible technology is usually used for CCZ, which leads to different temperature distribution, melt flow, impurity transport and crystal growth compared with the CZ method. So it is necessary to learn about the effects of inner crucible in the CCZ system.

## Numerical Model

### Geometric model




1: Crystal
2: Melt
3: Outer crucible
4: Graphite crucible
5: Flow guide
6: Heater
7: Support rod
8: Carbon fiber felt
9: Inlet
10: Outlet
11: Heating furnace wall
12: Inner crucible

**c. Monocrystalline silicon growth system for CCZ**

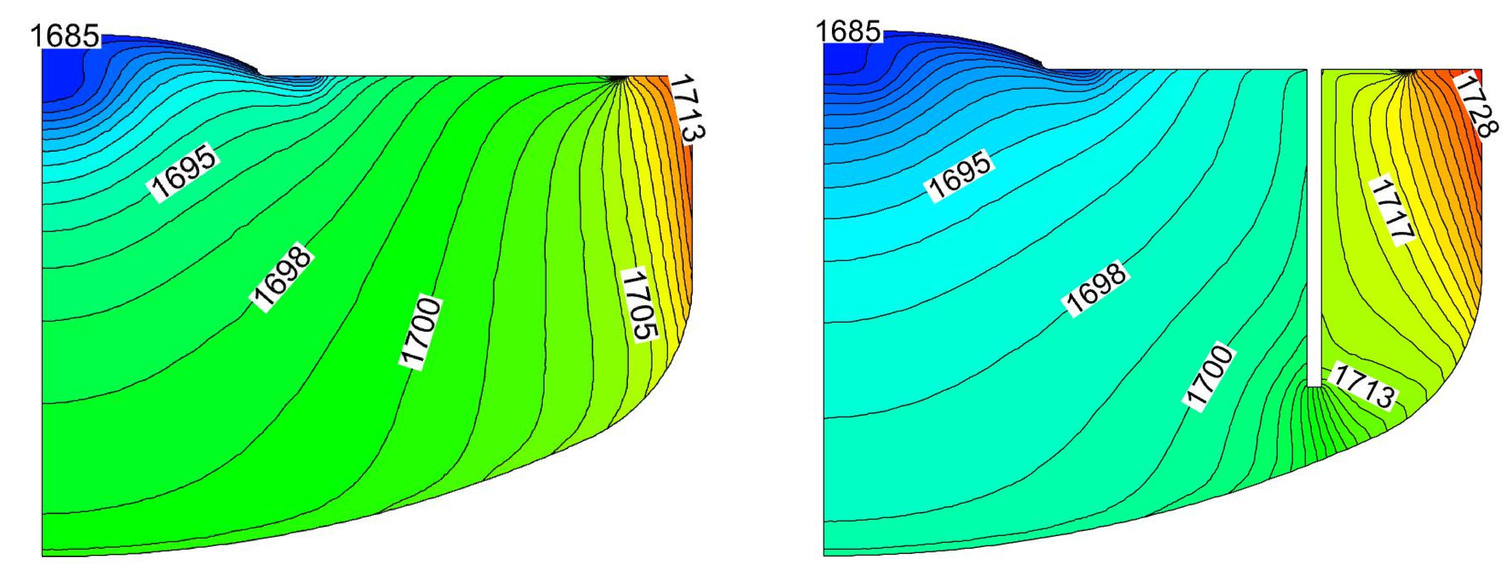
### Governing equation

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

Momentum conservation equation: $\frac{\partial}{\partial t}(\rho\vec{u})+\nabla\cdot(\rho\vec{u}\vec{u})=-\nabla p+\nabla\left(-\frac{2}{3}\mu\nabla\cdot\vec{u}\right)+\nabla\cdot(2\mu\dot{S})+\rho\vec{f}$

