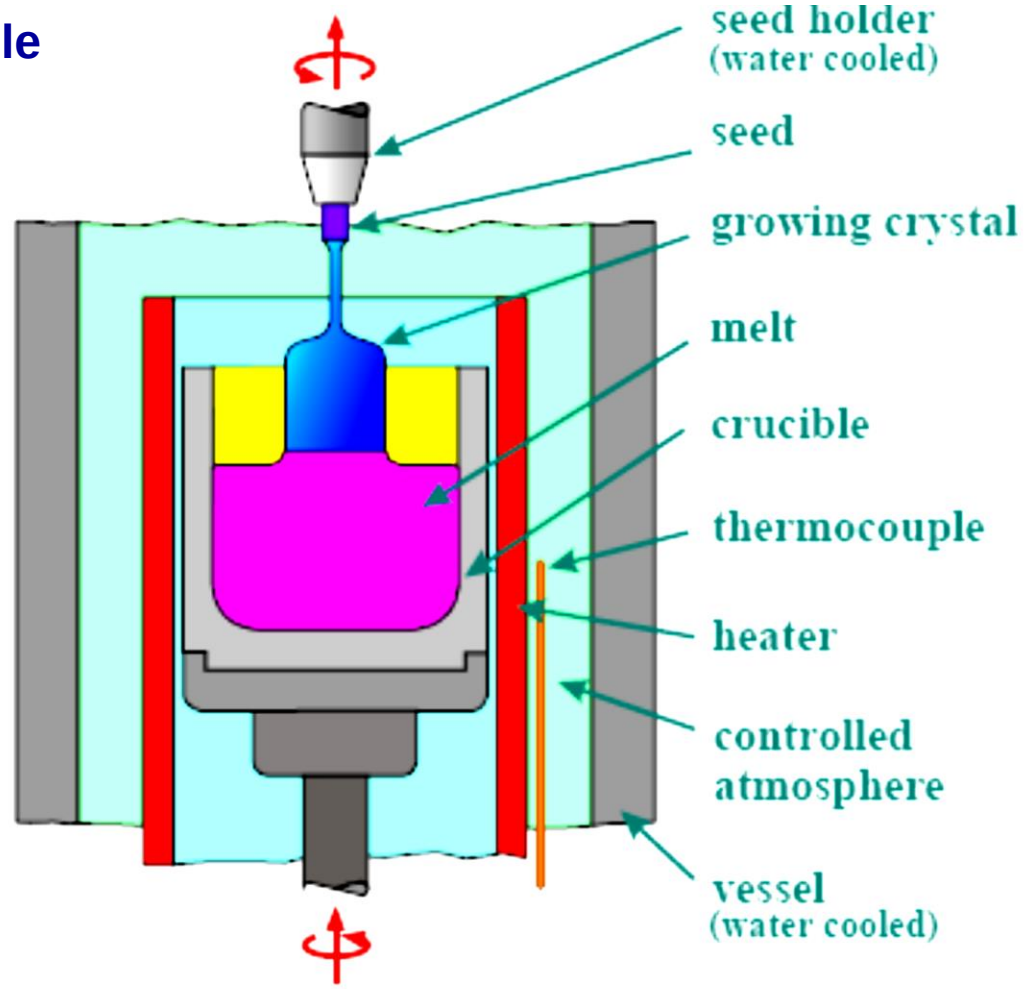
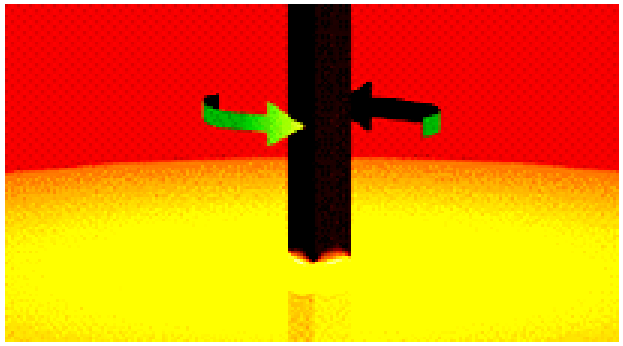
production of EG-Si monocrystals

