

production of EG-Si monocrystals

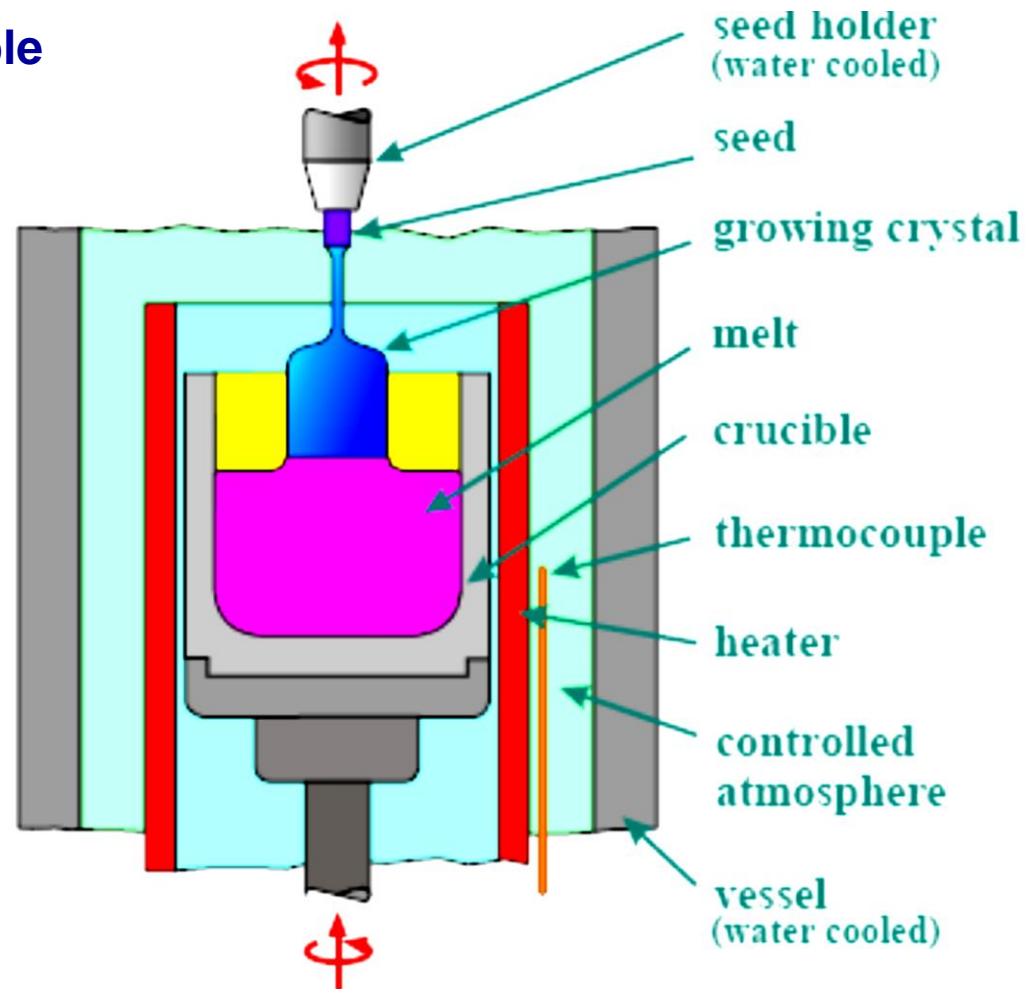


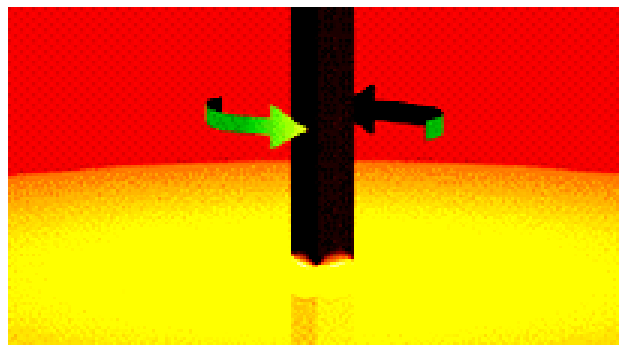
Czochralski method = **pulling**

advantage:

no contact of crystal with **crucible**
→ **min structural defects**

- **temperature** 1412 °C
- **crystal seed** (100) or (111)
- **crucible** SiO₂ (~ stable)
- **Ar flow** (SiO)
- crucible rotation 10-15 min⁻¹
- **crystal rotation** (diameter)
- **pull** 1-5 mm/min (diameter)

