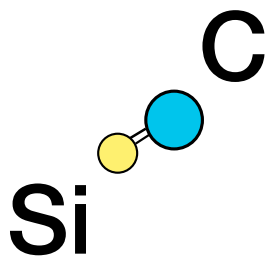
Optical properties of free-standing cubic silicon carbide

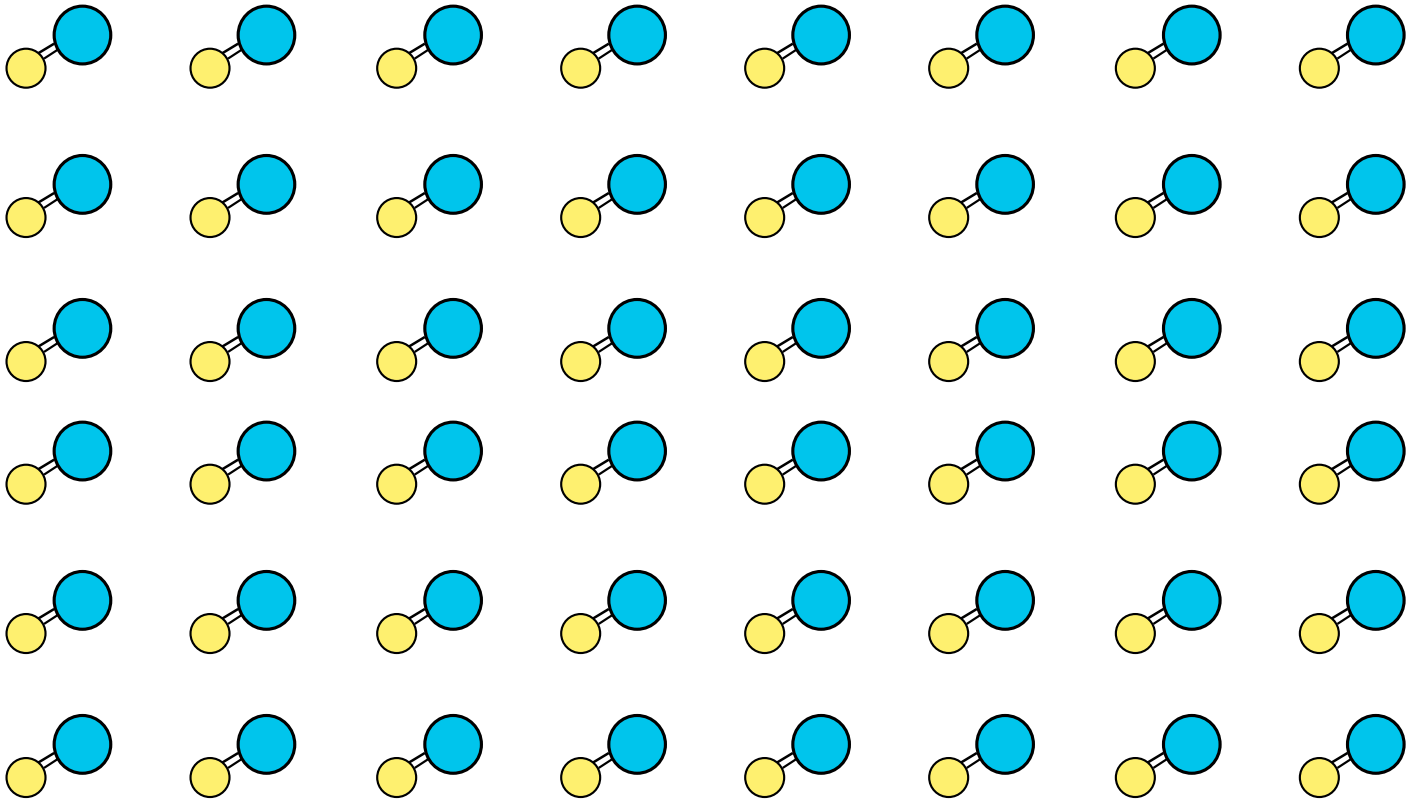
Mattias Jansson

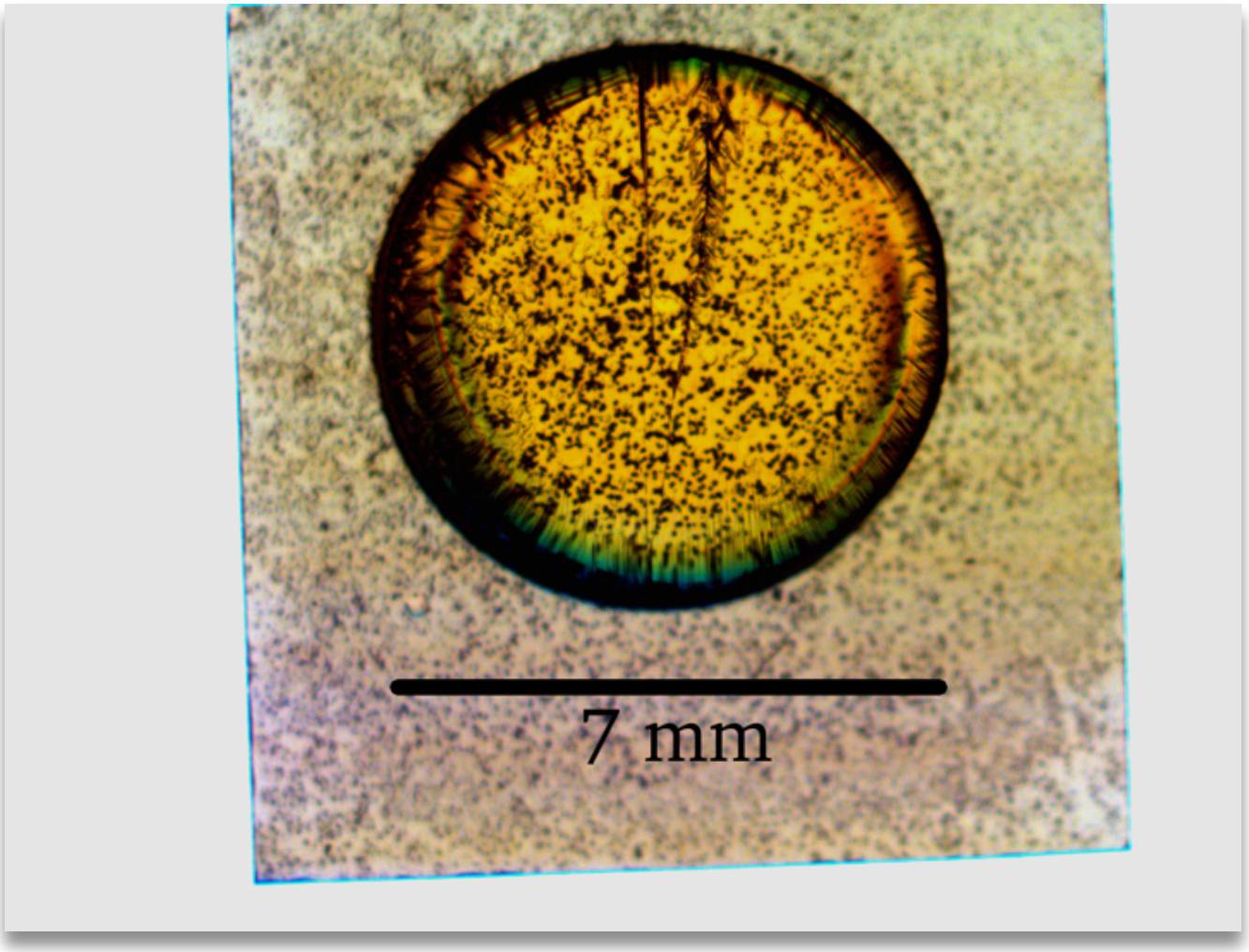
LINKÖPING UNIVERSITY

Outline

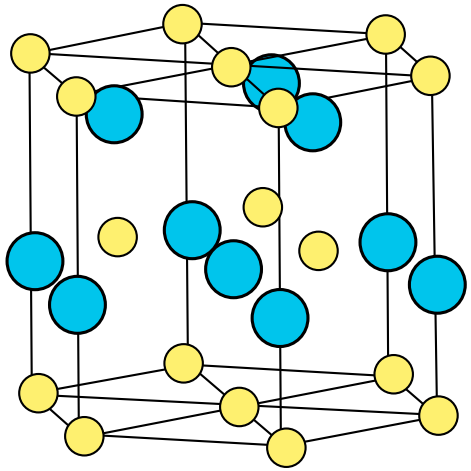
- Introduction to silicon-carbide
- About growth
- About optical characterization


