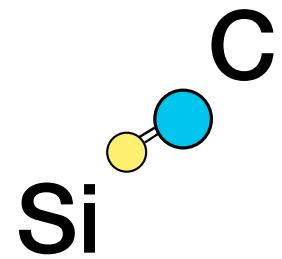


Optical properties of free-standing cubic silicon carbide

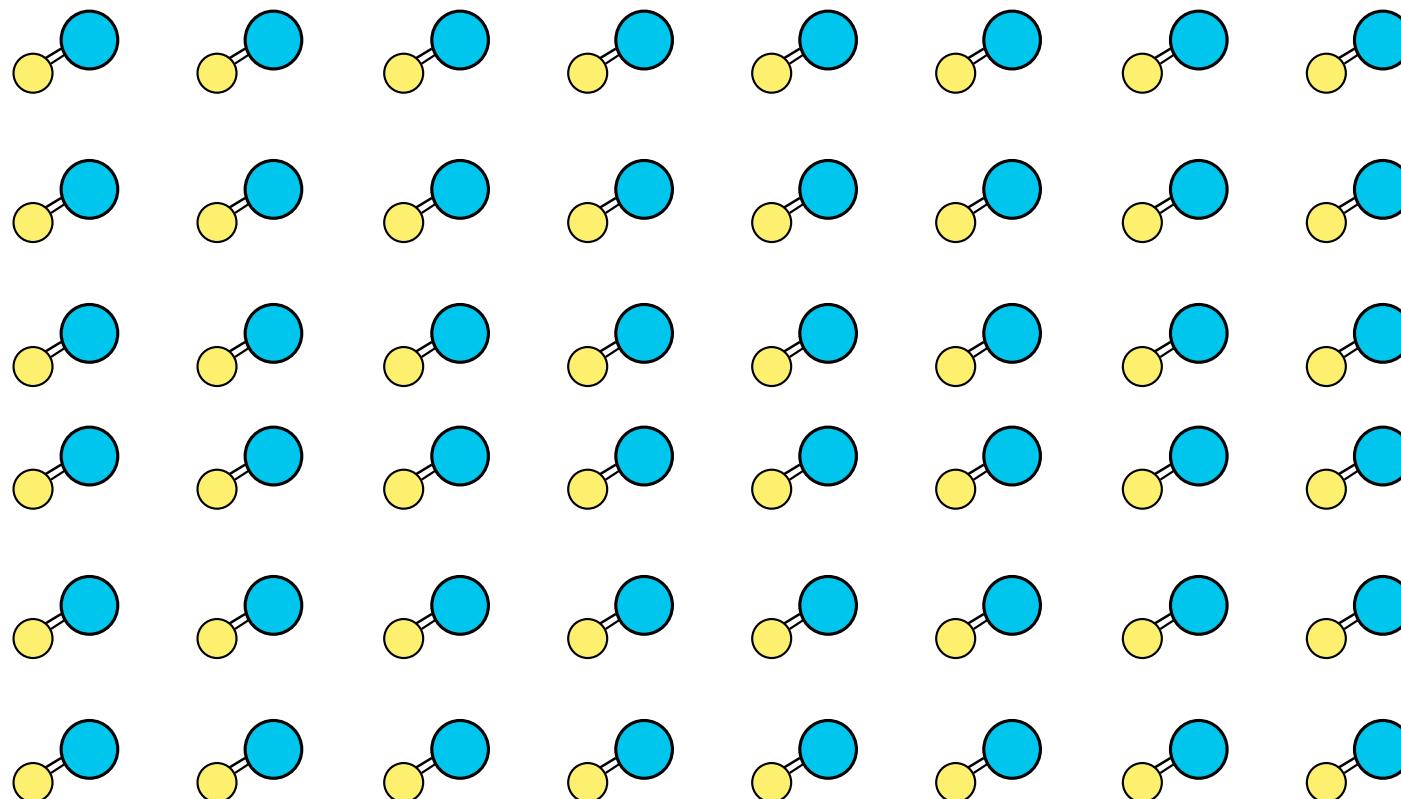
Mattias Jansson

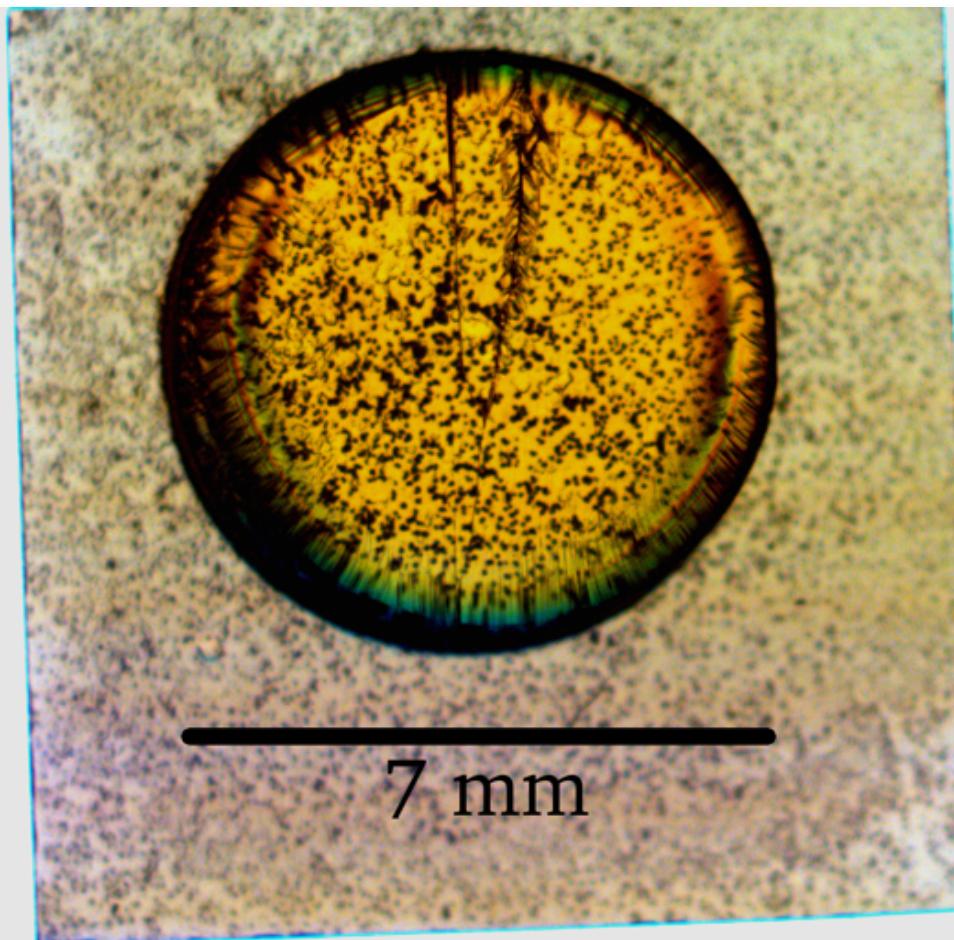
Outline

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

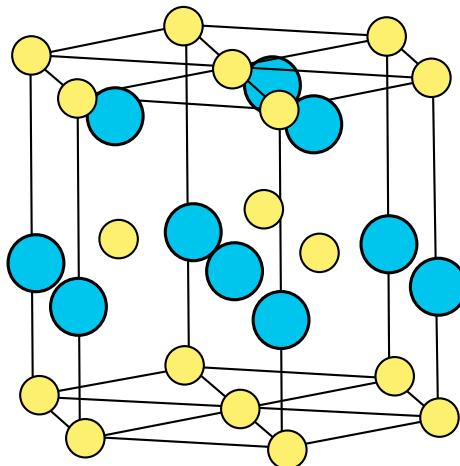