Czochralski method = **pulling**

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

- **temperature** 1412 °C
- **crystal seed** (100) or (111)
- **crucible** SiO_2 (~ stable)
- **Ar flow** (SiO)
- crucible rotation 10-15 min^{-1}
- **crystal rotation** (diameter)
- **pull** 1-5 mm/min (diameter)

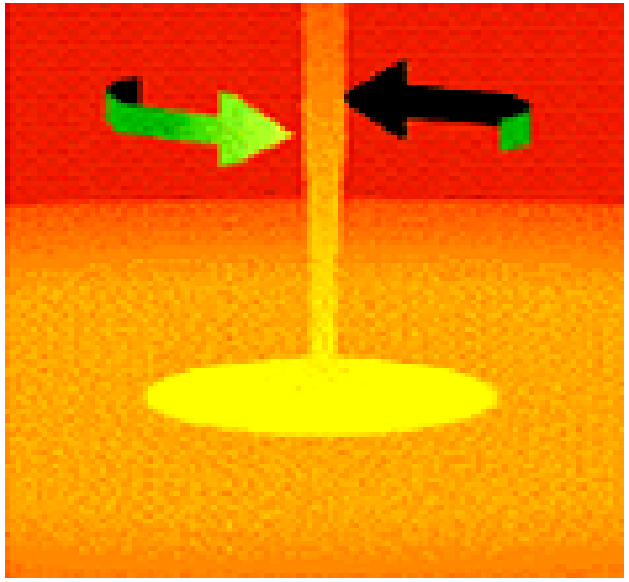




crystal seed

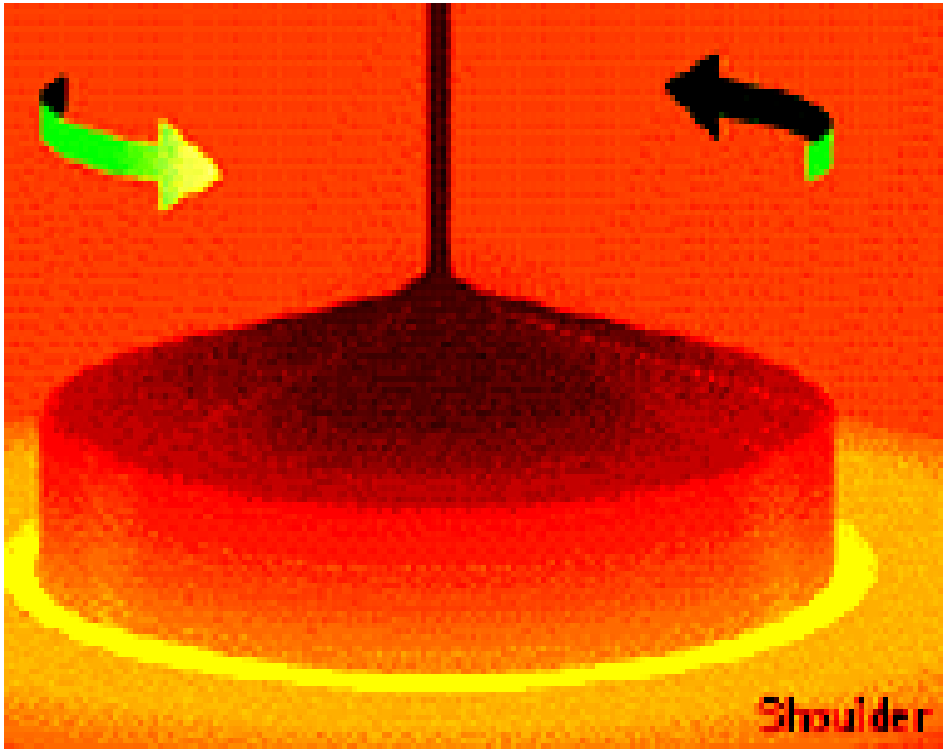
(100) or (111) plane