C
Si

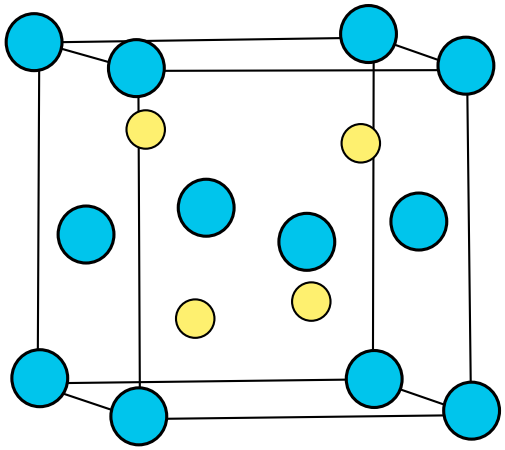



7 mm

Polytypes - atomic arrangements

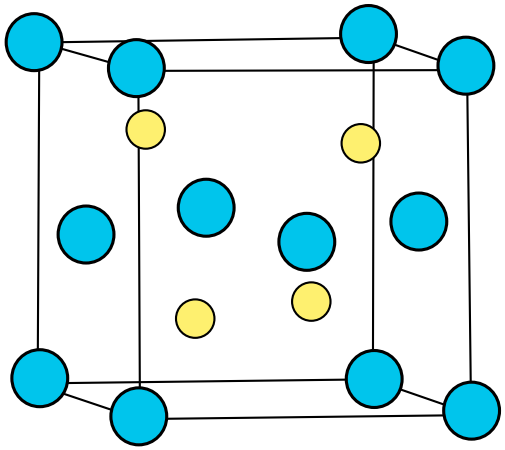


Hexagonal

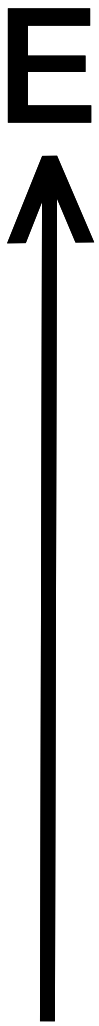


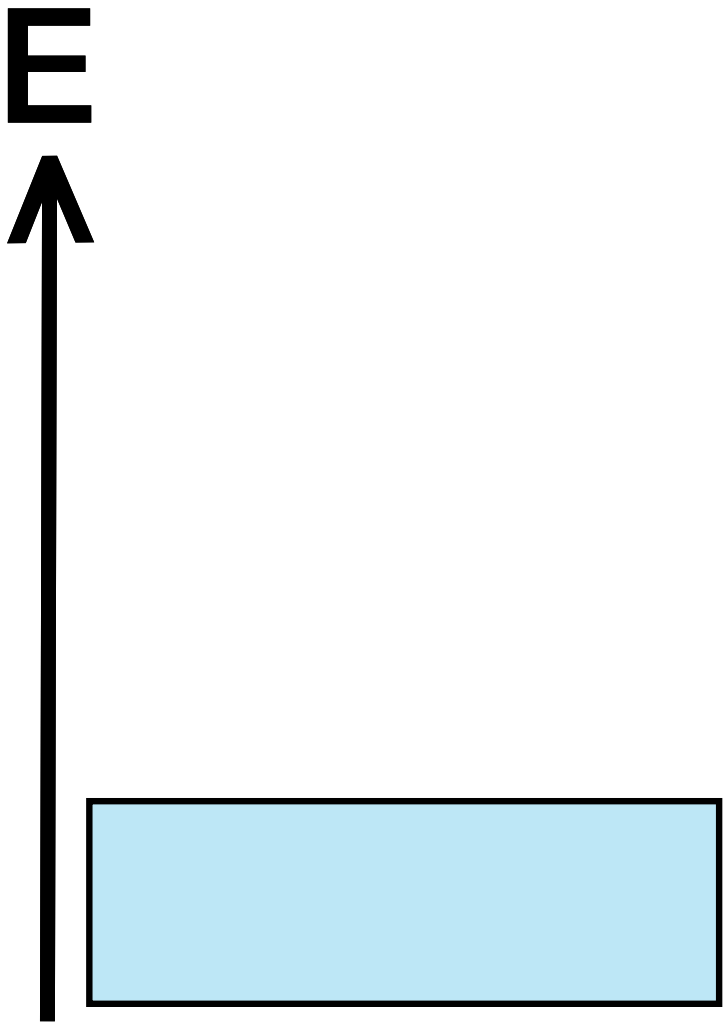
Cubic

Polytypes - atomic arrangements

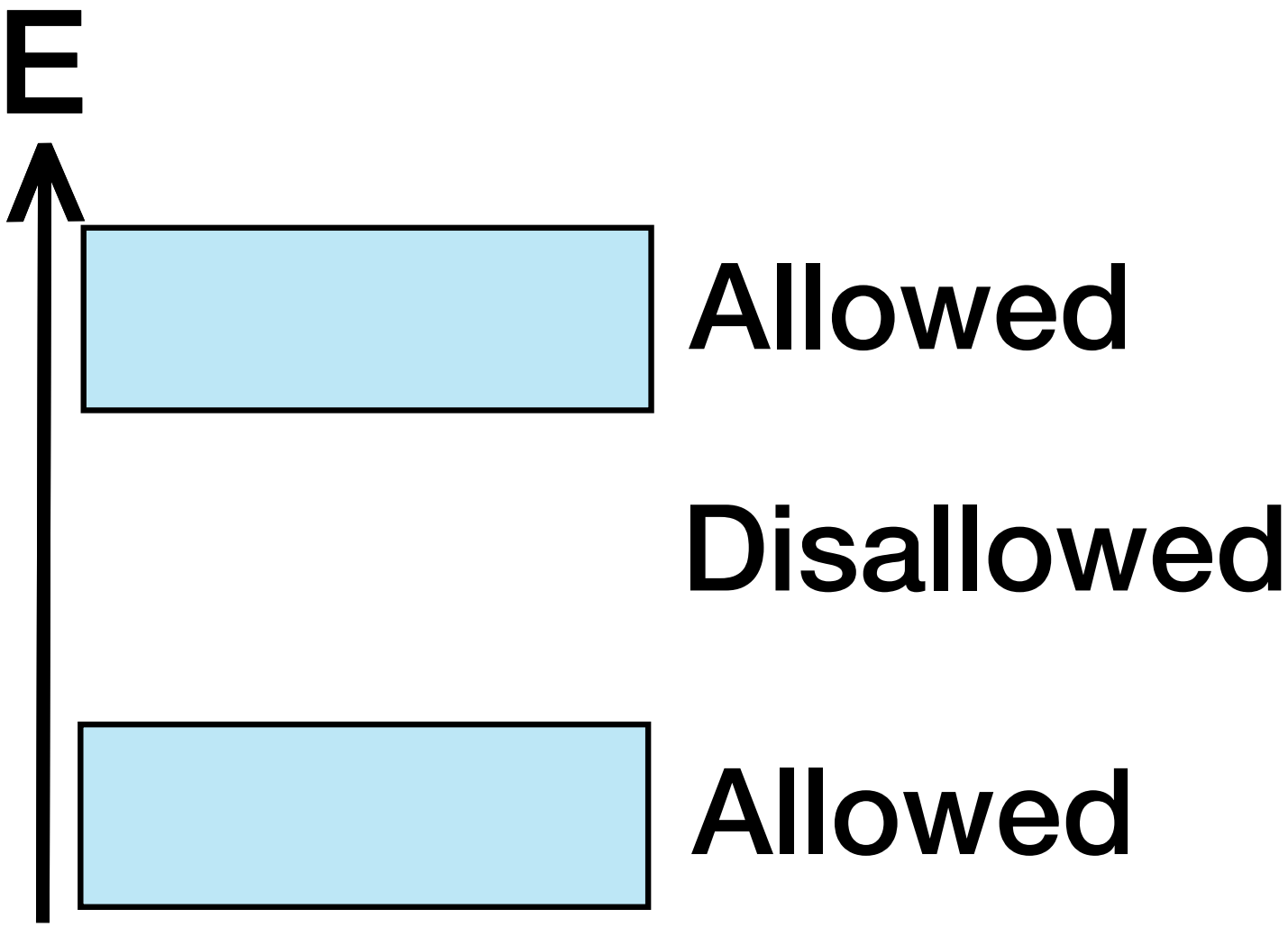


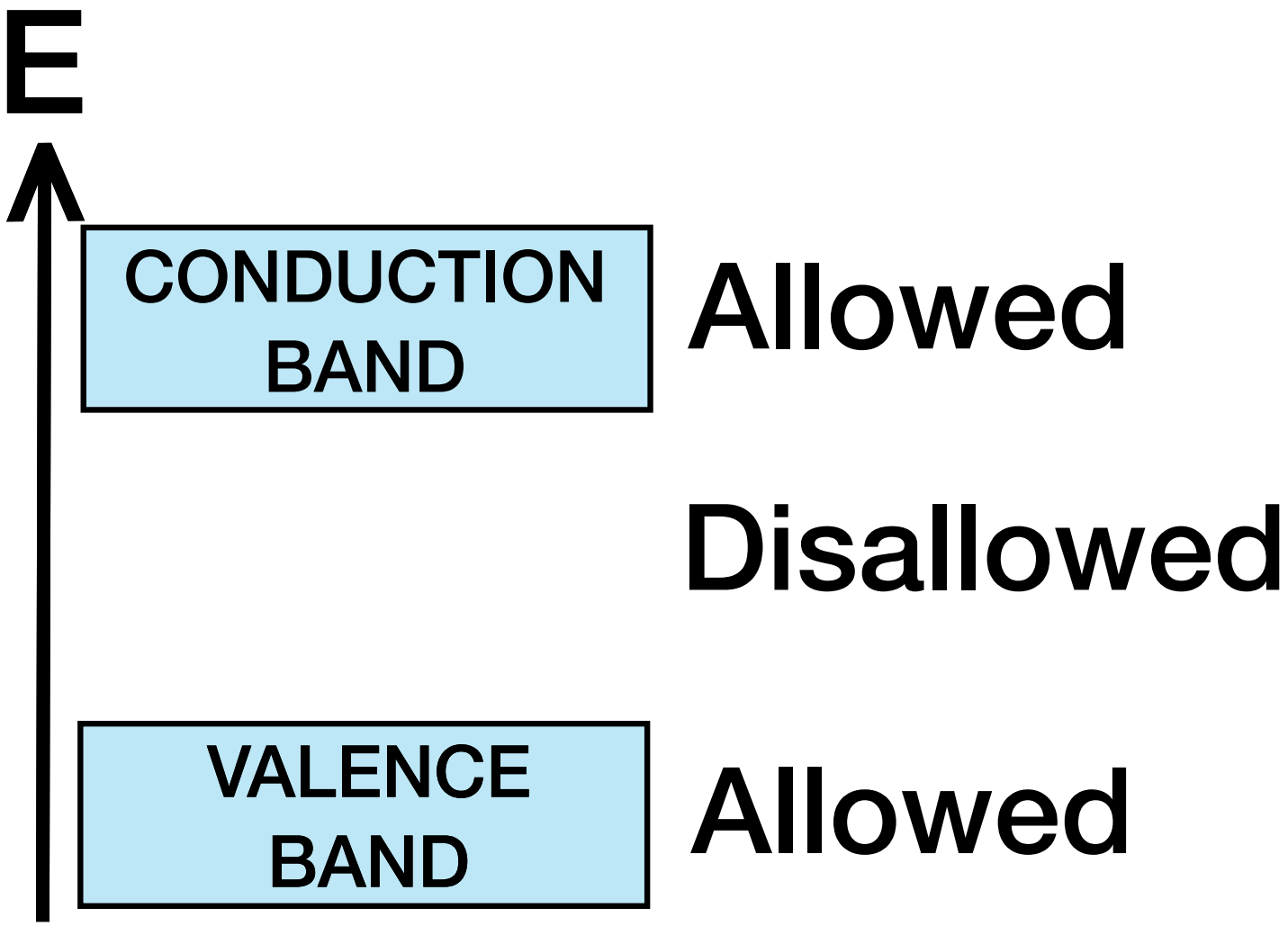
Cubic
3C-SiC

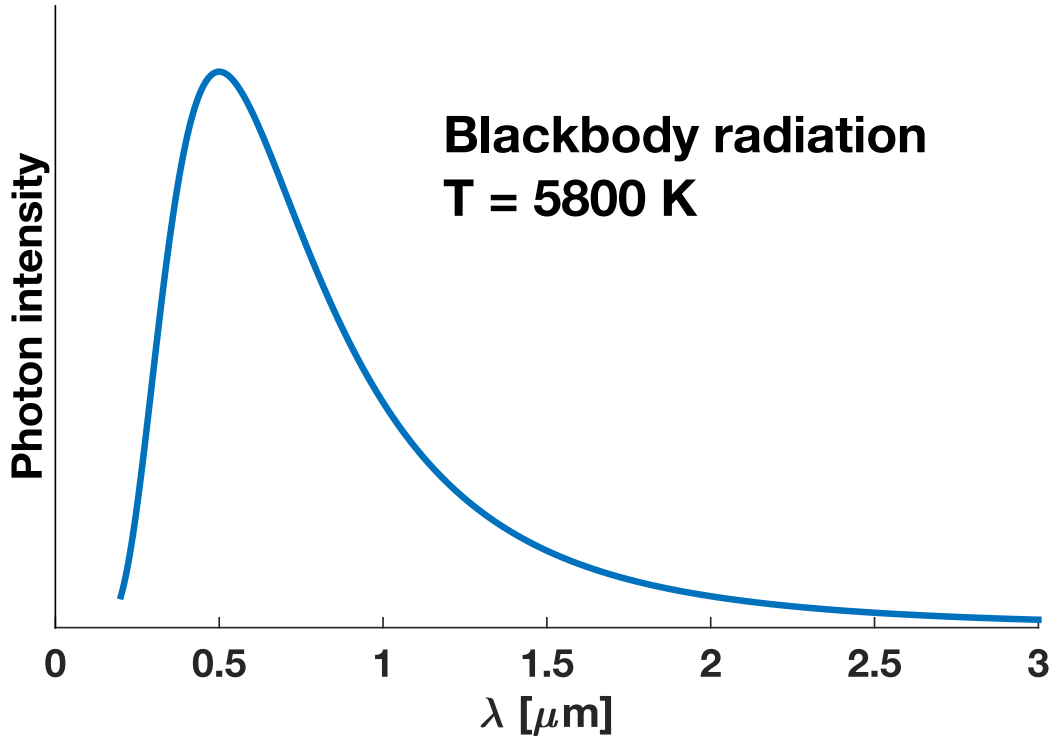

E

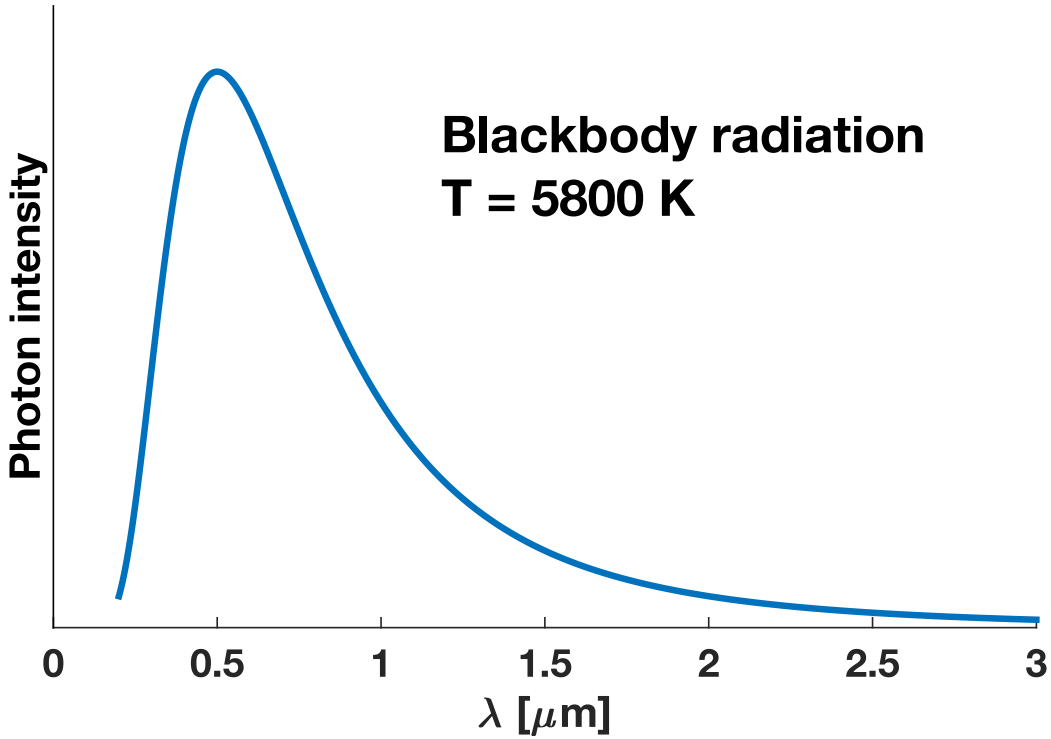


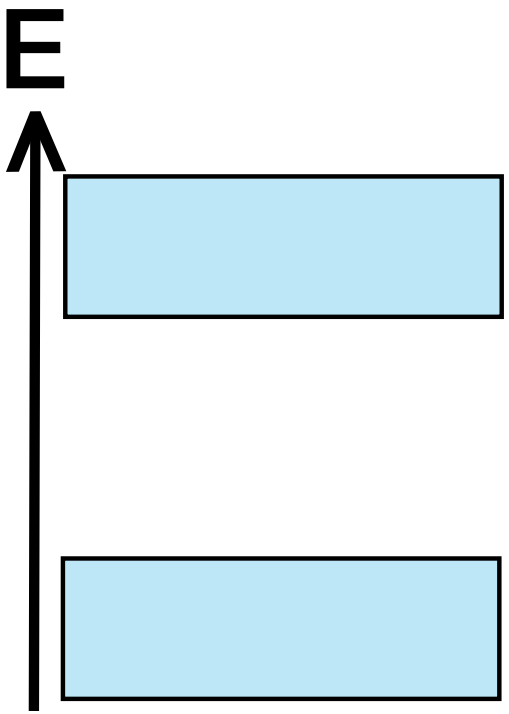
Allowed

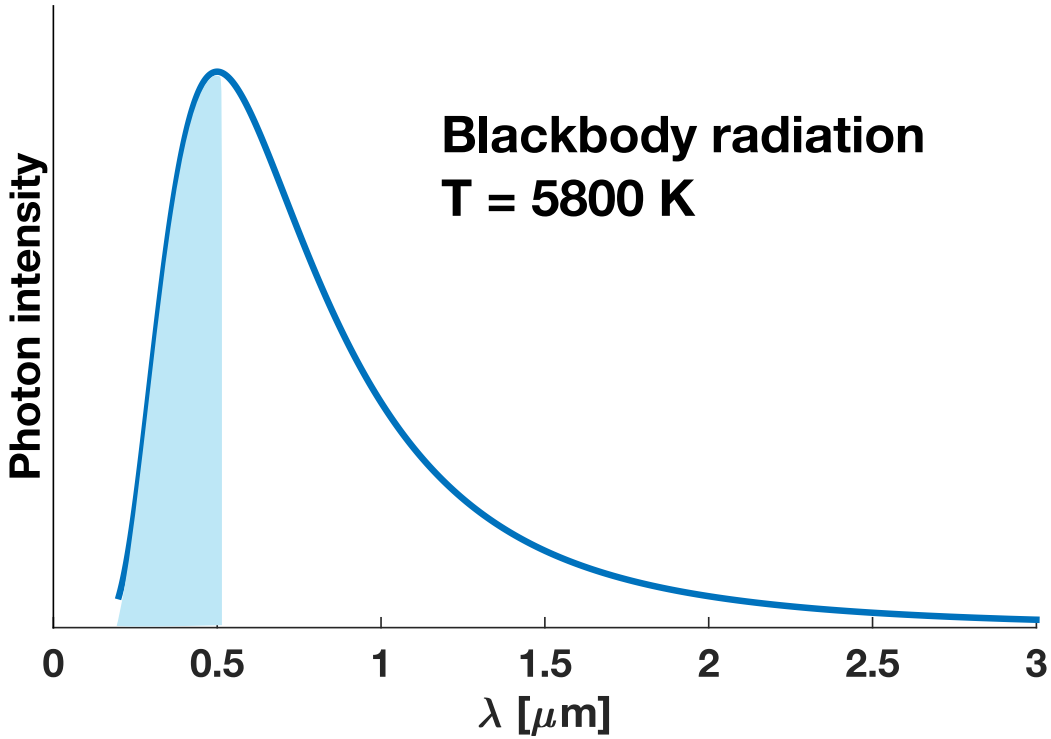