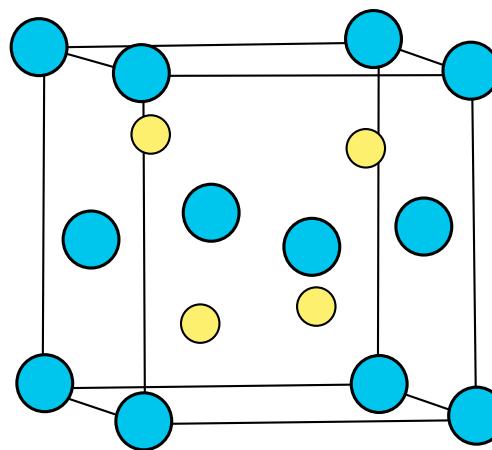




Polytypes - atomic arrangements

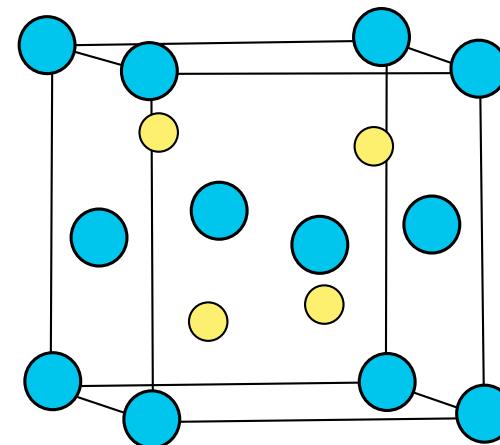


Hexagonal



Cubic

Polytypes - atomic arrangements



Cubic
3C-SiC

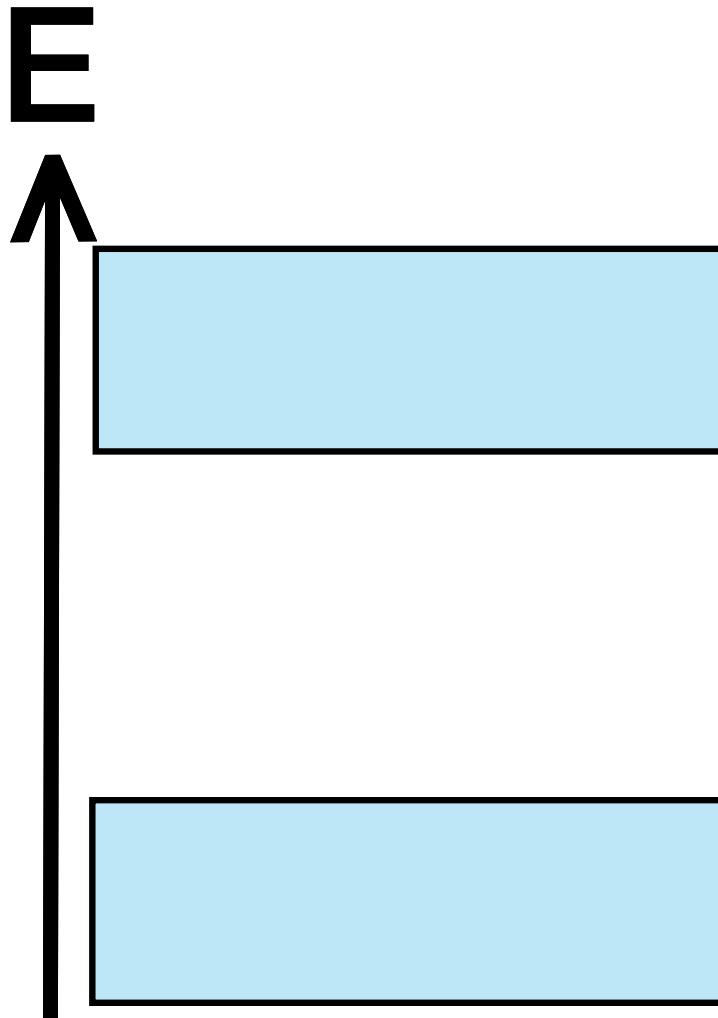
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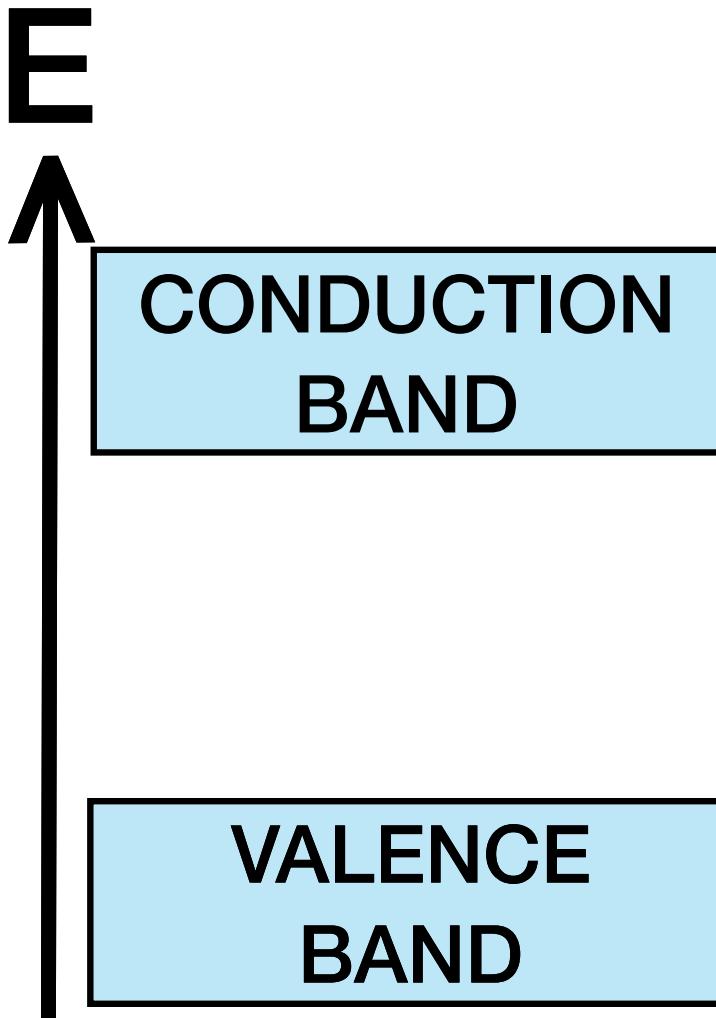
Allowed