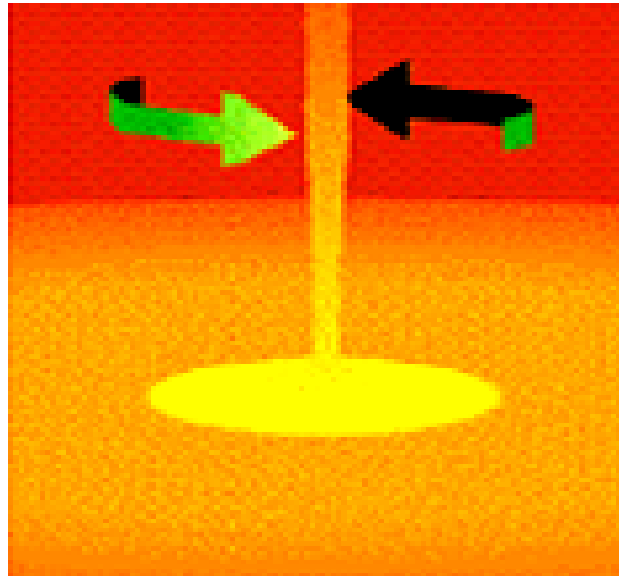




crystal seed

(100) or (111) plane

thermal shock → defects

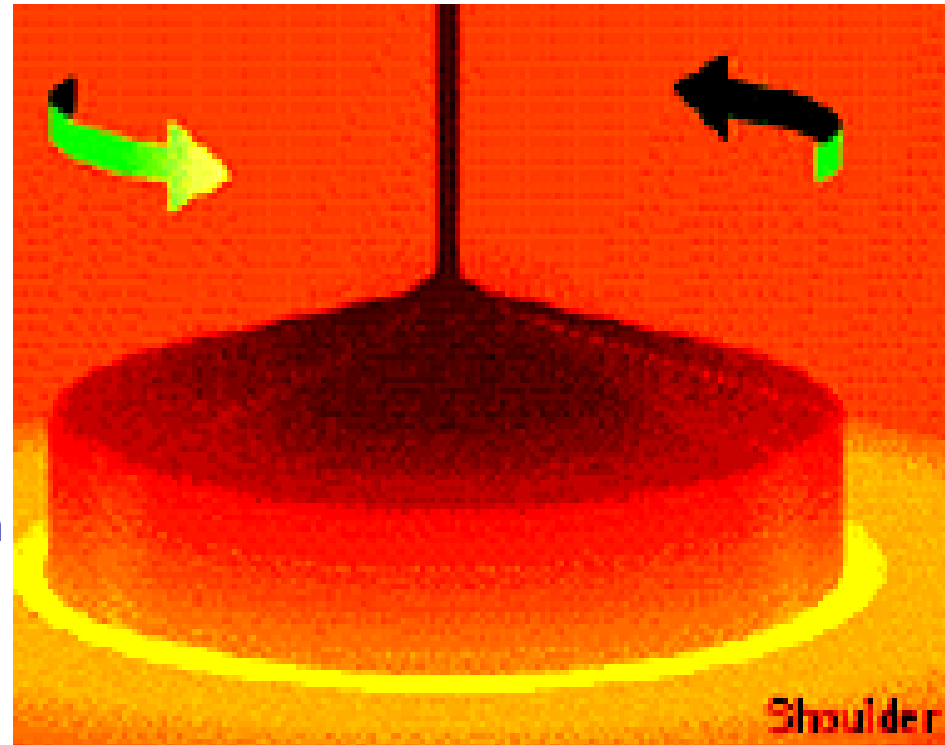


high pull rate → „neck” → min defects

increasing pull rate → reverse cone → fewer defects

pull rate diminished → diameter increased

constant diameter growth



impurity and dopant segregation

- ✓ refining
- doping level is not constant

segregation coefficient $k = C_{\text{solid}}/C_{\text{liquid}}$