E
Allowed
Disallowed
Allowed

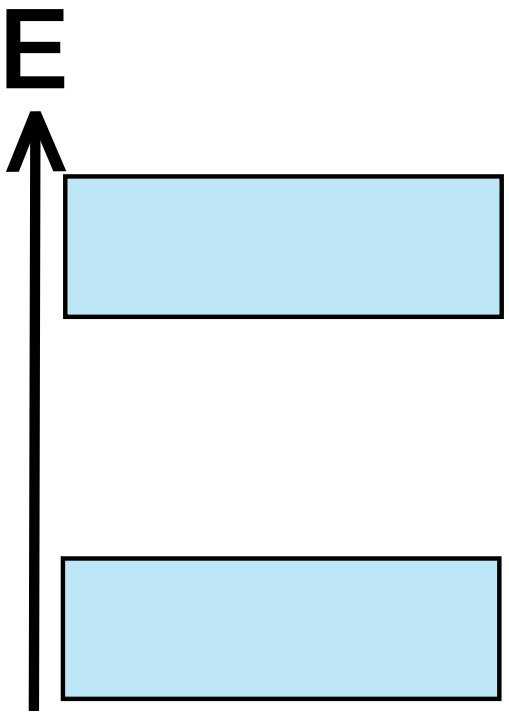

E
CONDUCTION BAND
Allowed
Disallowed
VALENCE BAND
Allowed

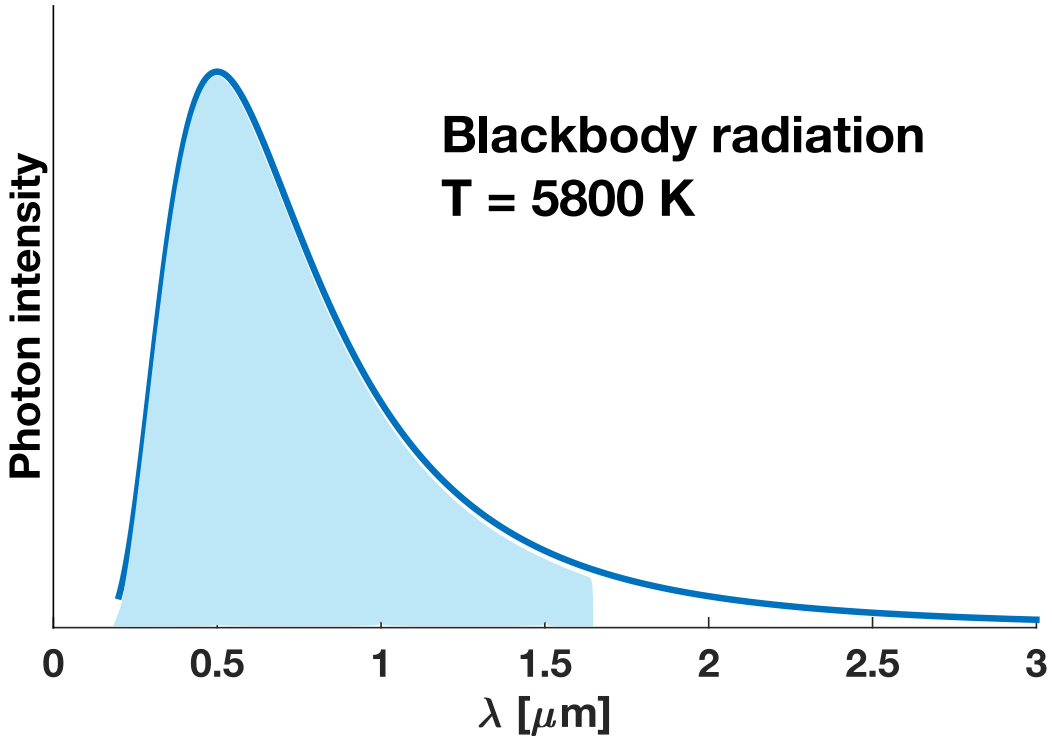

Blackbody radiation
T = 5800 K
Photon intensity
0
0.5
1
1.5
2
2.5
3
λ [μm]

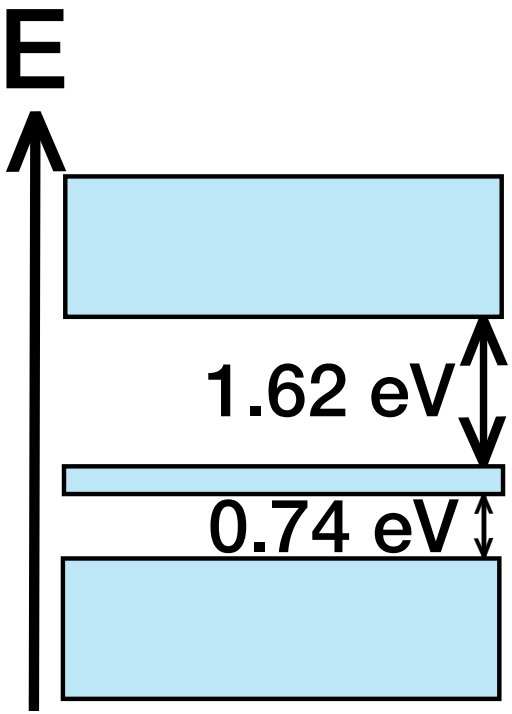

Blackbody radiation
T = 5800 K
Photon intensity
0
0.5
1
1.5
2
2.5
3
λ [μm]


E


Photon intensity
Blackbody radiation
T = 5800 K
0
0.5
1
1.5
2
2.5
3
λ [μm]


E


Blackbody radiation
T = 5800 K
Photon intensity
0
0.5
1
1.5
2
2.5
3
λ [μm]