Allowed

Disallowed

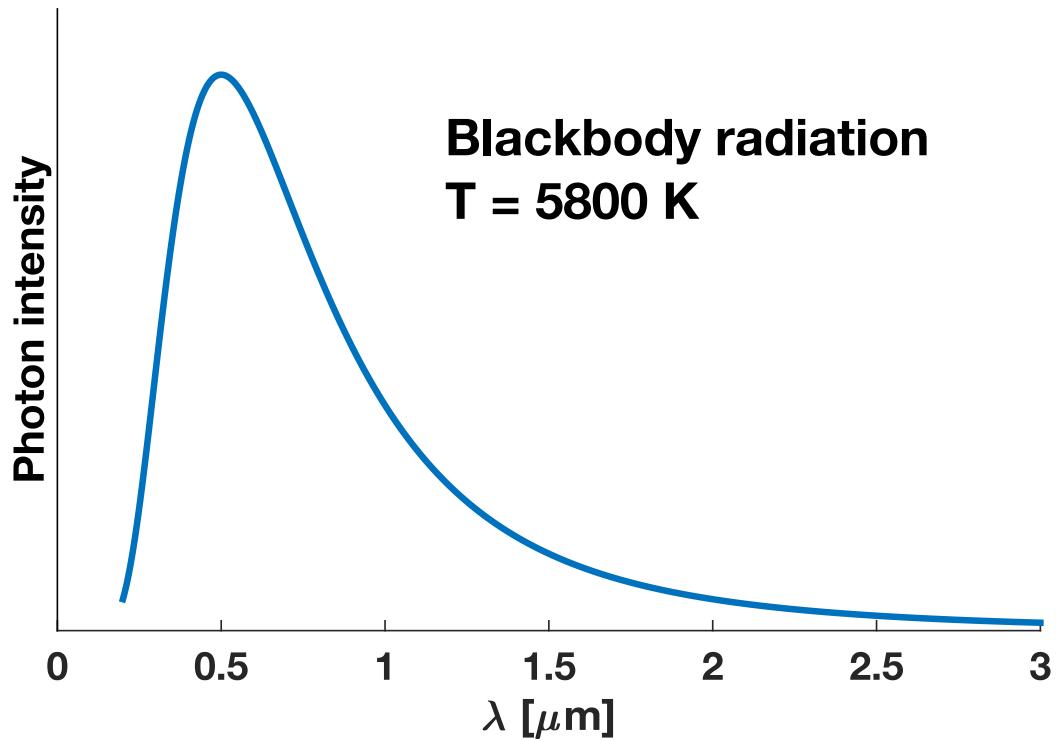
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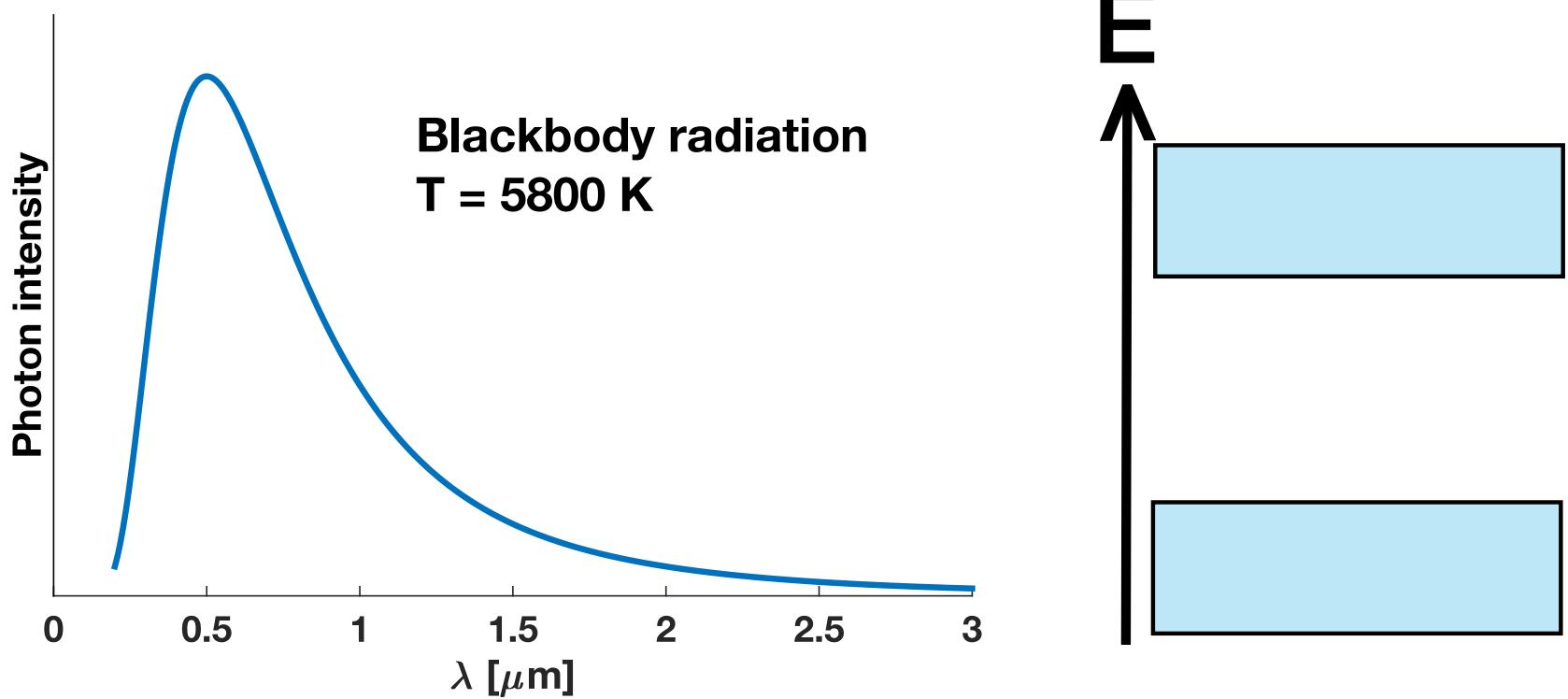


