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IKZ

What is imaginable by use of magnetic fields at Czochralski growth of III-Vs in low-temperature gradients ?

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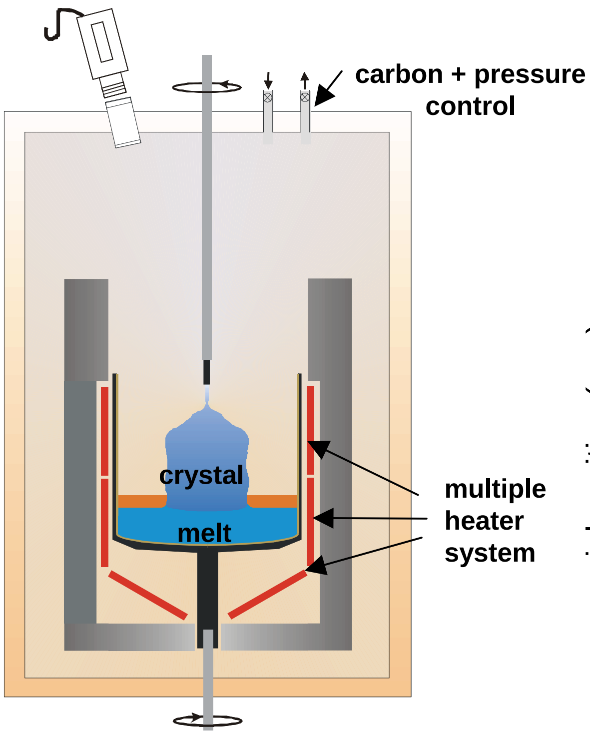
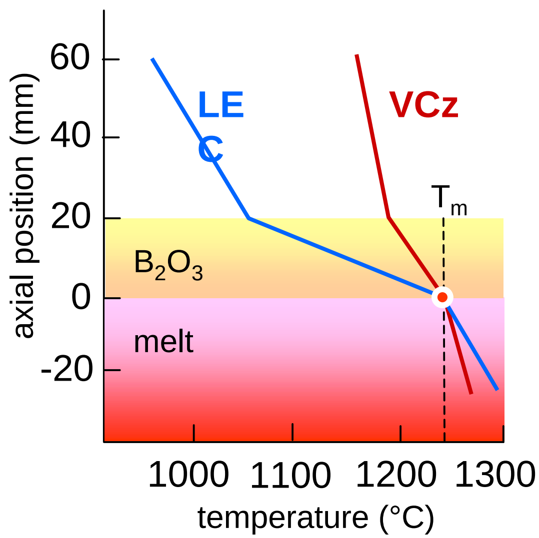
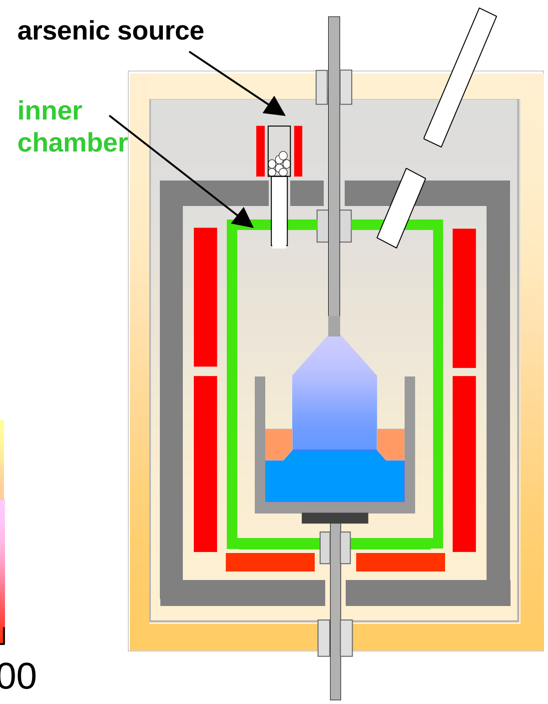
Comparison between LEC and VCz methods