E
1.62 eV
0.74 eV

My contributions

My contributions

- Growth of boron-doped samples

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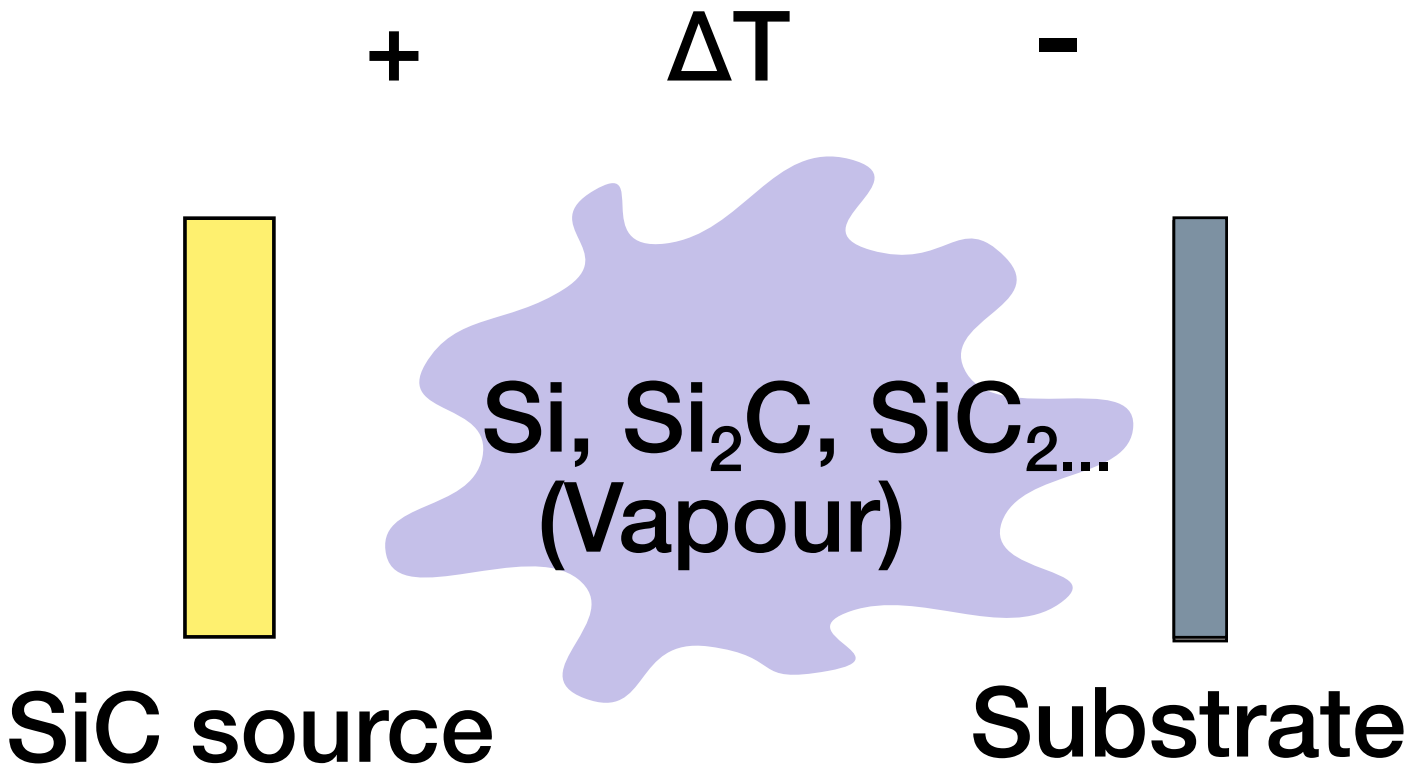
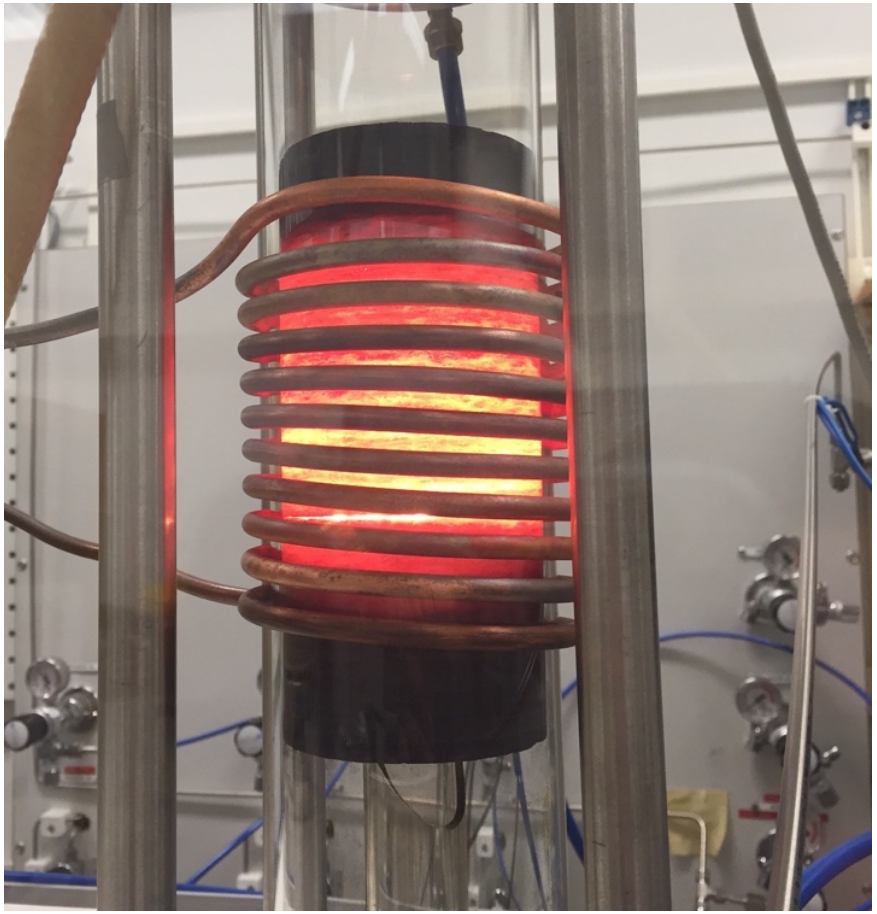
- Optical characterization