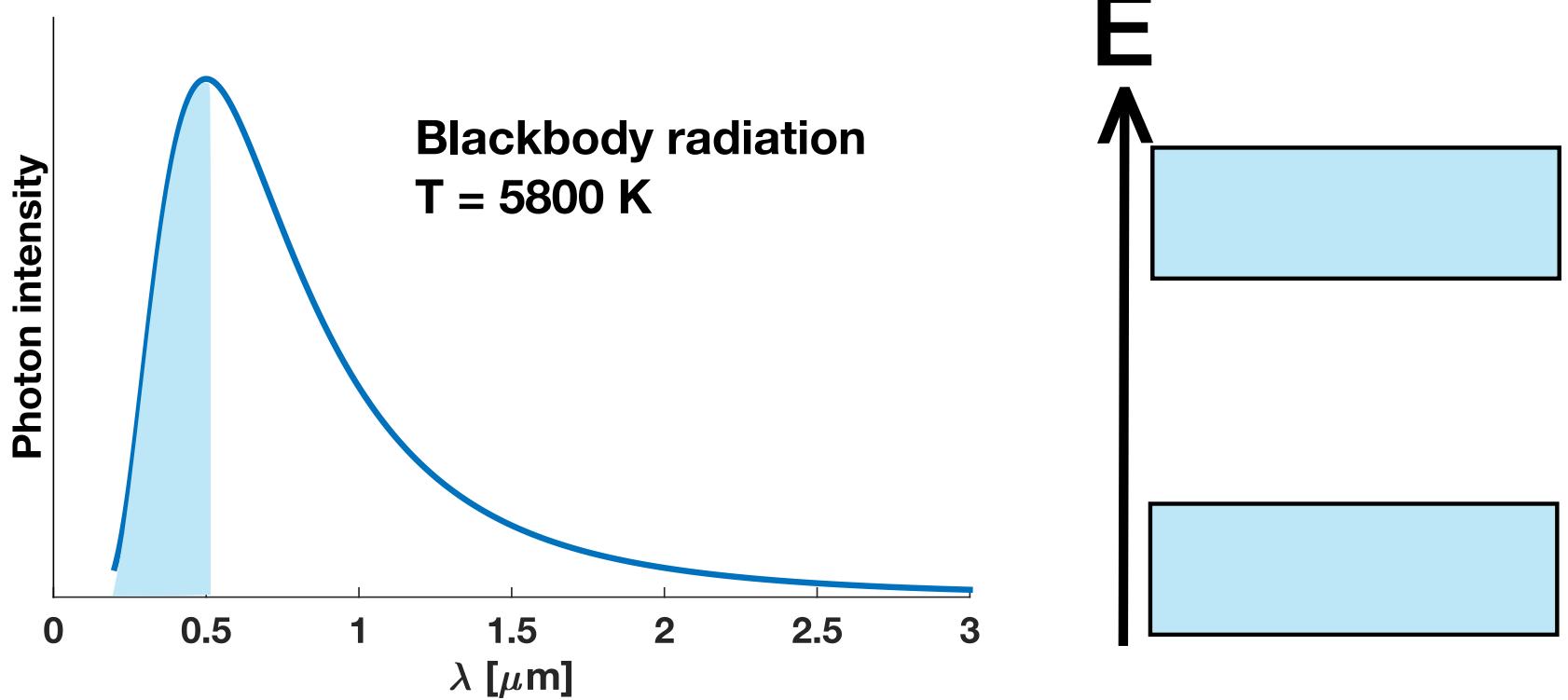
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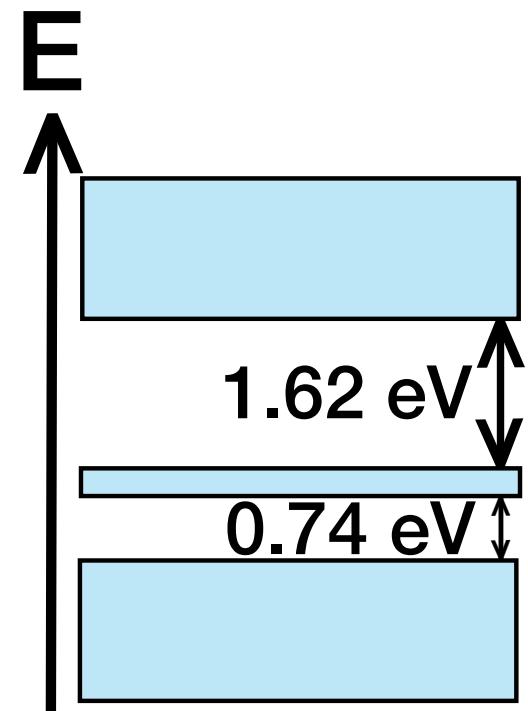
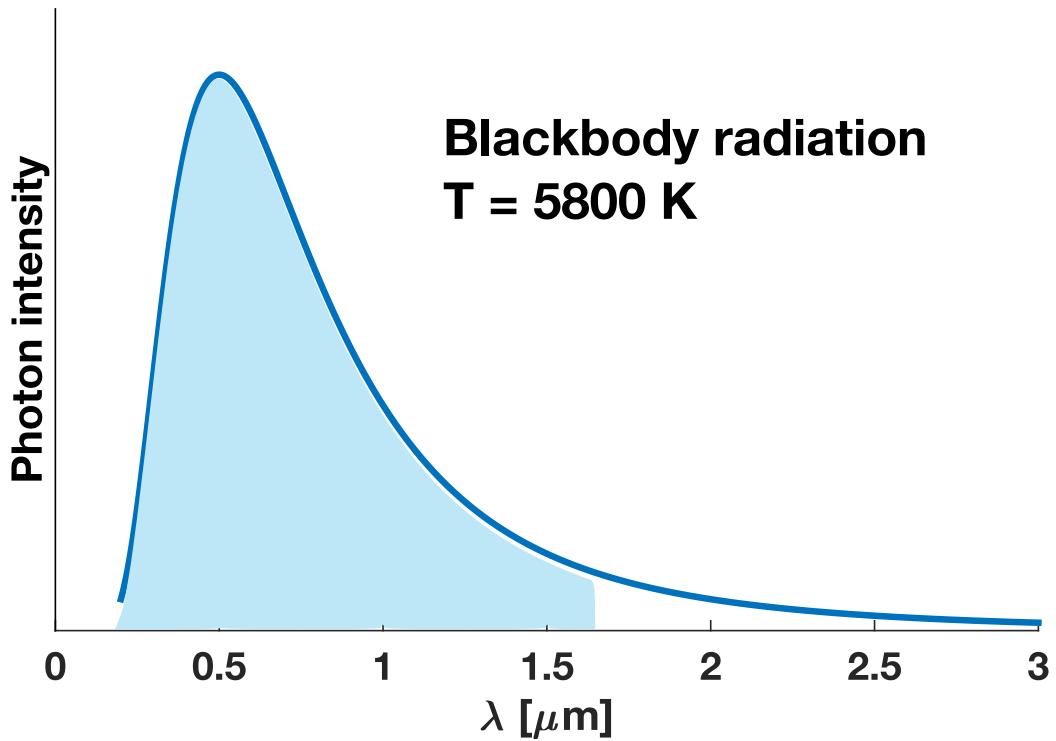
Disallowed