thermal shock → defects



high pull rate → **„neck”** → min defects

increasing pull rate → reverse cone → fewer defects



pull rate diminiszed → diameter increased

constant diameter growth

impurity and dopant segregation

✓ refining

• **doping level is not constant**

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

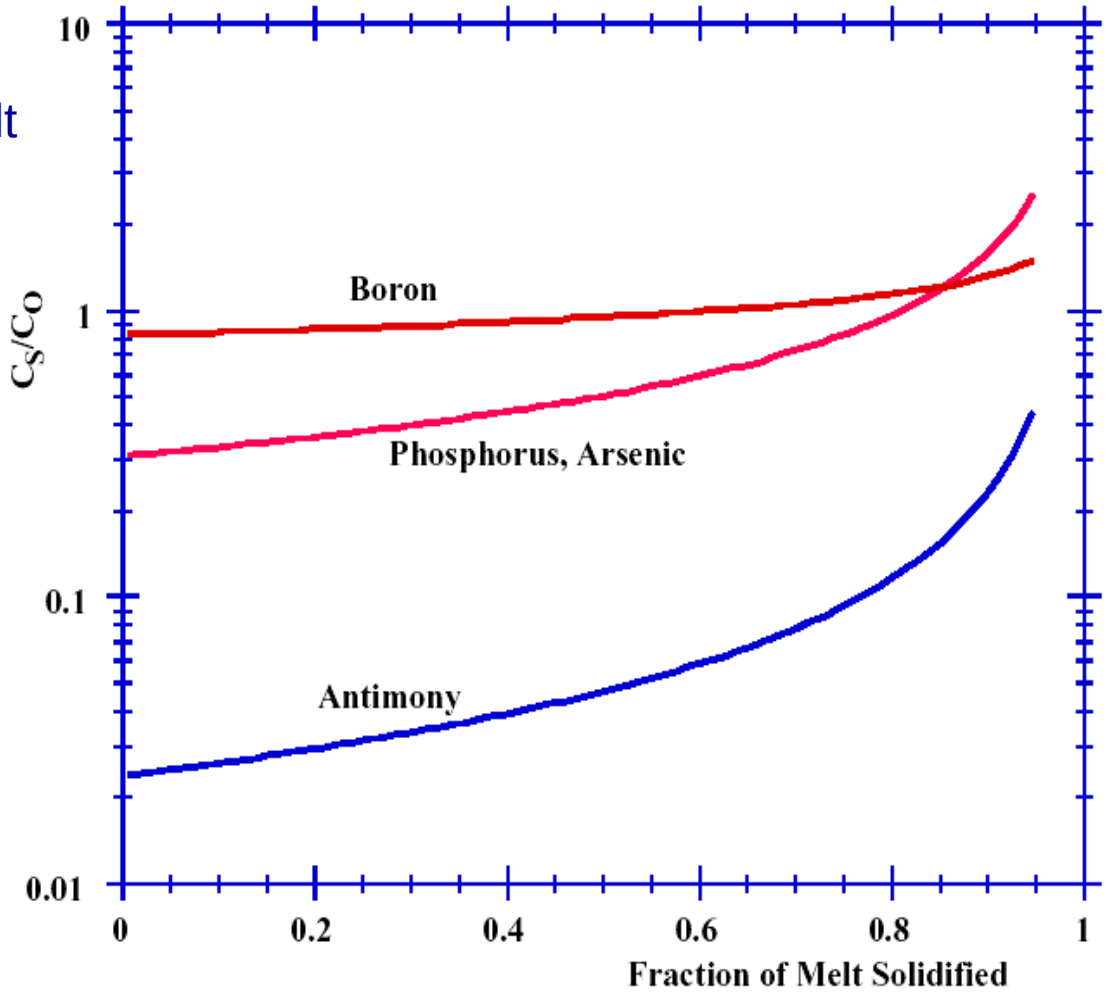
$$C_s = k \cdot C_o \cdot (1 - x)^{k-1}$$