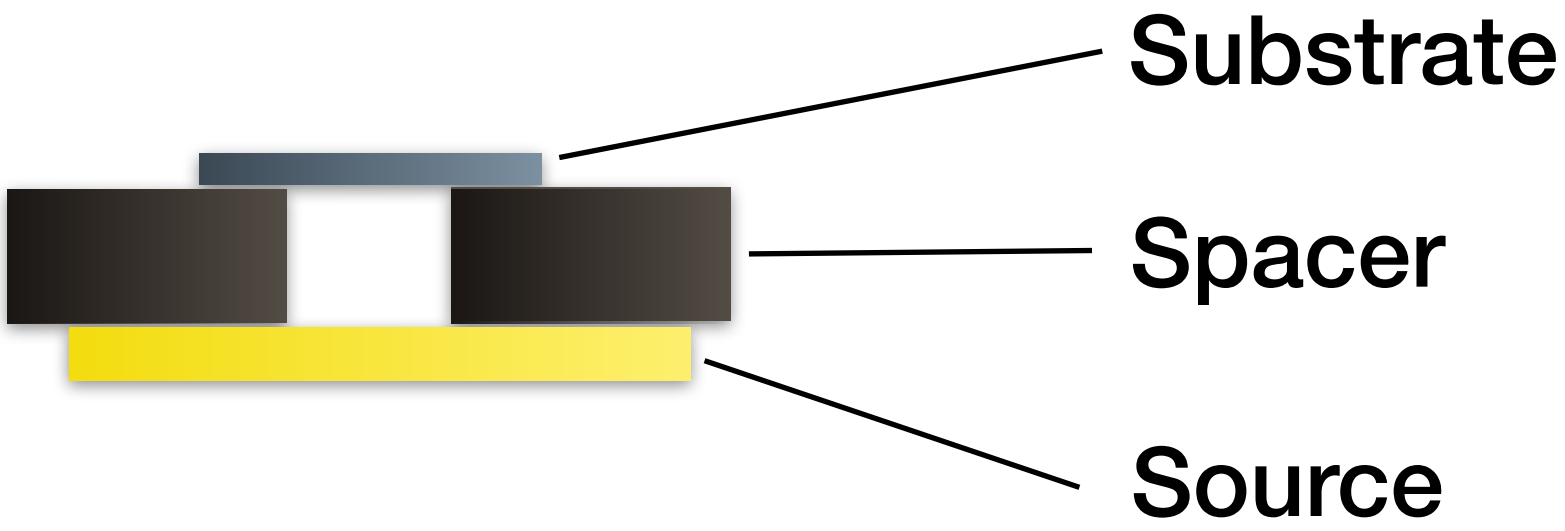
Sublimation growth



The reactor

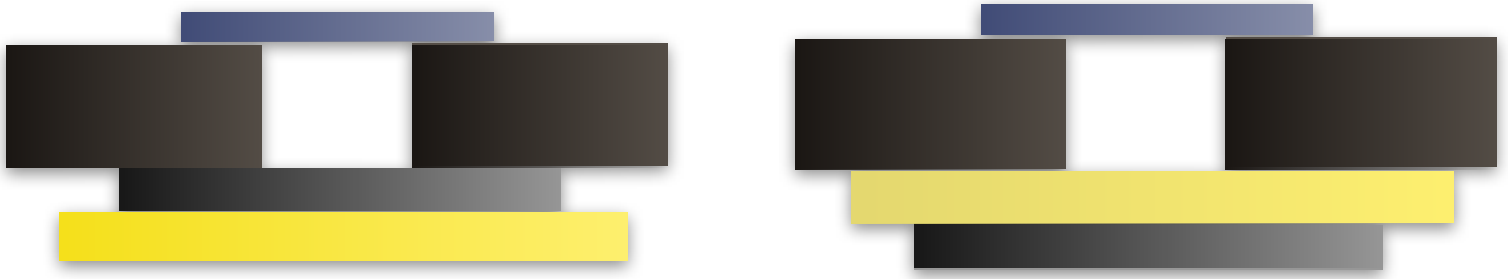


The growth setup

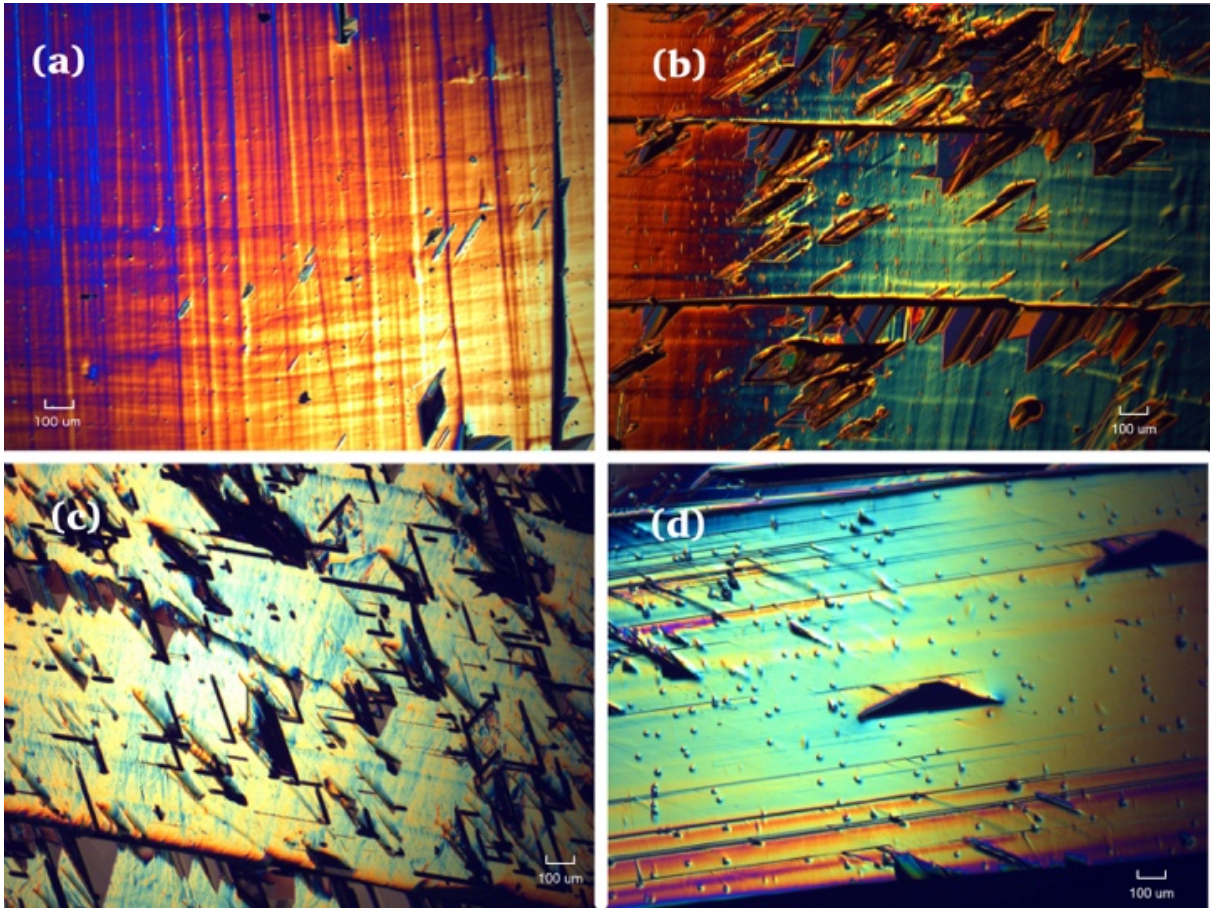


Investigated parameters

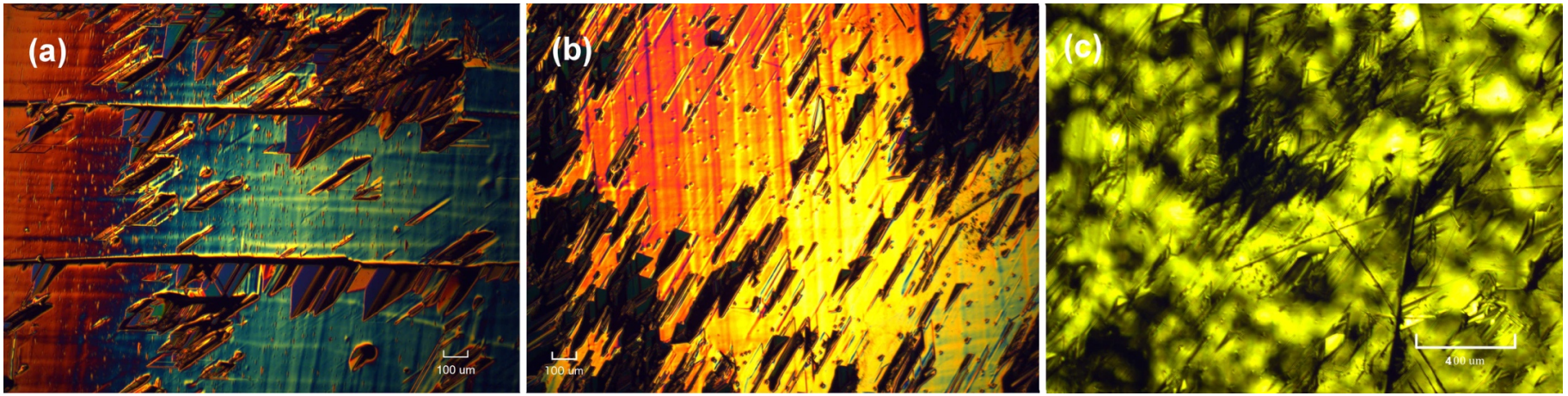
- Doping concentrations (10^{18} - 10^{20} cm^{-3})
- Growth on 3C seed or 4H substrate
- Direct or indirect doping method