Allowed









My contributions

My contributions

- Growth of boron-doped samples

My contributions

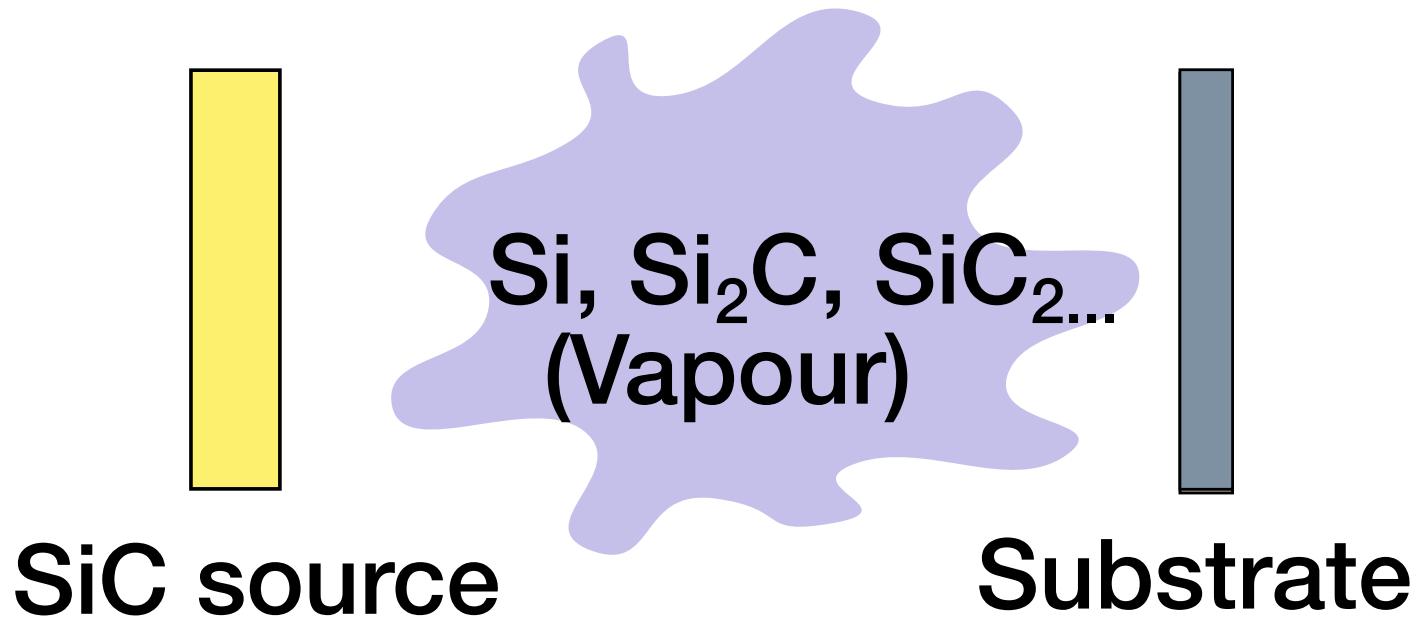
- Growth of boron-doped samples
- Optical characterization