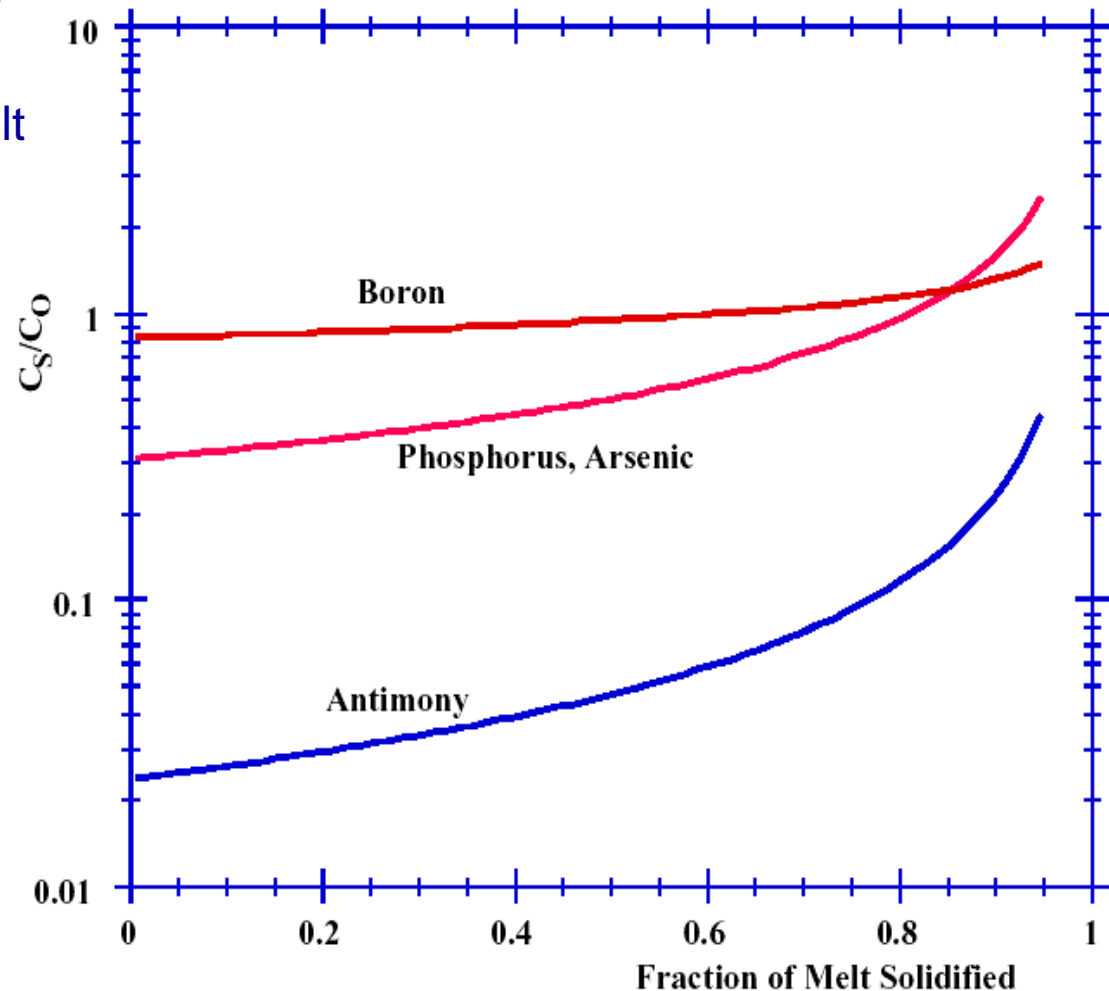
$$C_s = k \cdot C_o \cdot (1 - x)^{k-1}$$

x – crystallization degree

C_o – initial concentration in melt

C_s – concentration in crystal

	k
B	0,8
P	0,35
As	0,3
Sb	0,02
Ge	0,03
Mn	0,00001
Cu	0,000004

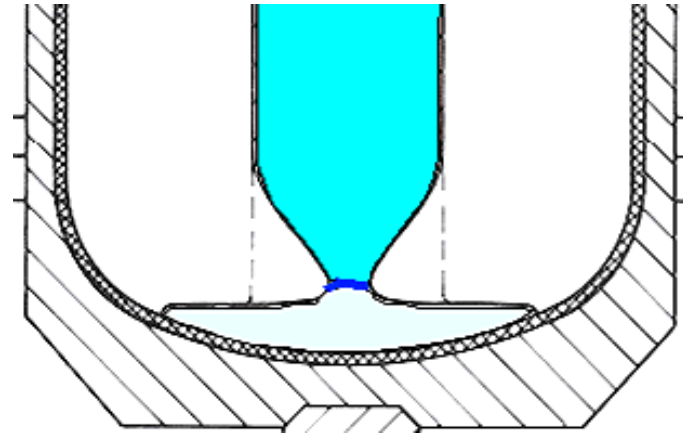




top part: hi purity
cut off → remelting

different dopant concentration →
different conductivity → control (^{32}P)