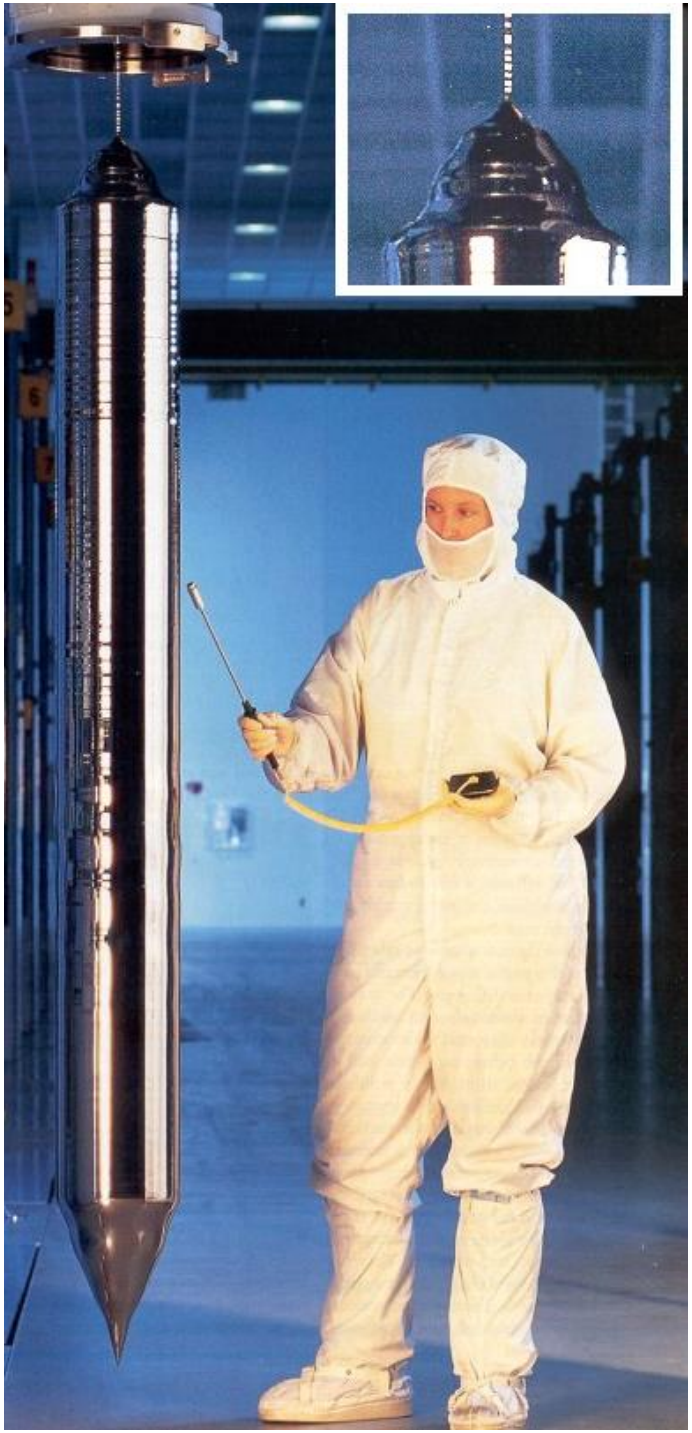
x – crystallization degree

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

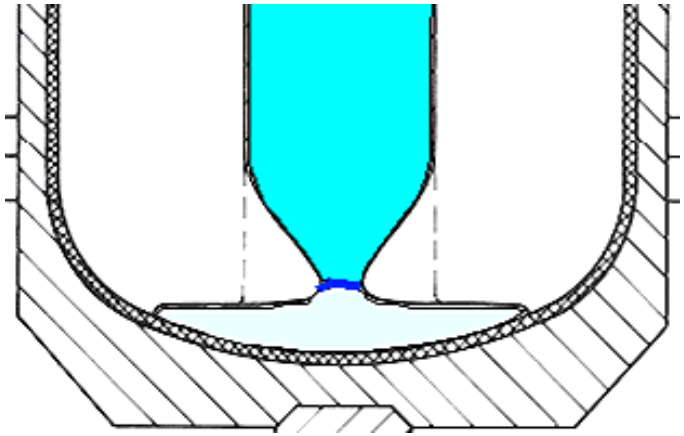