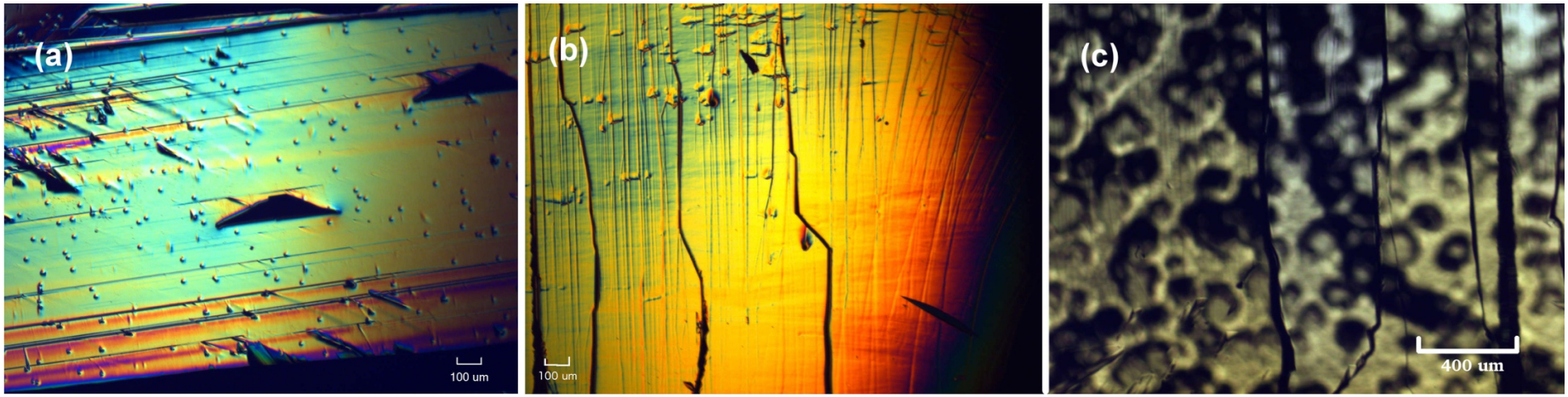
Doping concentrations



Indirect/direct doping, 10^{18} cm^{-3}

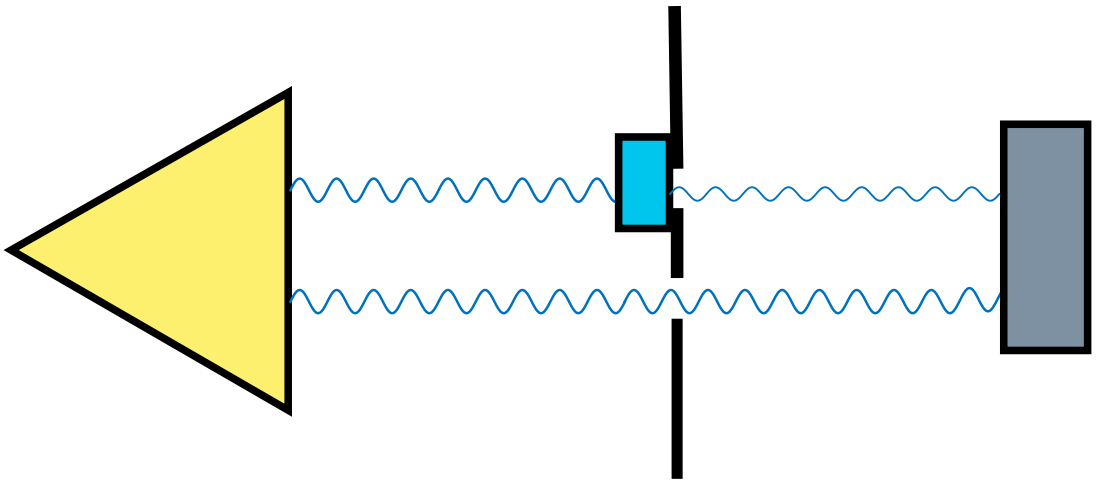


Indirect/direct doping, 10^{20} cm^{-3}

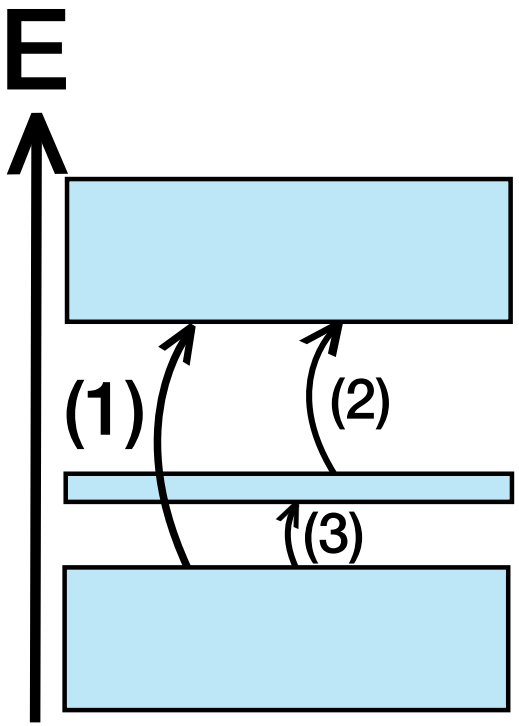


Absorption spectroscopy

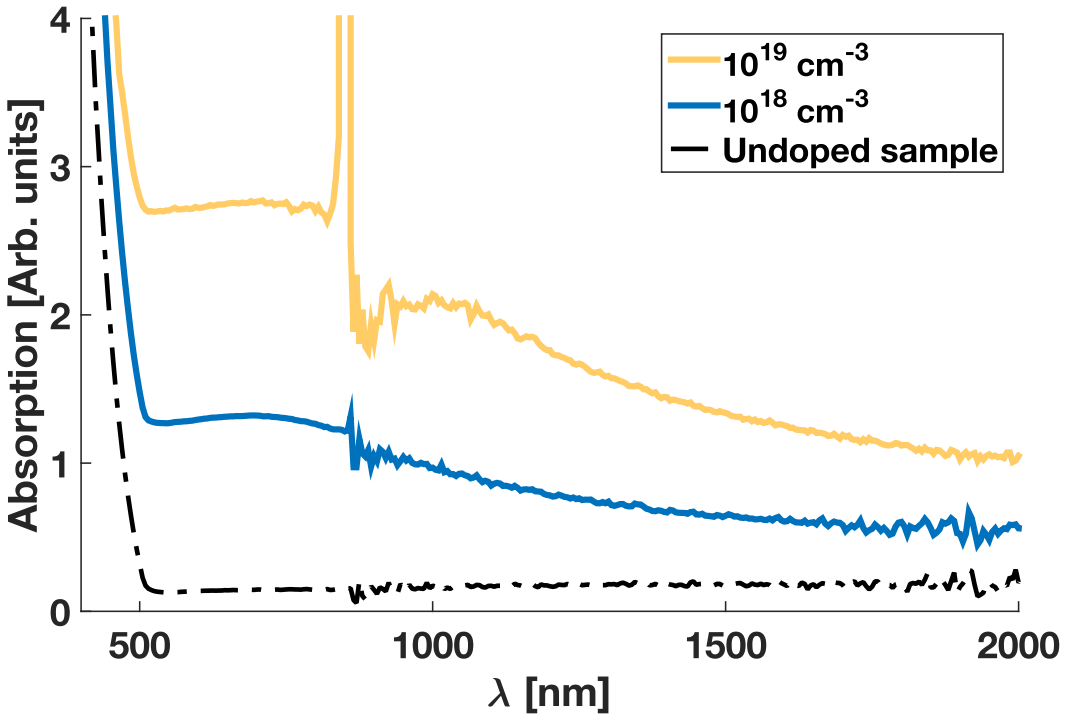
Absorption spectroscopy

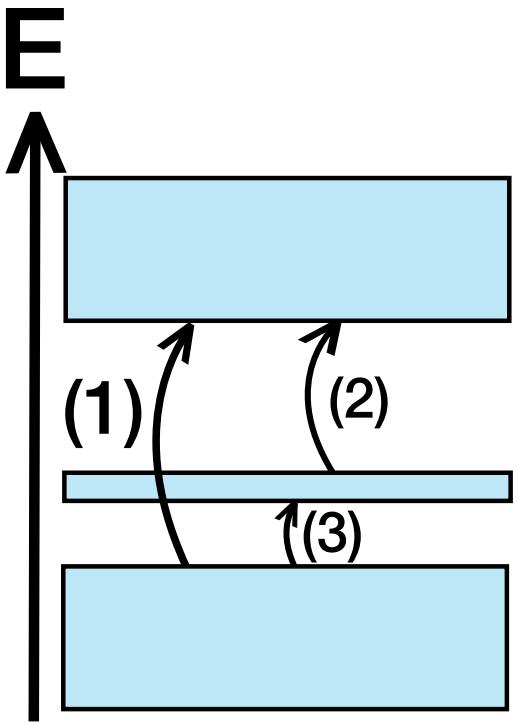


Absorption spectroscopy

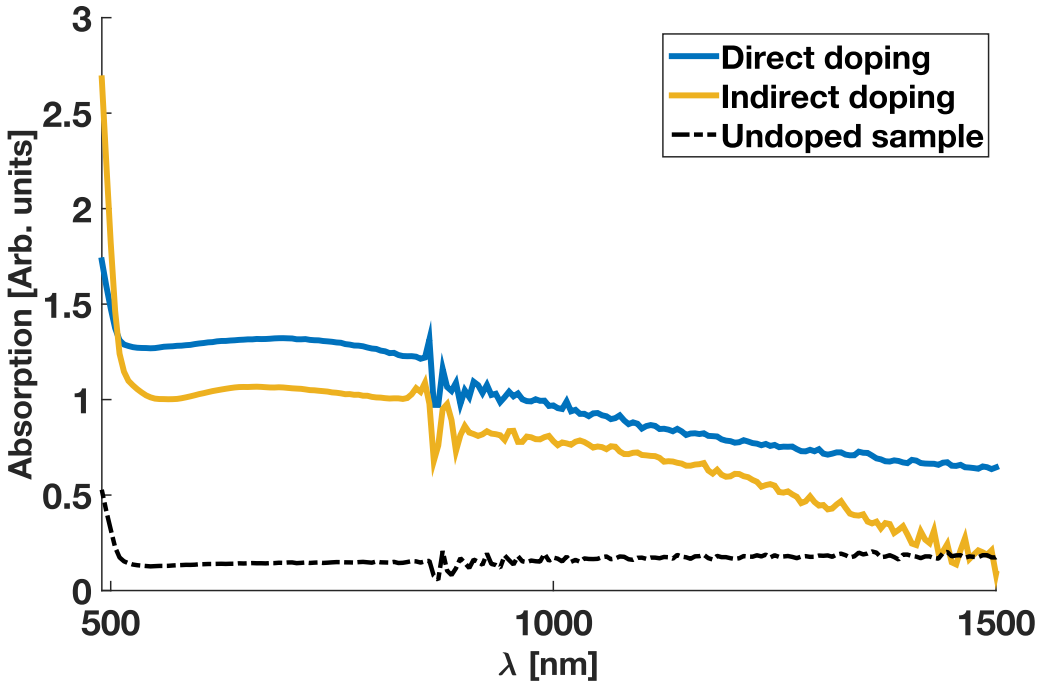


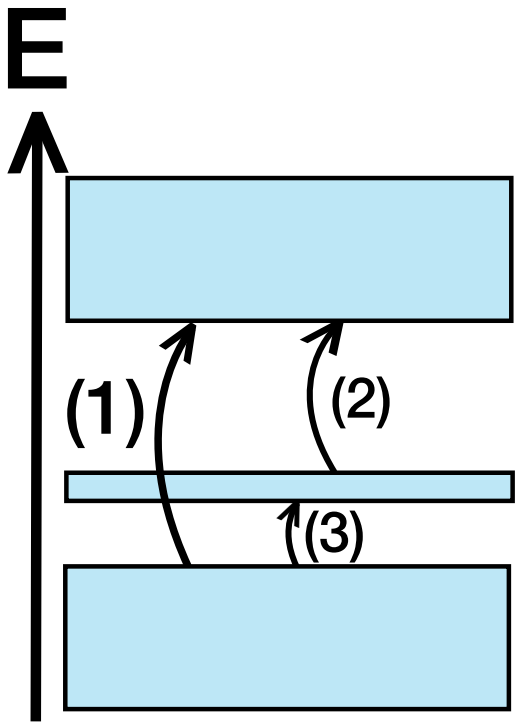
Absorption spectroscopy



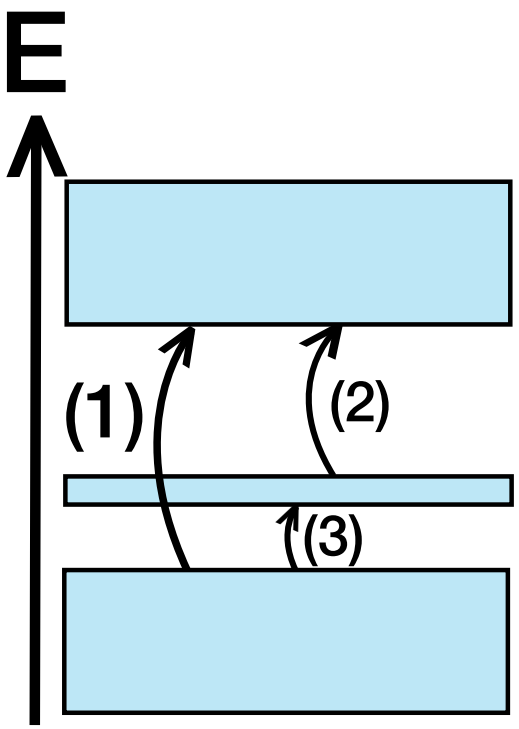


Absorption spectroscopy



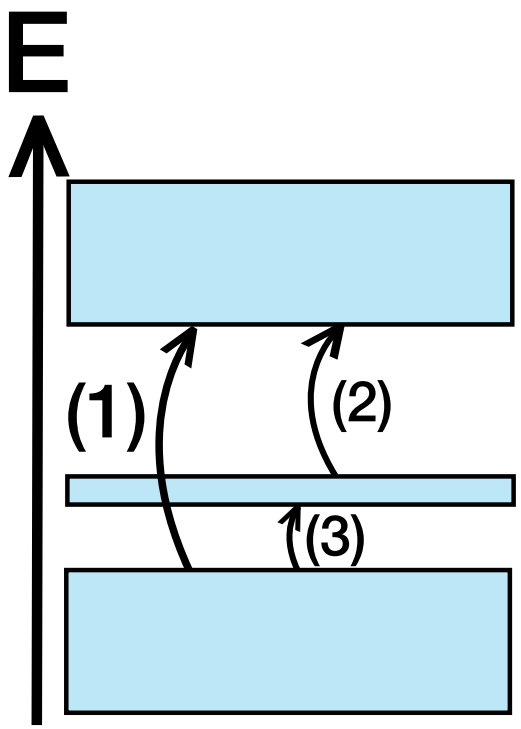


Fermi level



Fermi level

$$p - n = N_A^- - N_D^+$$



Fermi level

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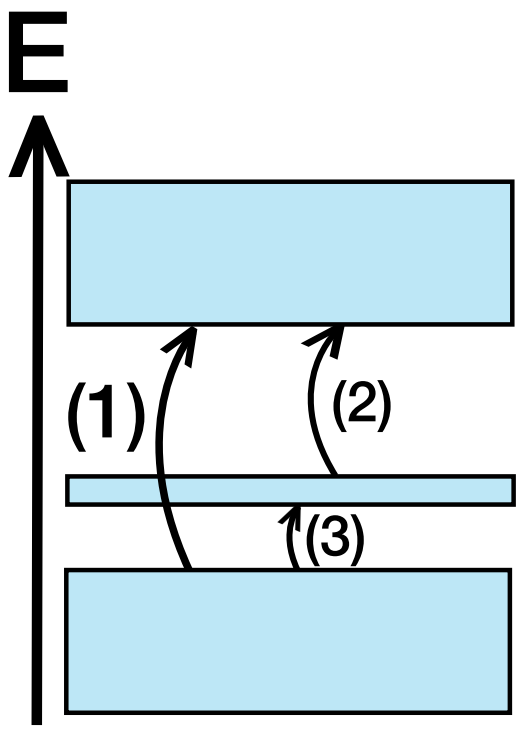


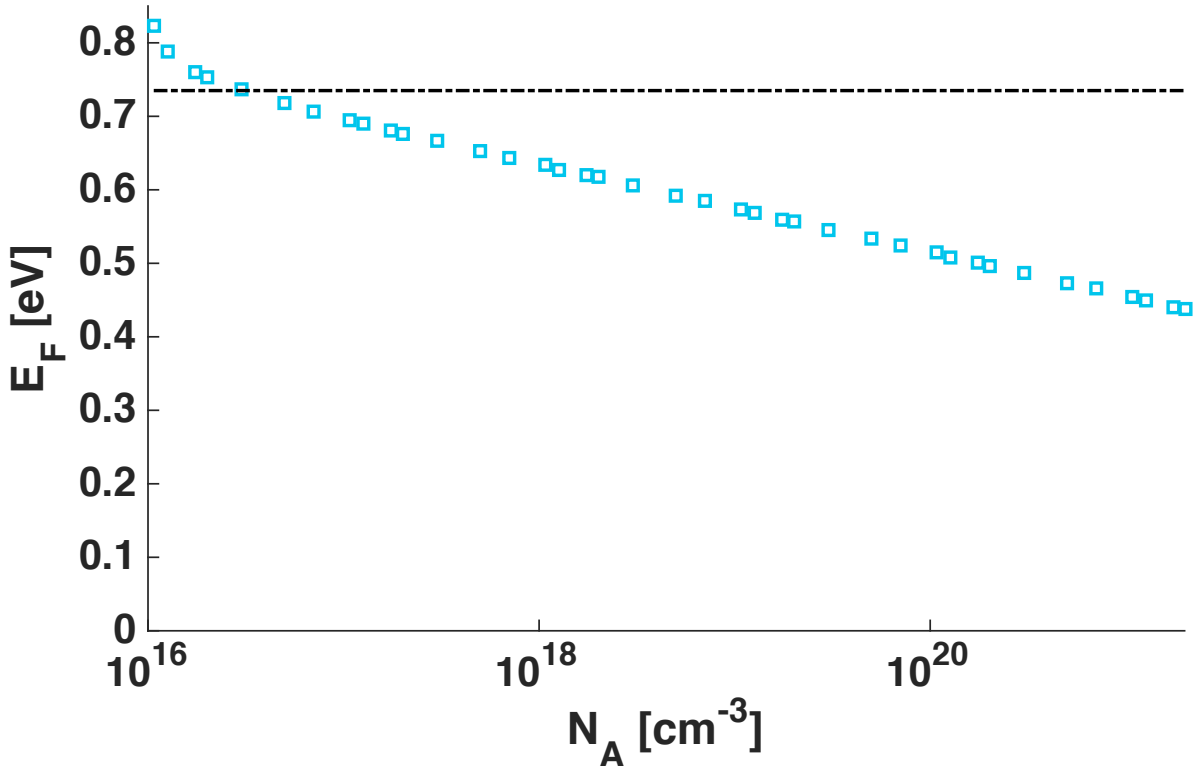
$$p >> n$$

$$N_D^+ \approx N_D$$

$$p \approx N_V e^{-E_F/kT}$$

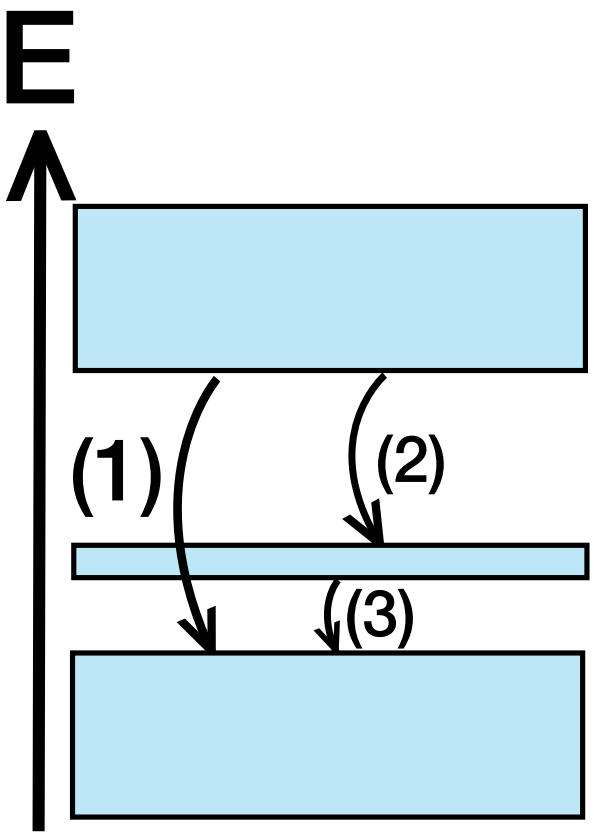
$$N_A^- = \frac{N_A}{1+2e^{\frac{E_A - E_F}{kT}}}$$

