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Segregation control by the use of dynamic magnetic fields during semiconductor crystal growth

Workshop
"Use of Magnetic Fields in Crystal Growth"
13.-14. June 2002, Riga, Latvia

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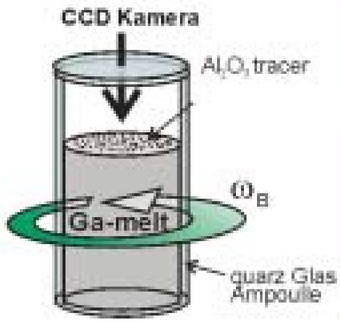
Content

1. Interaction of fluid flow and crystal growth
2. Established magnetic field facilities
3. Float zone growth of silicon in a rotating magnetic field
   - radiation heated process (mirror furnace)
   - radio frequency heated process (600 kHz inductor)
4. Czochralski growth of germanium with rotating magnetic field

Flow Configuration on the Free Surface

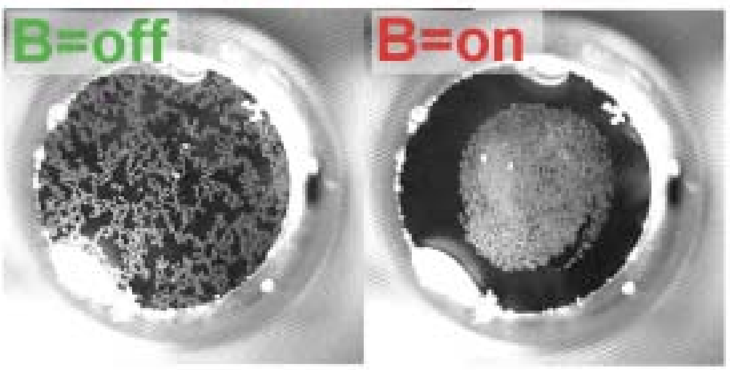
Tracer observation at an oxid-free gallium surface



25 mm

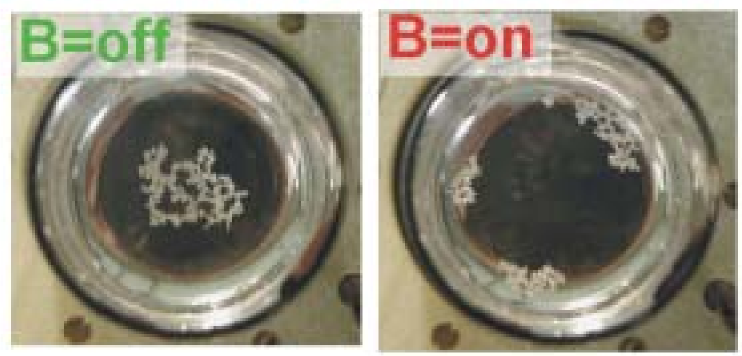
rotating magnetic field:
flow is inward directed
alternating magnetic field:
flow is outward directed

rotating magnetic field



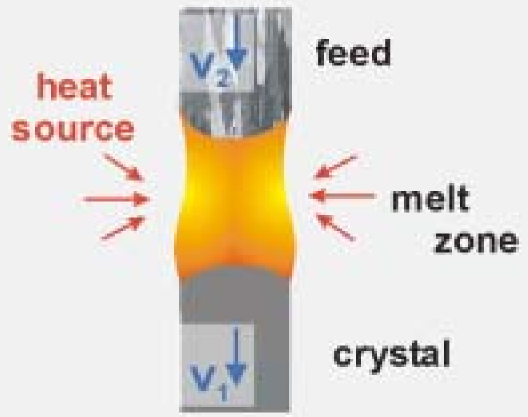
25 mm

alternating magnetic field



50 mm

Float Zone Silicon



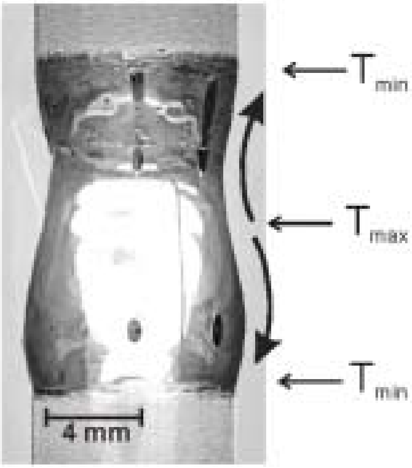
Silicon: T_m=1412°C

Float Zone: Ø ≤1.4 cm

strong, time-dependent convection

heat source:
- radiation heating
- radio frequency (600 kHz)