top part: hi purity
cut off → remelting

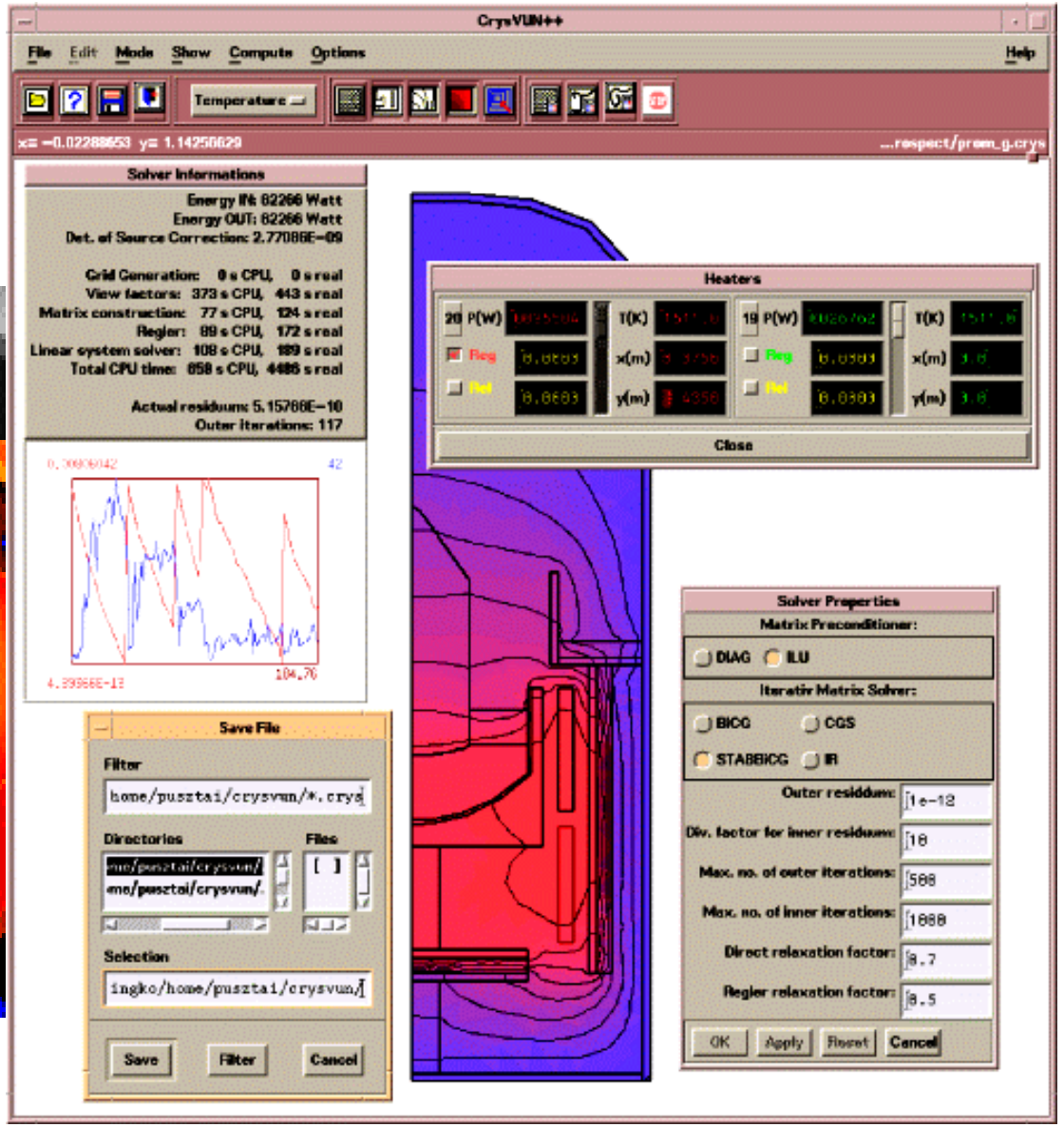
different dopant concentration →
different conductivity → control (^{32}P)

