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Numerical study of die shape for the β-Ga_2O_3 crystal growth by EFG

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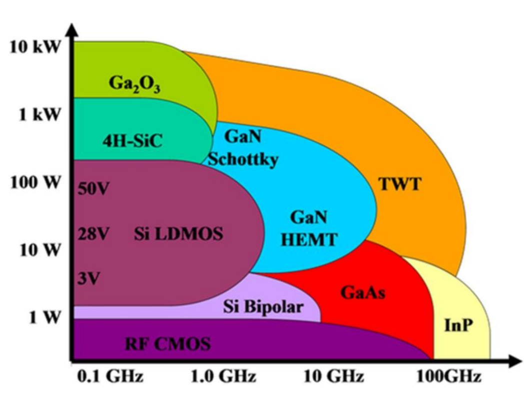
Introduction

β-Ga_2O_3 and EFG

- **β-Ga_2O_3 is a novel ultra-wide bandgap semiconductor material with many excellent properties, such as large band gap width and high breakdown field strength.**
- **β-Ga_2O_3 is the preferred material for making ultra-high voltage power devices and deep ultraviolet photovoltaic devices.**



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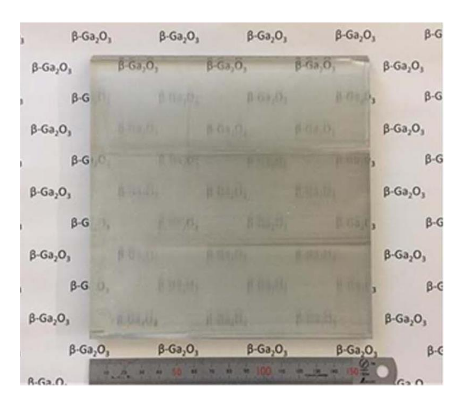

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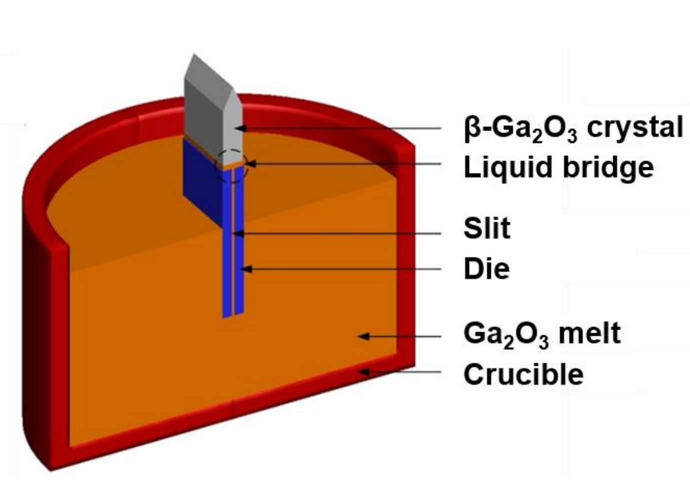
- **The EFG is an ideal method for growing high-quality and large-size β-Ga_2O_3 single crystals.**
- **The EFG has many advantages, such as high growth rate, low crystal growth cost and high utilization rate of raw material.**
- **The die shape affects the β-Ga_2O_3 crystal growth and determines the crystal quality, and therefore should be specially designed.**

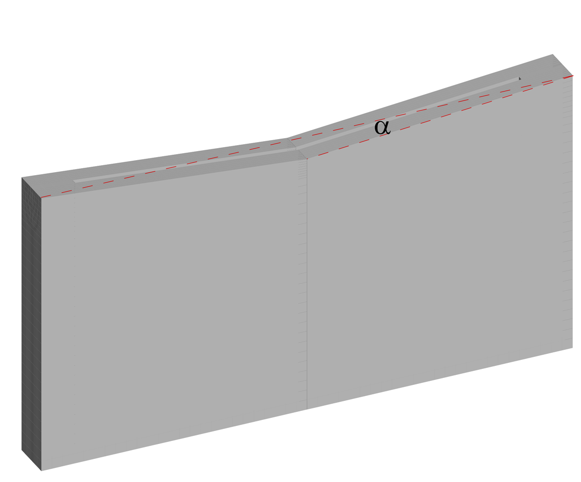
Research purpose

- **Design the die shape, mainly the tilt angle on the die top surface.**
- **Reveal the effects of die shape on the thermal field distribution, melt-crystal interface shape and β-Ga_2O_3 crystal growth.**