control of convective flows:
- static axial magnetic fields
- static transversal magnetic fields
- rotating magnetic fields
- axial vibrations

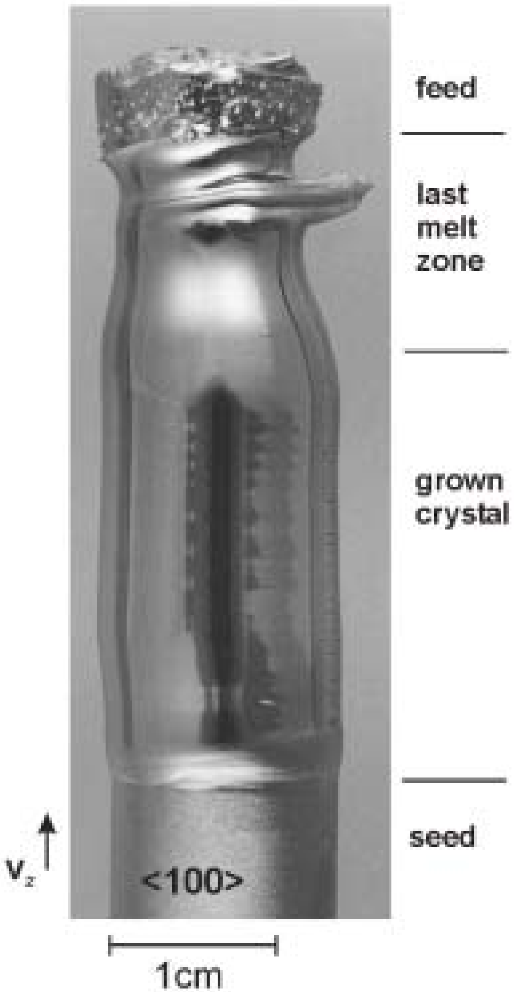


analysis tools:
- temperature measurements in the melt
- concentration field in the crystal
- measurement of the (microscopic) growth velocity
- 3D numerical simulations (FIDAP)

FZ-Silicon: Microsegregation as a Function of the RMF

f_B=50Hz

(Si:Sb, <100>, v_z=1mm/min, no crystal rotation)