Sublimation growth

+

ΔT

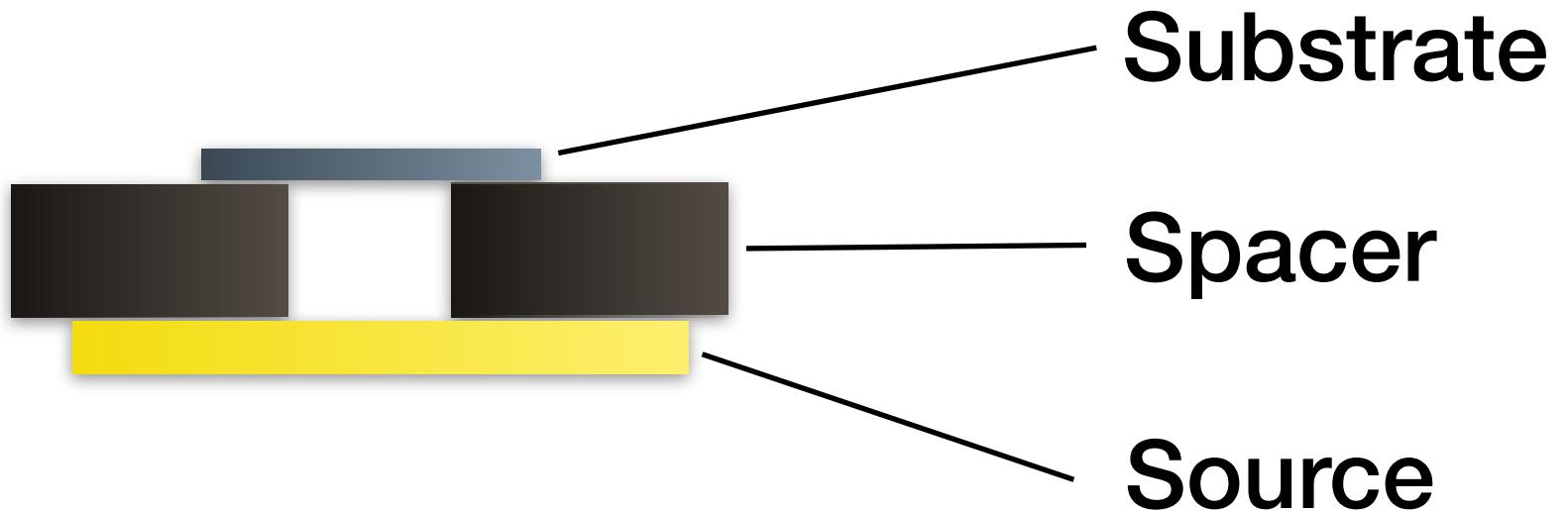
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The reactor