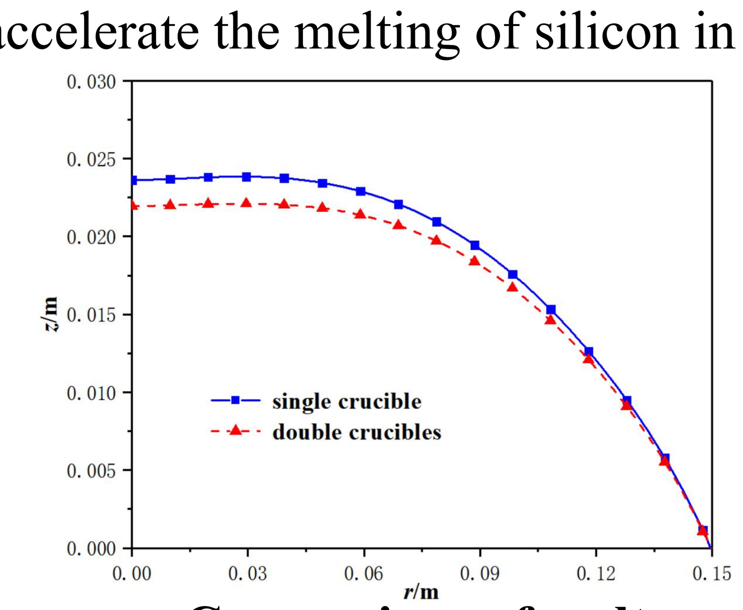
Energy conservation equation: $\frac{\partial}{\partial t}(\rho c_p T)+\nabla\cdot(\rho c_p\vec{u}T)=\nabla\cdot(\lambda\nabla T)+S_Q$

## Result Analysis

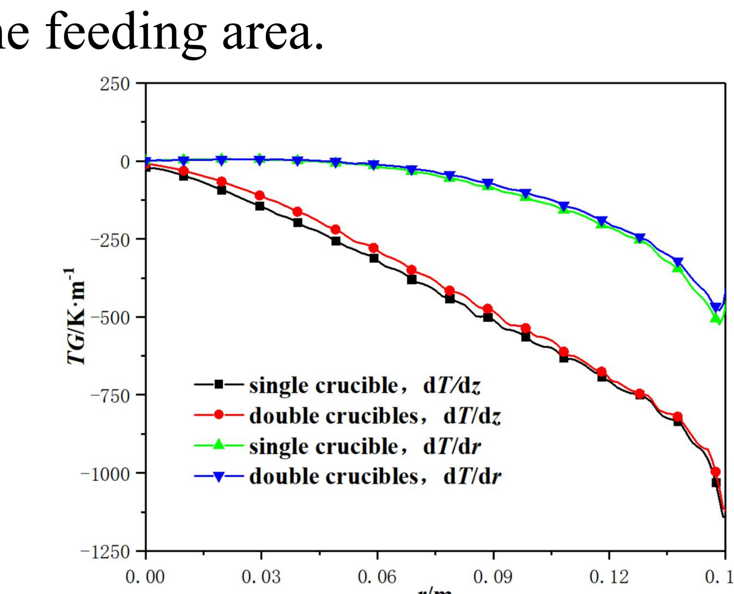



**d. Temperature distribution of melt**
**d1. single crucible d2. double crucibles**

*d* It can be found that when the inner crucible is used, the temperature difference in the melt increases **from 28K to 43K**, which increases 35%. This is because the inner crucible is made of quartz, and its thermal conductivity is much lower than that of silicon melt, which hinder the heat transfer from the outer crucible wall to the melt-cystal interface. The increase of melt temperature near the crucible wall is beneficial to accelerate the melting of silicon in the feeding area.