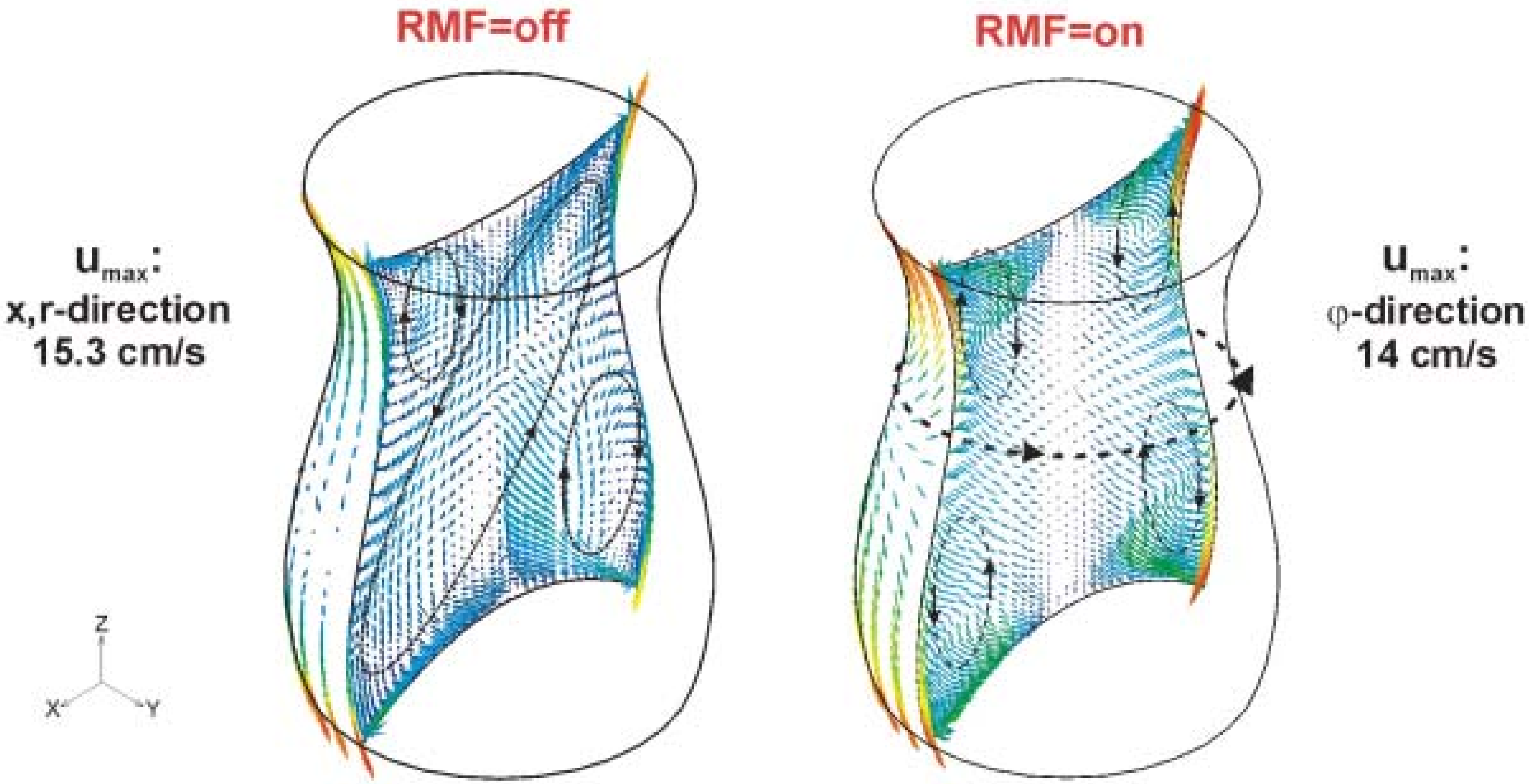


P. Dold et al., *J. Crystal Growth* 231 (2001) 95-106.

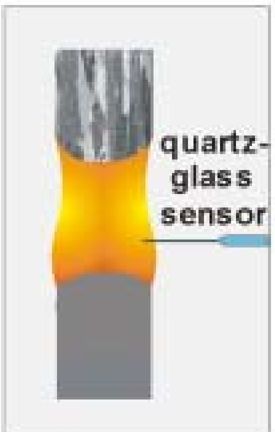
FZ-Silicon: Numerical Simulation of the Flow Field