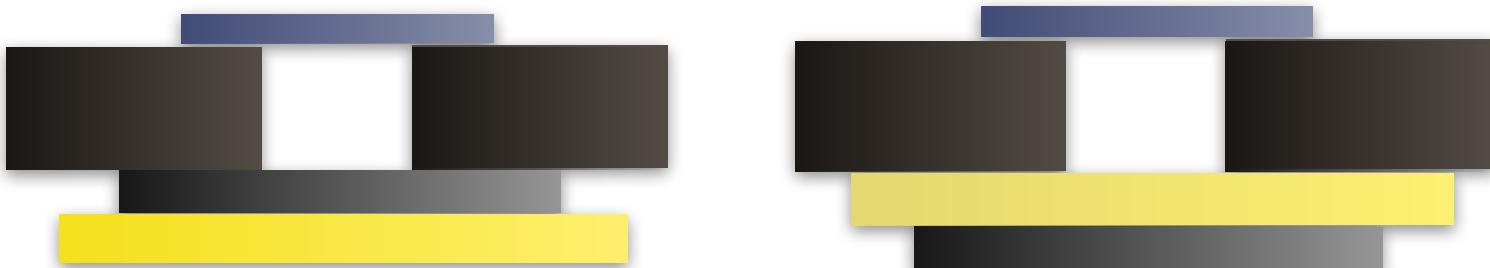


The growth setup

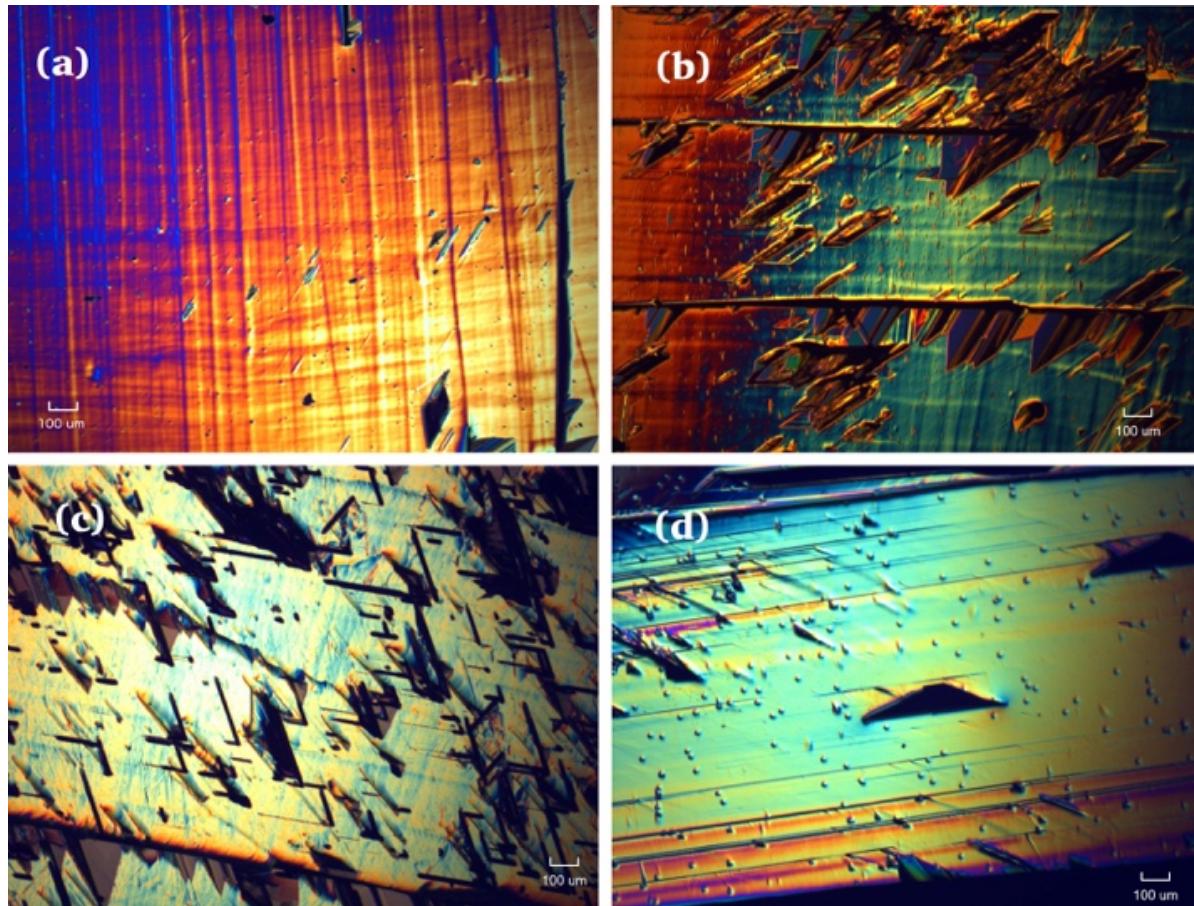


Investigated parameters

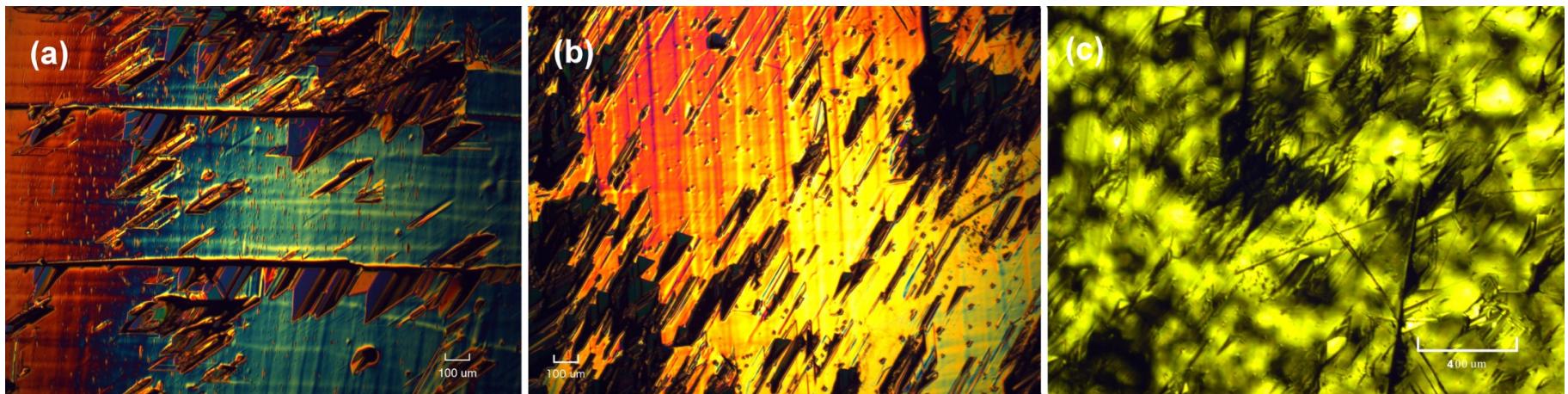
- Doping concentrations (10^{18} - 10^{20} cm $^{-3}$)