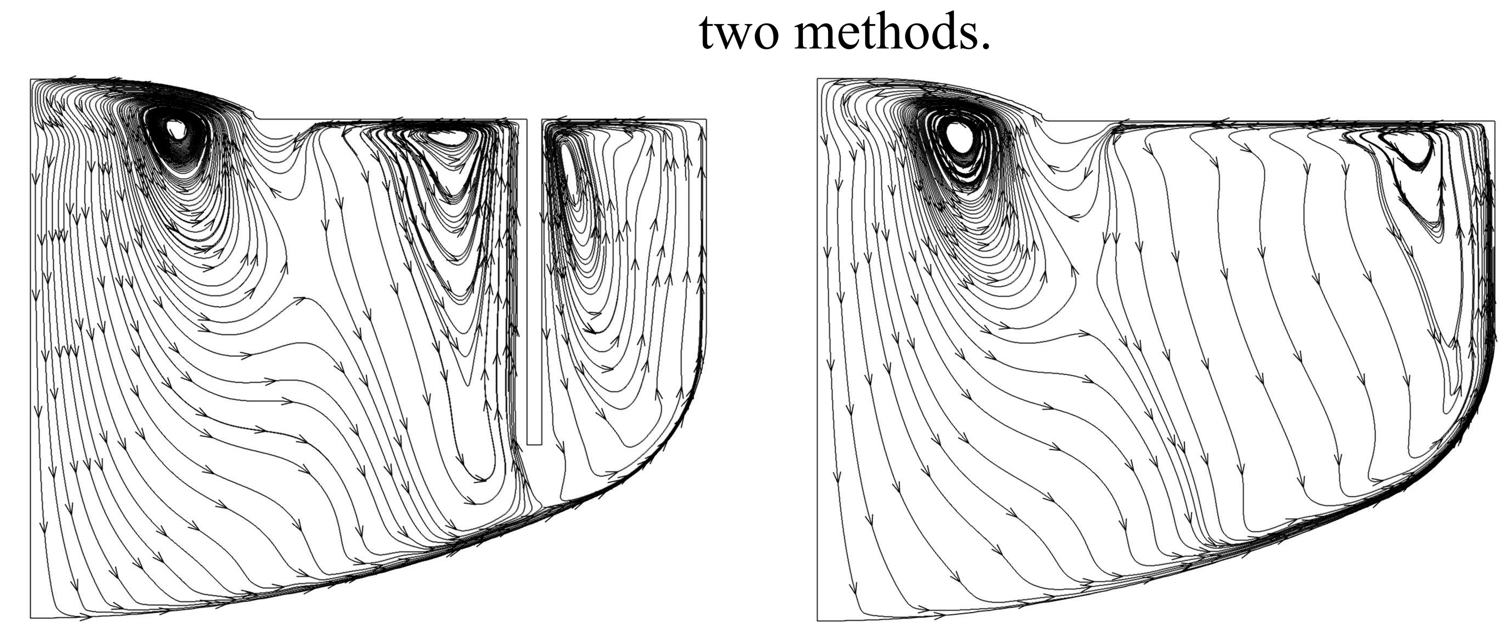

**e. Comparison of melt-cystal interface**




**f. Temperature gradient of melt-cystal interface**

*e* Compared with the situation without inner crucible, it can be found that the convexity of melt-cystal interface is **lower** than the situation with inner crucible.

*f* The shape of melt-cystal interface depends on the distribution of its radial and axial temperature gradients. The temperature gradients of melt-cystal interface is basically the **same** for the two methods.



**g. Flow field distribution of melt**
**g1. single crucible g2. double crucibles**

*g* When the inner crucible is not used, due to the influence of thermal buoyancy, the melt near the crucible wall flows upward, forming two counterclockwise rotating vortices inside the crucible. When the inner crucible is used, it divides the melt area into two parts, and there also two large anticlockwise vortices on the inner side of the inner crucible.

## Conclusion

- The **melting latent heat** generated in the feeding process **only affects** the **local** temperature field and flow field distribution.
- Inner crucible can **reduce** the influence of feeding process of melt-cystal interface.
- When inner crucible is used, the temperature difference of the melt will **increase**.
- The flow field distribution of the two case is roughly **similar** except the area near the inner crucible.