Model

Numerical model

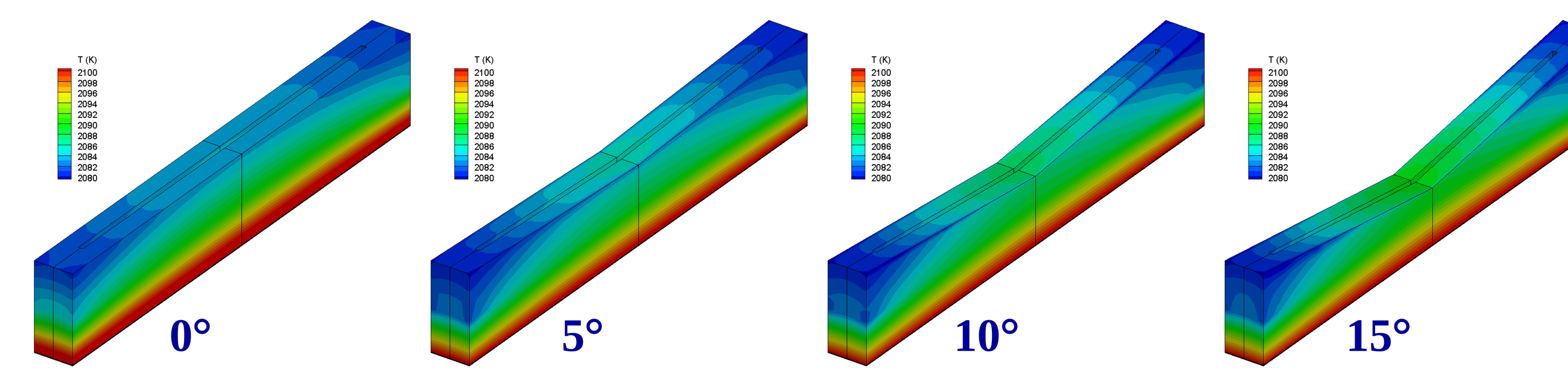




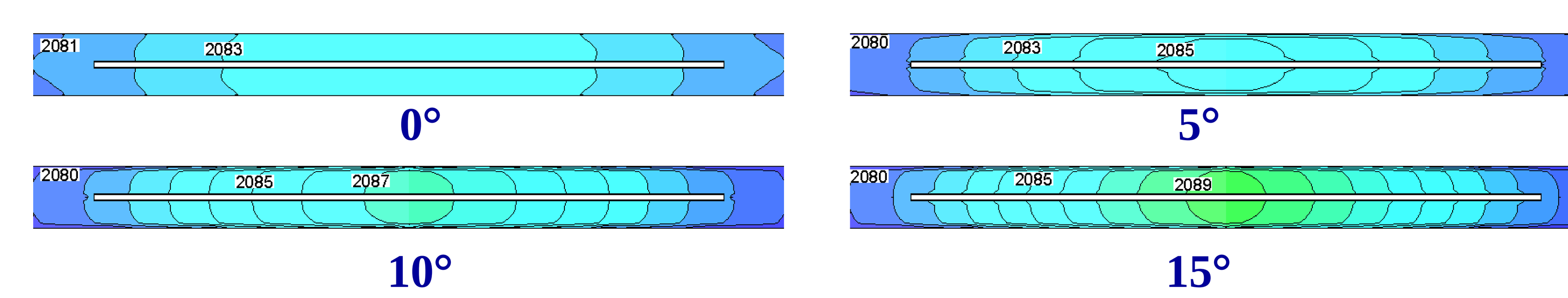
- **All the main components of the EFG furnace are considered in the numerical model.**
- **3D global heat transfer model, including the coupling of electromagnetic, thermal and flow fields, is established for the β-Ga_2O_3 crystal growth by EFG.**
- **The tilt angle on the die top surface varies from 0° to 15°.**
- **An alternating current (AC) with high frequency is input to the coil to generate induction heating power in the iridium crucible.**
- **The radiative surfaces of all solids located in non-participating medium are diffuse-gray.**
- **The melt is laminar, incompressible and the Boussinesq approximation is applied.**