Impure end part → purification



crystal is deeper in crucible → temperature profile is changed continuously

- heating power (hi frequency)
- **rotation rate**
- pulling rate

A screenshot of the CrysVUN++ software interface. The window title is "CrysVUN++". The menu bar includes "File", "Edit", "Mode", "Show", "Compute", "Options", and "Help". The status bar shows coordinates "x=-0.02288653 y= 1.14256629" and a file path "...respect/prom_g.crys".
Solver Informations
Energy In: 62266 Watt
Energy Out: 62266 Watt
Det. of Source Correction: 2.77086E-09
Grid Generation: 0 s CPU, 0 s real
View factors: 373 s CPU, 443 s real
Matrix construction: 77 s CPU, 124 s real
Regler: 88 s CPU, 172 s real
Linear system solver: 108 s CPU, 189 s real
Total CPU time: 658 s CPU, 4486 s real
Actual residuum: 5.15788E-10
Outer iterations: 117
A line graph shows two data series (red and blue) over a range from 0 to 104.76. The y-axis values are 0.3095042 and 4.39366E-13.
Heaters
20 P(W) 1000.000 T(K) 1511.0
19 P(W) 8020.762 T(K) 1511.0
Reg 0.0003 x(m) 3.750 Reg 0.0003 x(m) 3.0
0.0003 y(m) 4.000 0.0003 y(m) 3.0
Solver Properties
Matrix Preconditioner:
 DIAG ILU
Iterativ Matrix Solver:
 BICG CGS
 STABICG IR
Outer residuum: 1e-12
Div. factor for inner residuum: 16
Max. no. of outer iterations: 588
Max. no. of inner iterations: 1888
Direct relaxation factor: 0.7
Regler relaxation factor: 0.5
Save File
Filter: home/pusztai/crysvun/*.*.crys
Directories: ma/pusztai/crysvun/ []
ma/pusztai/crysvun/
Selection: ingko/home/pusztai/crysvun/
Buttons: Save, Filter, Cancel



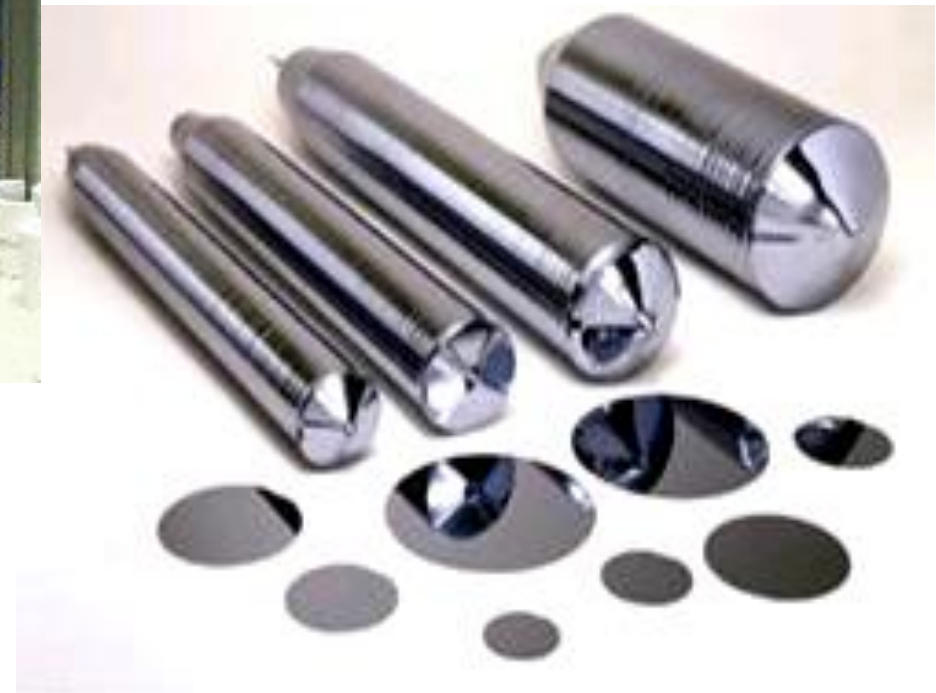
industrial puller

~ 90% EG-Si

**advantage:
large diameter 300-400 mm**

versatile:

- **Si, Ge**
- **GaAs, GaN**
- **CsI, KBr, CaF₂**
- **LiNbO₃, YAIO₃**



Zone Melting (1952)
melted drop is moved along a crystal

