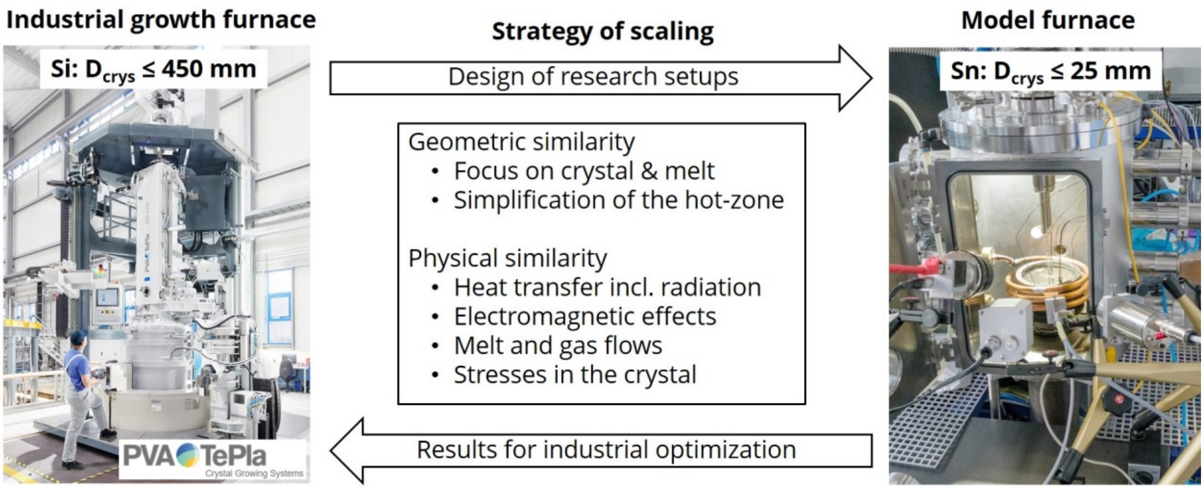
Scaling bulk crystal growth processes between industry and research

Dadzis K*, Wintzer A, Tsiapkinis I, Foroushani S.
*lead presenter: kaspars.dadzis@ikz-berlin.de
Leinbiz-Institut für Kristallzüchtung (IKZ), Berlin, Germany

The industrial equipment for many crystal growth processes, such as growing silicon from melt, could be grossly described as large, expensive and hardly accessible. Consequently, research and development is usually conducted using simplified and down-sized (e.g., by a factor of 4 and higher [1]) research furnaces. Simplifications may include reduced hot-zone geometry as well as the use of different crystalline materials (e.g., with a lower melting point). In all these cases, one question must be answered: which features and results can be transferred between the two scales and with what limitations [2]. We will present a systematic analysis of scaling:

- Geometric similarity – what geometric features of the hot-zone are crucial for practically relevant parameters such as temperature distributions in the crystal and the melt?
- Physical similarity – how can macroscopic physical phenomena such as heat transfer or gas flow be compared between systems of different dimensions or even different materials using dimensionless numbers and scaling of the governing equations?

As practical examples, we will consider the growth of silicon and oxides/fluorides using the Czochralski (CZ) and floating zone methods. In the first step, we will focus on scaling the system size (both up and down) and analyzing the impact on various physical phenomena. In the second step, in addition to geometric scaling, the crystalline material (based on selection criteria that will be discussed) and the related temperature level will be modified. At this stage, while increasing deviations from the target system may compromise overall similarity, possibilities for in-situ observations will be much higher. As an extreme example, we will discuss CZ growth of tin crystals with 25 mm diameter as a scaled model of the growth of large silicon crystals (see figure below). This study will showcase the strategy of the NEMOCRYS project, which entails development and validation of numerical models at research scale and application of those models at industrial scale [3].



Acknowledgement: This work has been funded by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 851768).

References

[1] Dadzis K, Niemietz K, Pätzold O, Wunderwald U, Friedrich J. J Cryst Growth. 2013;372:145-156.
[2] Zlokarnik M. *Scale-Up in Chemical Engineering* (Wiley, 2nd ed., 2006).
[3] Enders-Seidlitz A, Pal J, Dadzis K. J Cryst Growth. 2022;593:126750.