Results & discussion

Temperature distributions in the die



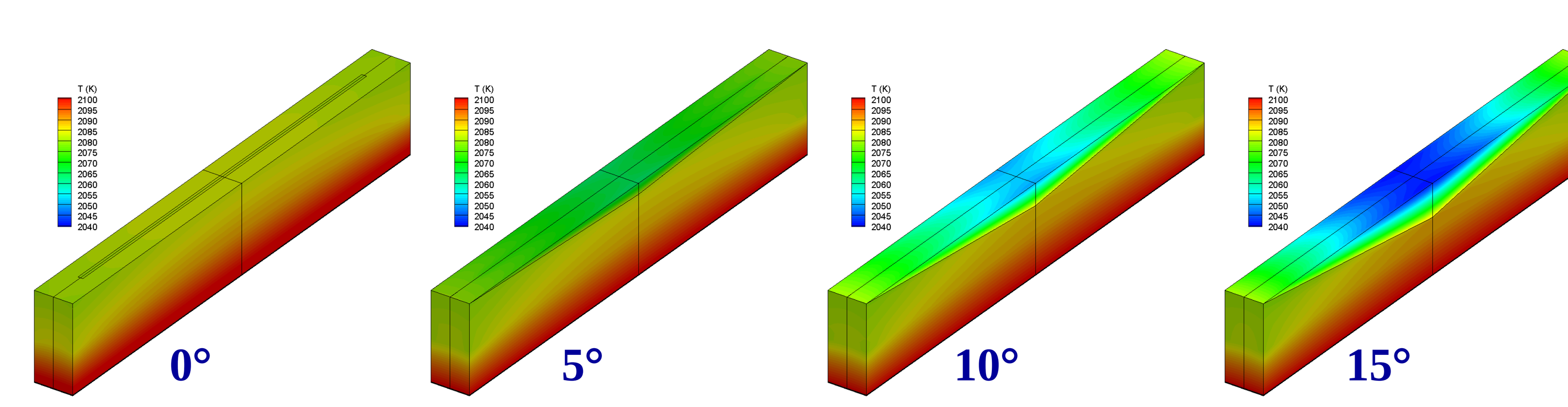
Temperature distributions on upper part of the die for different tilt angles



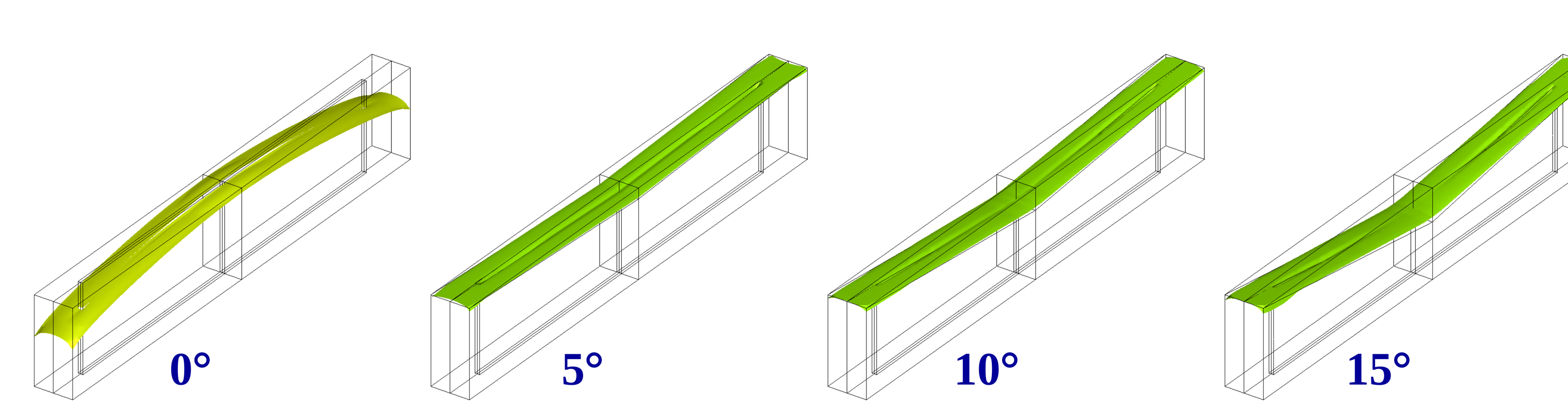
Temperature distributions on top surface of the die for different tilt angles

- **The temperature in the die upper part decreases from bottom to top, which provides temperature gradient for crystal growth.**
- **For the original case with tilt angle of 0°, the temperature on the die top surface decreases from center to periphery, which means the melt in the die center is solidified later than the other parts and the holes are easily formed along the central axis.**
- **With the increase of tilt angle, the minimum temperature at the die top surface is kept at the melting point of 2080 K, whereas the maximum temperature in the die center increases significantly. The temperature differences for the cases of 0°, 5°, 10° and 15° are 3 K, 5 K, 7 K and 9 K, respectively.**

Temperature distributions in the melt



Temperature distributions in the melt above the die for different tilt angles



Melt-crystal interface shapes for different tilt angles

- **With the increase of tilt angle, the melt depth above the die top surface increases and the temperature in the melt center decreases significantly, which means the melt above the die center is easily solidified.**
- **The melt-crystal interface is more likely concave to the melt for the case with tilt angle of 0°, whereas it's convex to the melt for the cases with tilt angle of 5°, 10° and 15°. The convexity increases with the increase of tilt angle, which means the melt-crystal interface shape can be adjusted by designing the die shape.**

Conclusions

1. **The temperature on the die top surface decreases from center to periphery, and the temperature difference in this surface increases with the increase of tilt angle.**
2. **The temperature in the melt above the die top surface increases from center to periphery, and the melt-crystal interface shape can be adjusted from concave to convex by designing the tilt angle.**