LEC

dT/dz = 50 - 100 K cm^{-1}

Freiberger Compound Materials GmbH

VCz

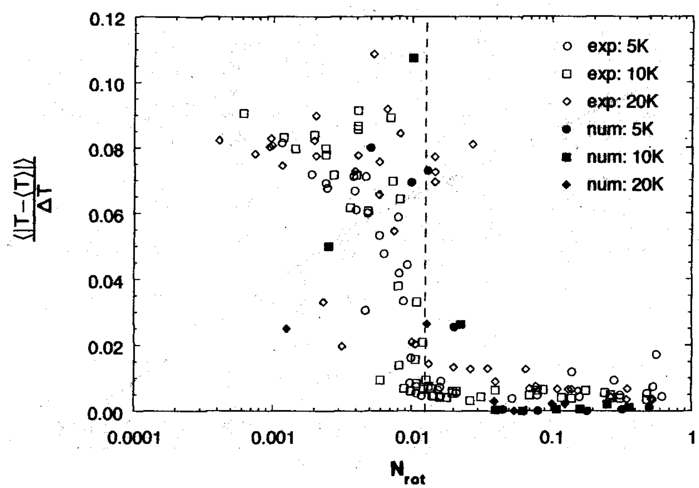
dT/dz = 10 - 40 K cm^{-1}

Institute of Crystal Growth in Berlin

Problems to be solved by using of magnetic fields (?)

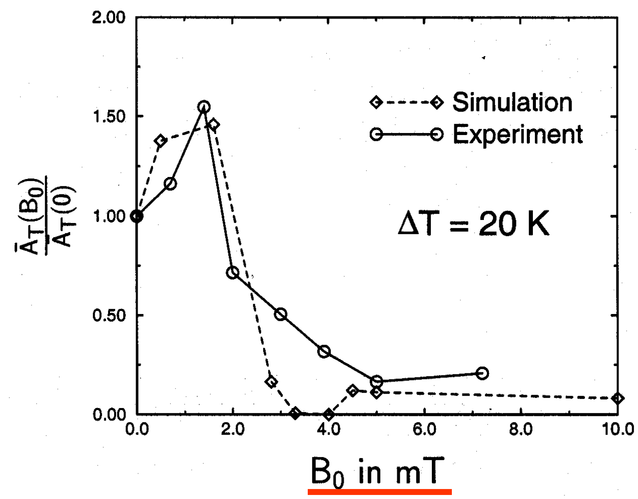
- to pull markedly longer crystals higher melt volumes are required; that increases turbulent flows and convection instabilities
- to flatten the interface high crucible rotation rates are favourable; that raises the mechanical risk especially for VCz growth
- appearance of Marangoni convection in case of failed B_2O_3 encapsulant
- doping striations (Fe in InP) due to convection oscillations
- much stronger disturbance of crystallization kinetics by temperature oscillations due to the low temperature gradients at VCz
- enhanced probability of twins
- macrosegregation (axial and radial Fe distribution in InP)

Damping of temperature fluctuations by the action of a rotating magnetic field



T-fluctuations vs. magnetic interaction parameter No = $B^2\ \omega_m\ /\Delta T$ in dependence on various B, ω_m and ΔT in fluid Ga

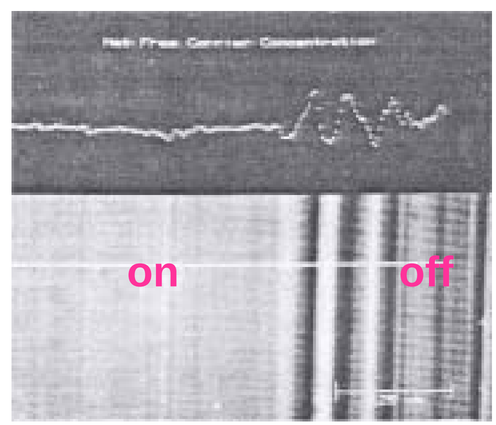
B. Fischer et al. Transfer Phenomena, Kluwer 1999, p.279 and Thesis, Univ. of Erlangen 2001 (group of G. Müller)



Amplitude of T-fluctuations vs. magnetic induction in fluid Ga
- aspect ratio H/ D = 1
- rotating magnetic field (p=2)

Dopant concentration oscillations in LEC InP crystals are damped by an steady axial magnetic field (6“ diameter, 0.2 T).