Fermi level

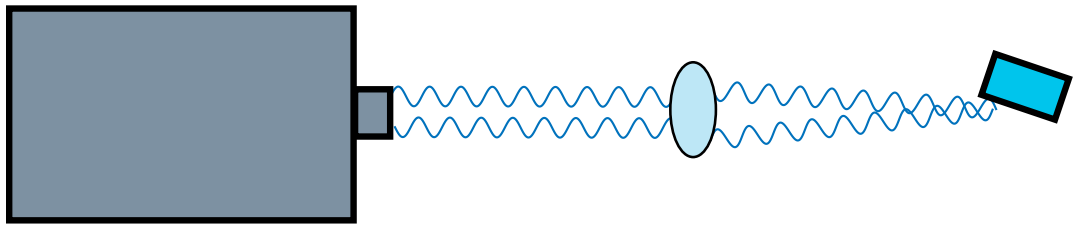


Photoluminescence spectroscopy

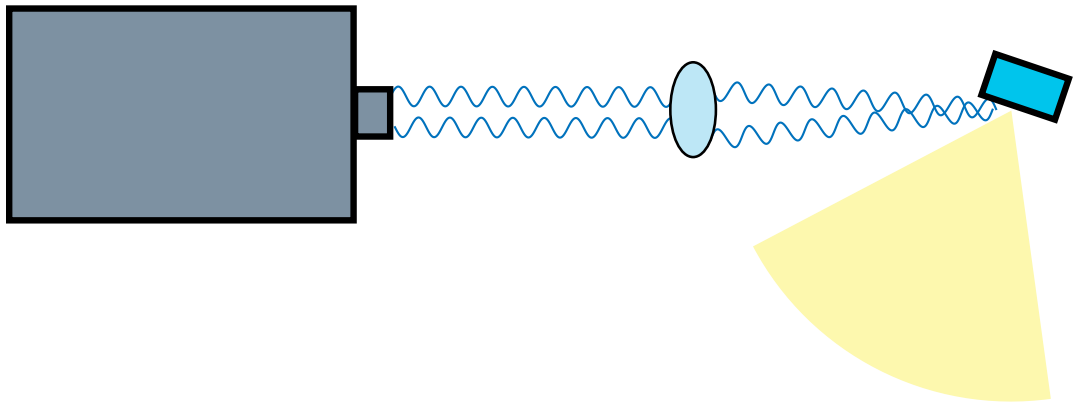
Photoluminescence spectroscopy



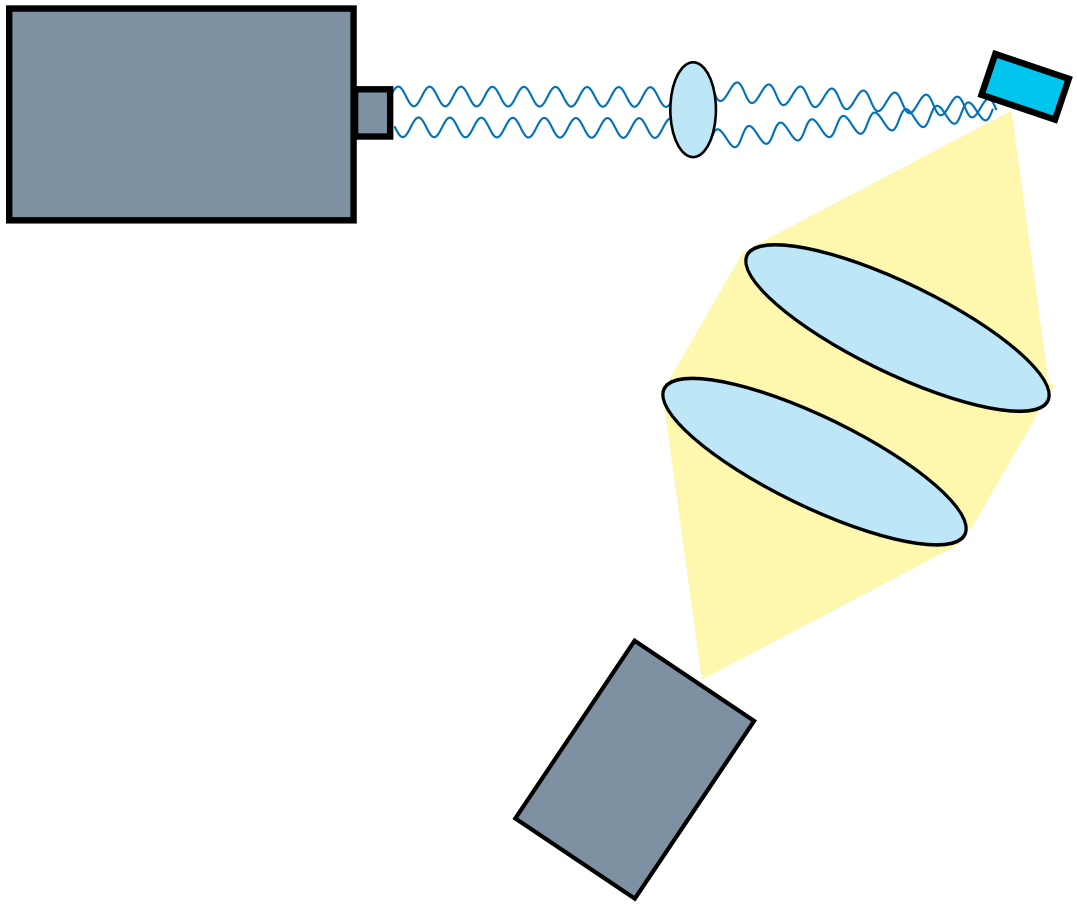
Photoluminescence spectroscopy



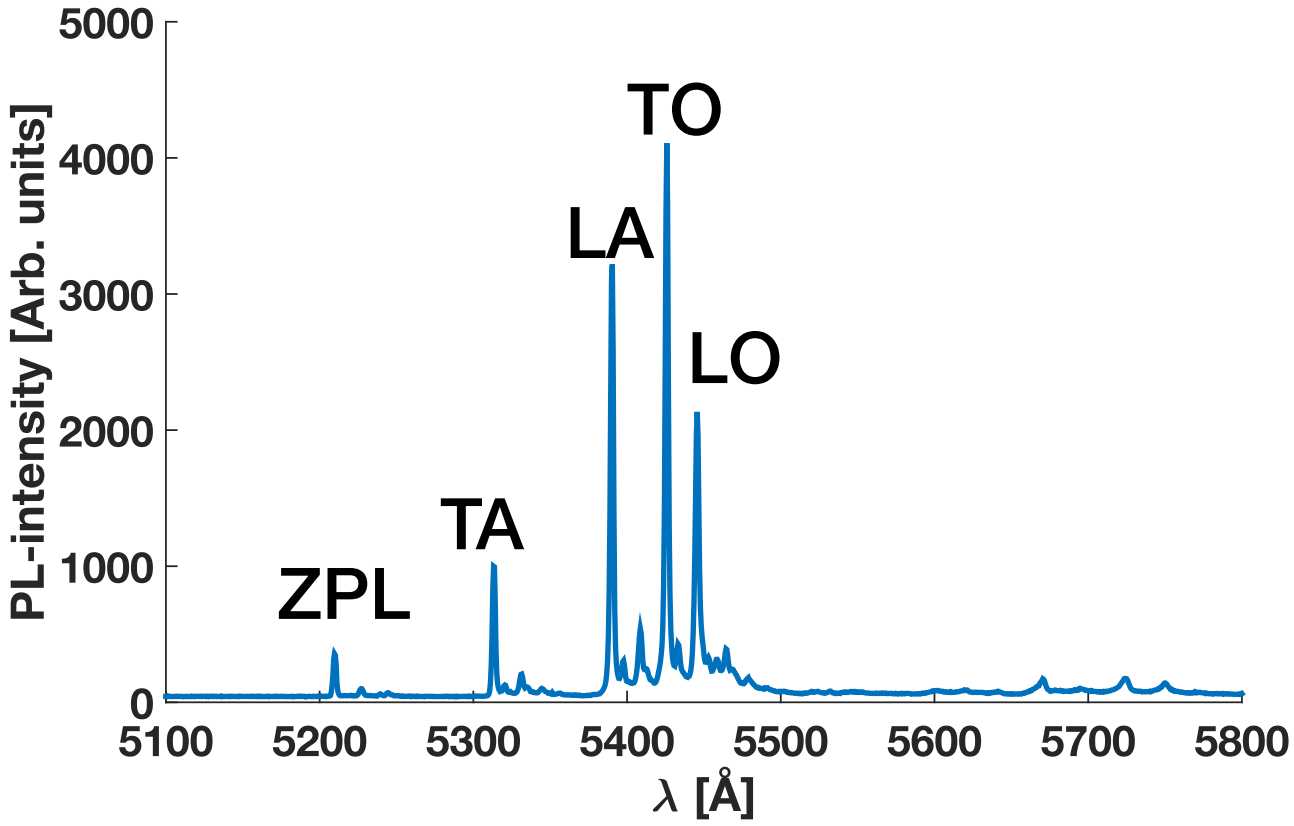
Photoluminescence spectroscopy



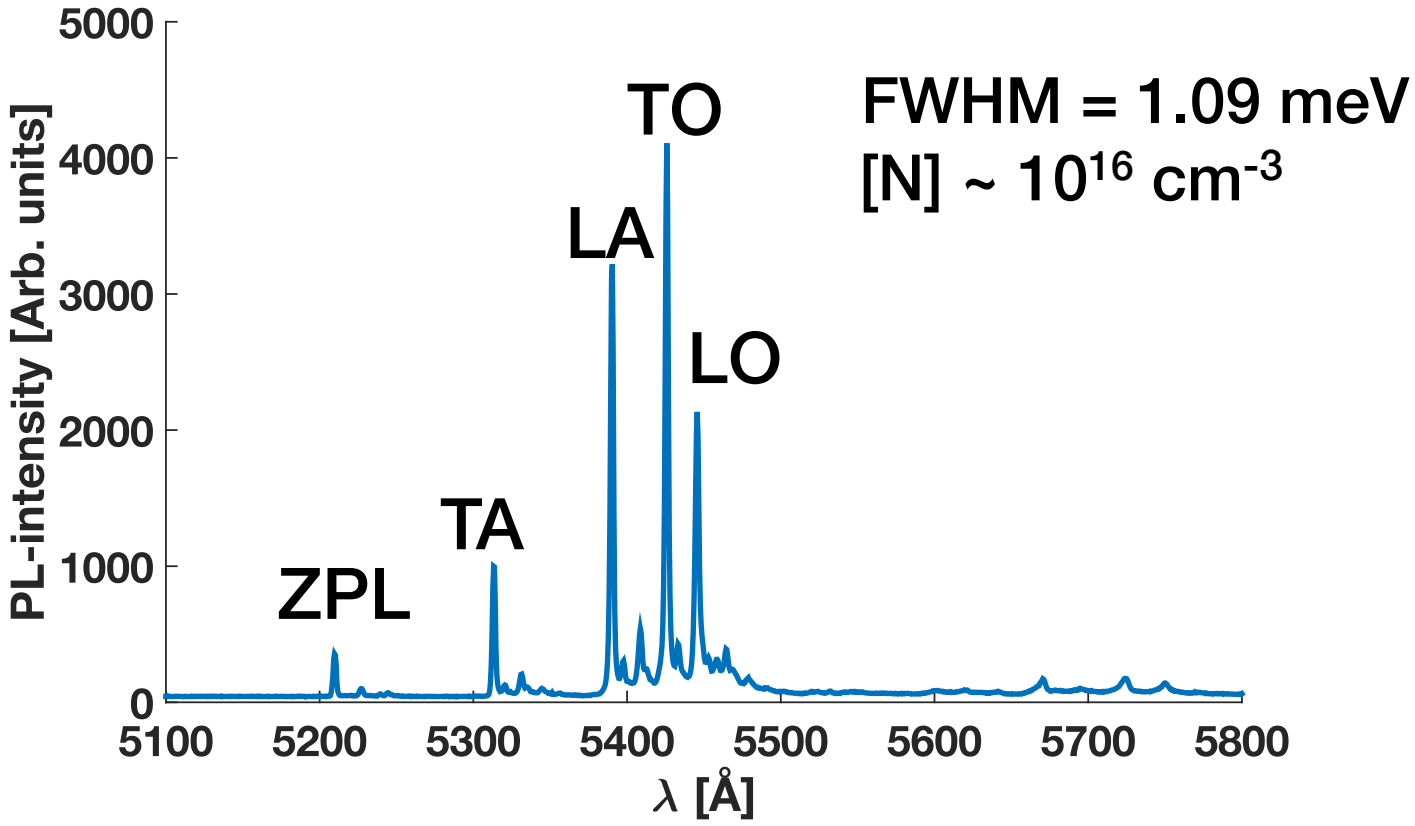
Photoluminescence spectroscopy



Photoluminescence spectroscopy



Photoluminescence spectroscopy



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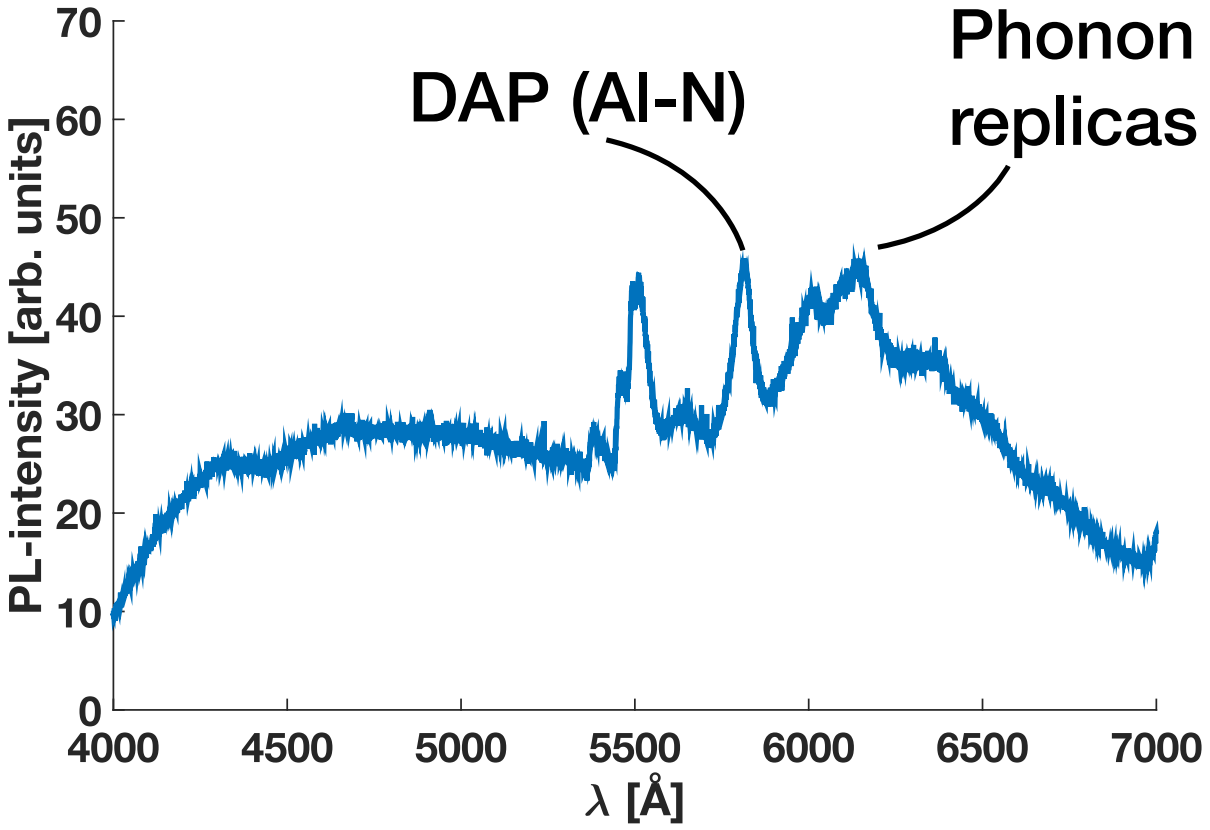

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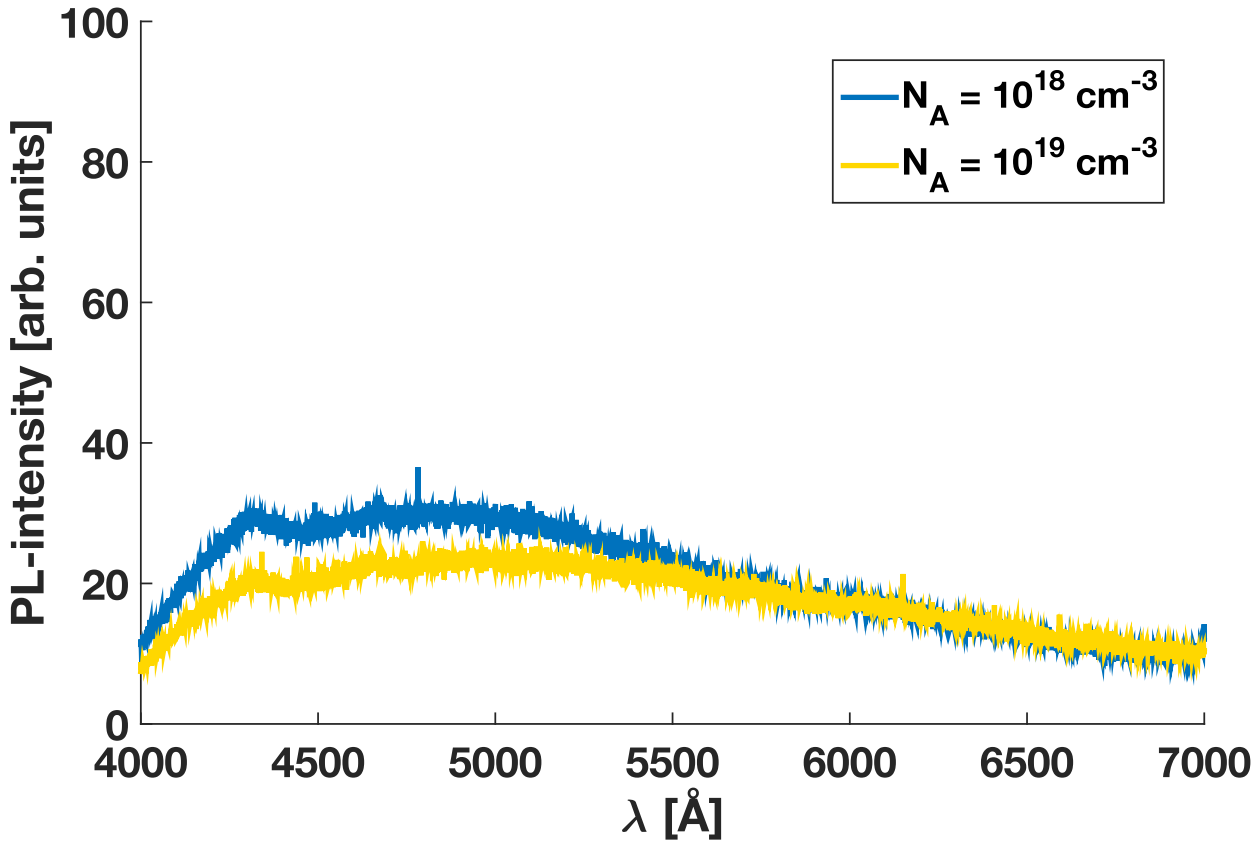
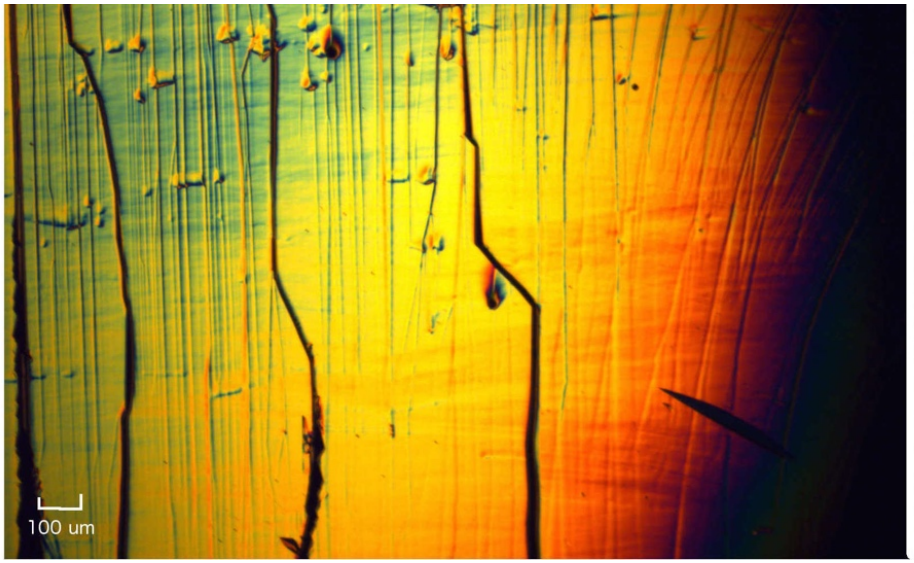
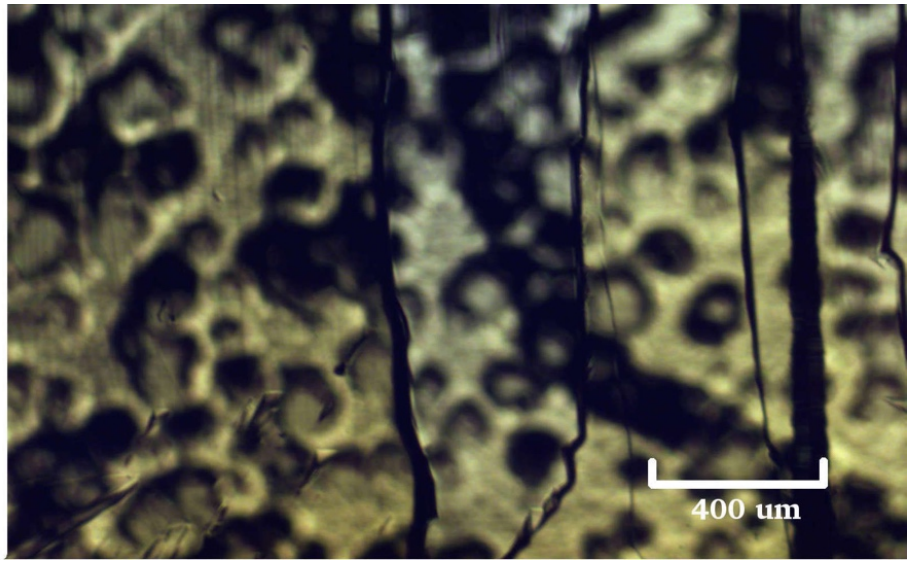


Photoluminescence spectroscopy





Photoluminescence spectroscopy

- Non-radiative impurity levels
- Non radiative defect states
- Competition between B and Al

Other results

- Cubic growth on C-face 4H not possible under same conditions as Si-face
- Water splitting possible using both p- and n-type 3C

Summary and conclusions

- Boron impurities lead to poor quality material
- Both direct and indirect doping methods give intermediate band
- No VB-B transition, possibly due to high occupancy
- N and Al inclusions
- No luminescence from B-doped 3C, but from 4H. Possibly due to non-radiative defects.
- Possible competition between Al and B

Thank you!

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