Impure end part → purification



crystal is deeper in crucible → temperature profile is changed continuously

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



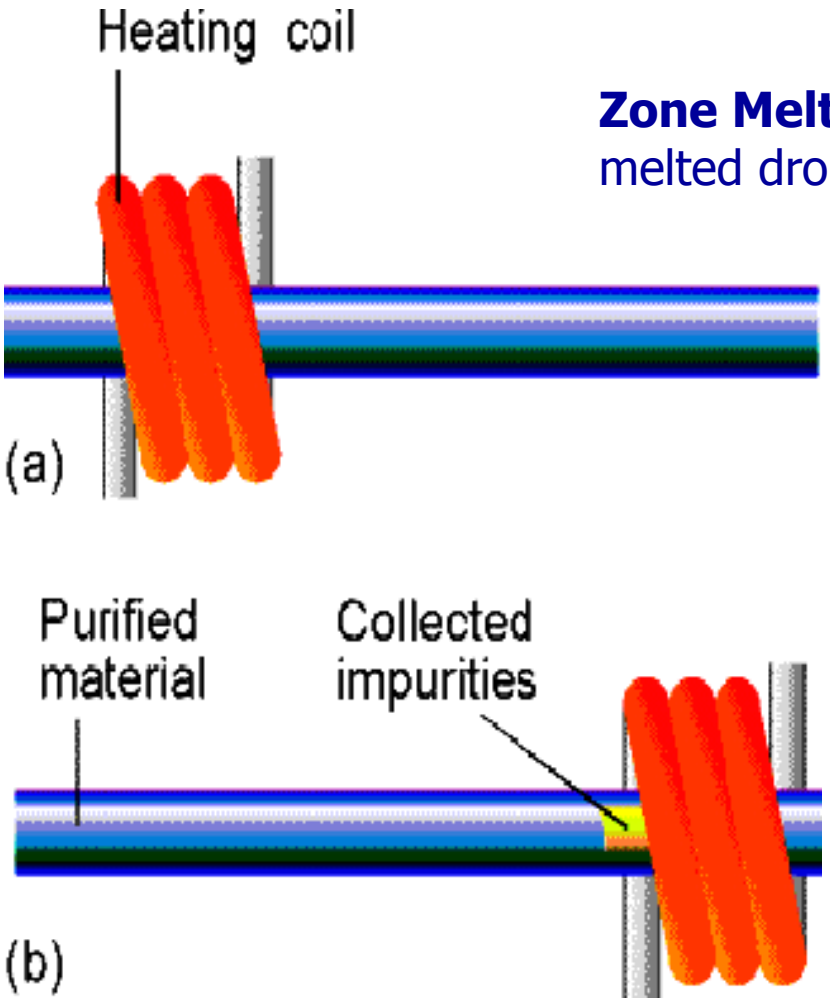
industrial puller

advantage:
large diameter 300-400 mm

versatile:

- **Si, Ge**
- **GaAs, GaN**
- CsI, KBr, CaF_2
- $LiNbO_3$, $YAlO_3$

~ 90% EG-Si



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