Bachowski et al. , 2nd Int. Conf. on InP 1990

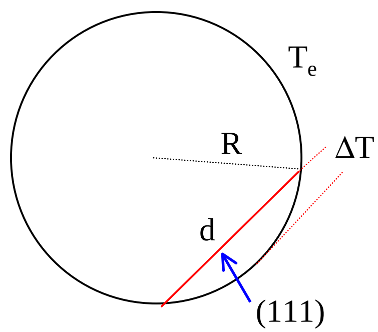


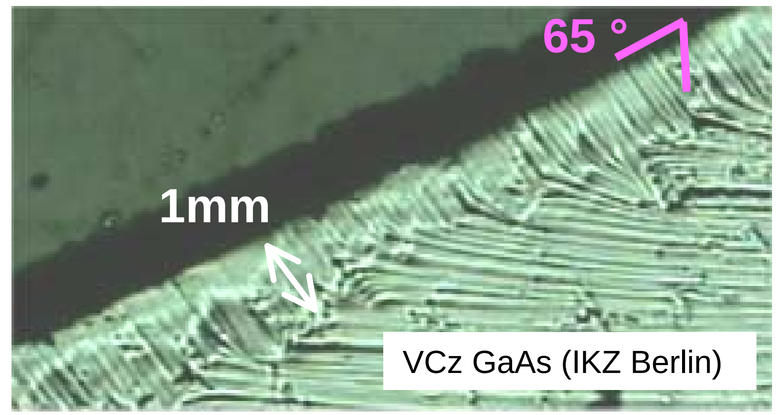
The problem of twinning at low temperature gradient growth

The facet dimension grows with decreasing *gradT*$_R$.
A twinned nucleus at a {111} facet, anchored at the three-phase boundary, is favoured if the supercooling exceeds a critical value.

$$d \approx 2\sqrt{2R\,\Delta T\,/\,gradT_R}$$

d – *facet extension*
R – *crystal radius*
T_e – *equilibrium temperature*
ΔT – *supercooling for nucleation*





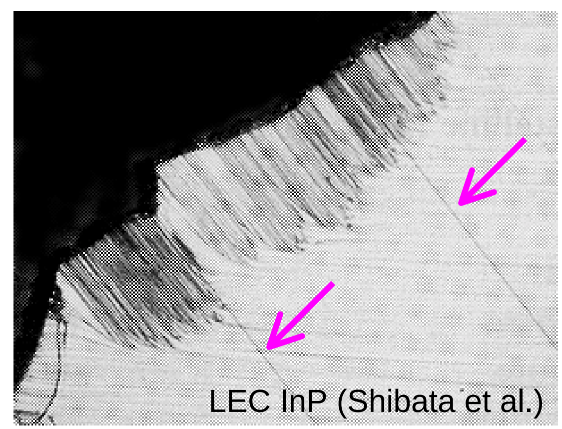
no T-fluctuations, stable facetting

no twinning *(image A. Dennstedt,IKZ)*

VCz GaAs
(IKZ)

A magnetic field damps T- fluctuations and stabi-lizes the facet growth !