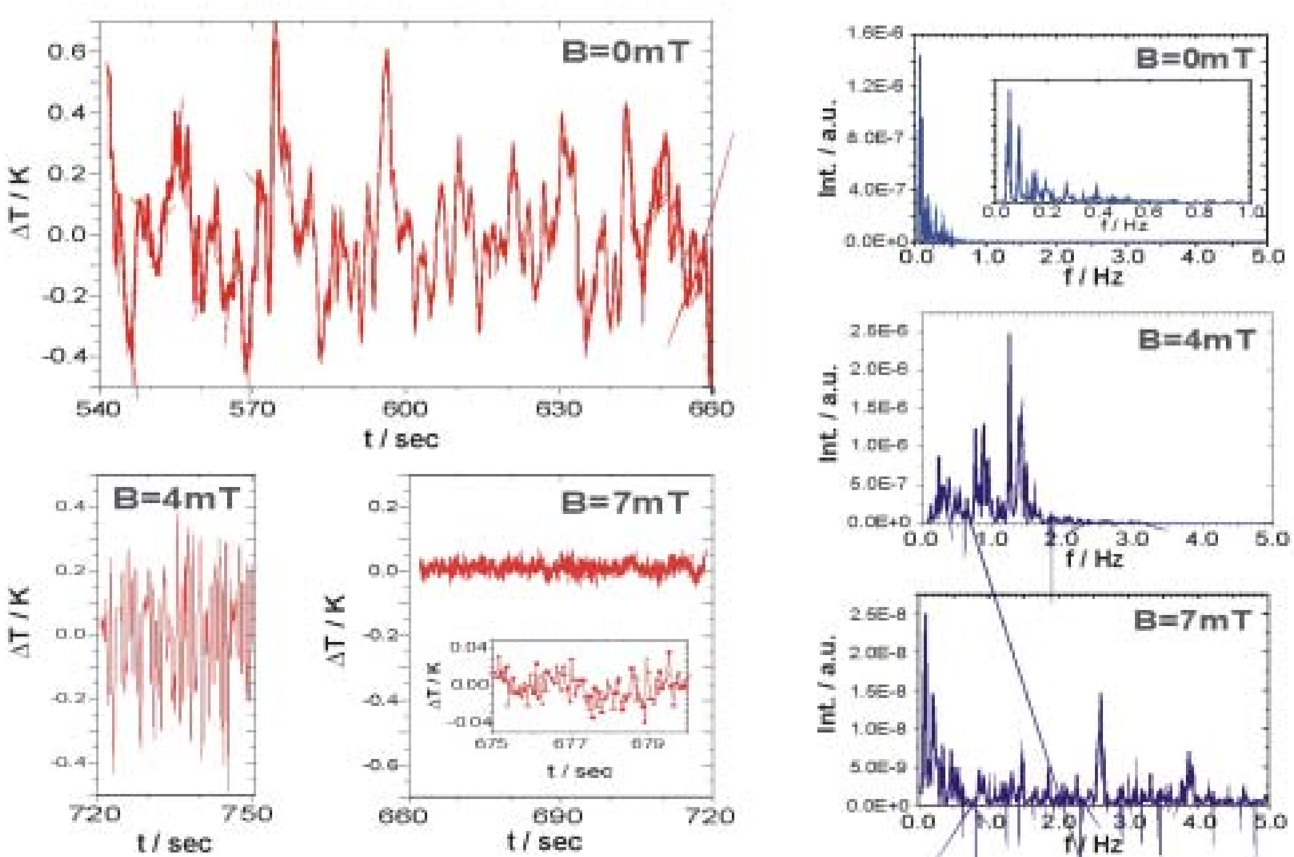
f_B=50Hz

(silicon float-zone, Pr=0.02, Ma=3000, d=8 mm, h=12 mm, B=0 / 21mT)



Convective Temperature Fluctuations in FZ-Silicon





B=0
$\Delta T \leqslant 1$ K $f \leqslant 0.2$ Hz

B=7 mT
$\Delta T \leqslant 0.07$ K $f_1 = 2.6$ Hz ($\hat{=}$ $v = 8.2$ cm/s)

Summary and Conclusions

1. Float zone, Czochralski, and Bridgman growth with rotating magnetic fields have been investigated yet. FZ-silicon served as a model substance for the investigation of magnetic field effects on segregational phenomena.

2. In all systems with time-dependent convection (i.e. rf-FZ, radiation FZ, Cz), the microsegregation was strongly improved due to the RMF. The required field strength depends on the melt volume (Cz->FZ) and the level of convection.

3. Convective temperature fluctuations are reduced by more than one order of magnitude due to the RMF (similar results were obtained by alternating magnetic fields in physical modelling experiments with gallium).

4. The induced azimuthal flow velocities due to the RMF can easily reach 10 cm/sec even in the case of FZ-growth with melt diameters of 10 to 14 mm.