T-fluctuations,
unstable facetting
twinning



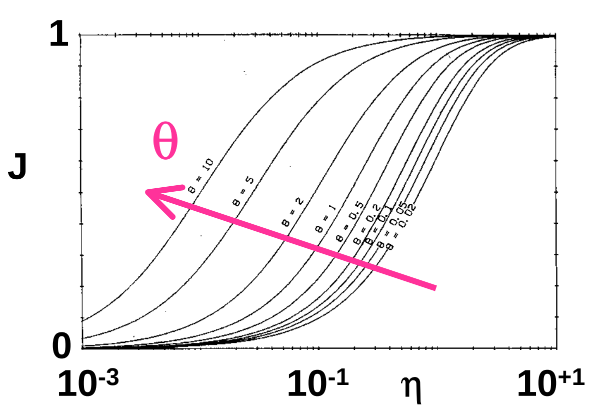
Axial dopant distribution in magnetic Czochralski growth

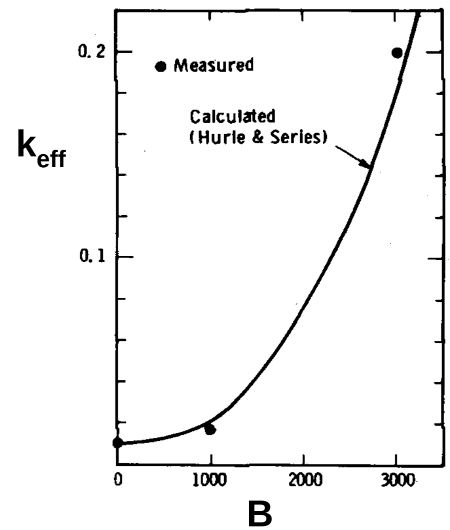
Hurle, Series JCG 73 (1985) 1:

$$\frac{C_s}{C_o} = k_{eff} = \frac{k_o}{1-(1-k_o)\,J}$$

$$J = \eta\theta^{-1/2}\int_0^{\infty}\exp\left[-\eta\theta^{-1/2}z - \ldots\right]$$

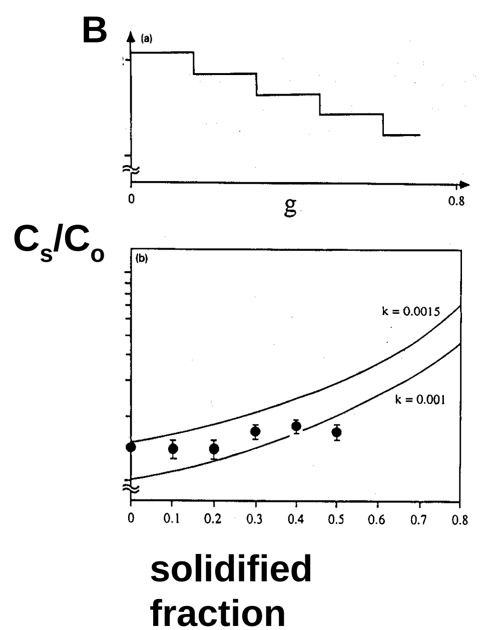
J - normalized boundary layer thickness
z - distance from the interface (disc)
η - $V_o/D\,(\nu/\Omega)^{-1/2}\,Sc^{-1/4}$
θ - $N'\,Sc^{-1/2}$
N' - magnetic interaction parameter
$= B^2\sigma/\rho\Omega + 0.427$





k_{eff} vs. magnetic field strength of Ga in Si

Ravishankar et al. JCG 104 (1990) 617



Step-wise reduction of B to minimise macro-segregation in Fe-doped LEC InP

Hofmann et al., SI III-V, Malmö 1988, p.429

Summary and outlook

- Steady and unsteady magnetic fields can help to damp numerous convection related problems, also in case of VCz growth, very effectively.
- Constant transverse or axial magnetic fields are already succesfully applied in 2 - 3 inch LEC growth of GaAs and InP. Recently, the VCz growth of 4-inch InP crystals under constant magnetic field was brought to Sumitomo`s production maturity
- The temperaure fluctuations and, hence twinning probability, were reduced markedly.
- A nearly uniform axial Fe distribution in InP crystals can be achieved due to the increase of k_{eff} towards unity.
- Magnetically drived flows are an excellent additional handle parameter to tailor the crystal growth process of III-Vs (InP).

☞ Preparation of a new project "MVCz growth of InP" (BMBF or ..?).

Possible partners: IKZ, FZ Rossendorf, Univ. Hannover/Riga, FCM, …