- Growth on 3C seed or 4H substrate
- Direct or indirect doping method



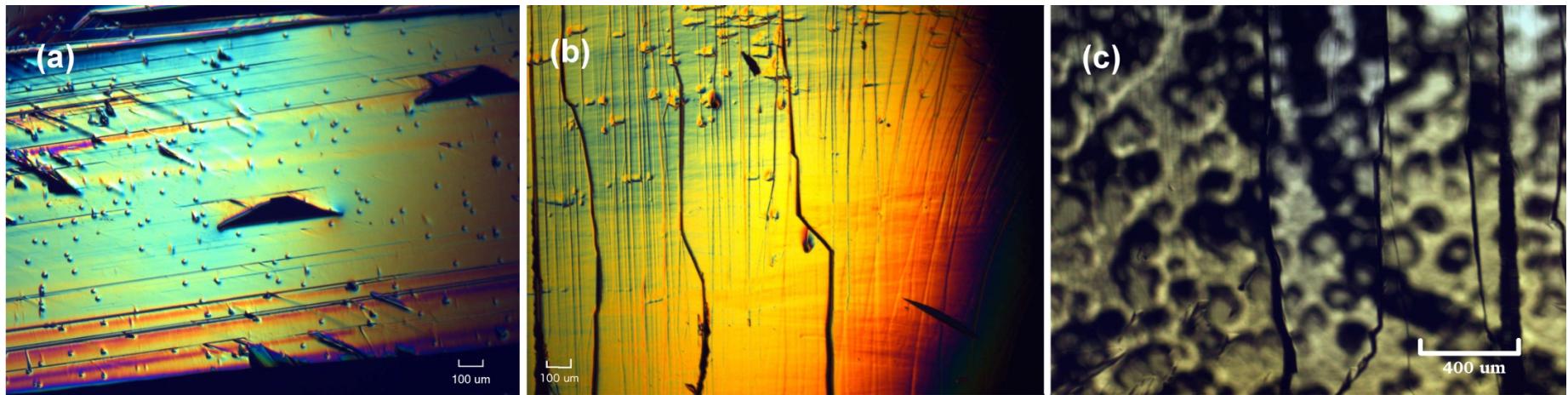
Doping concentrations



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

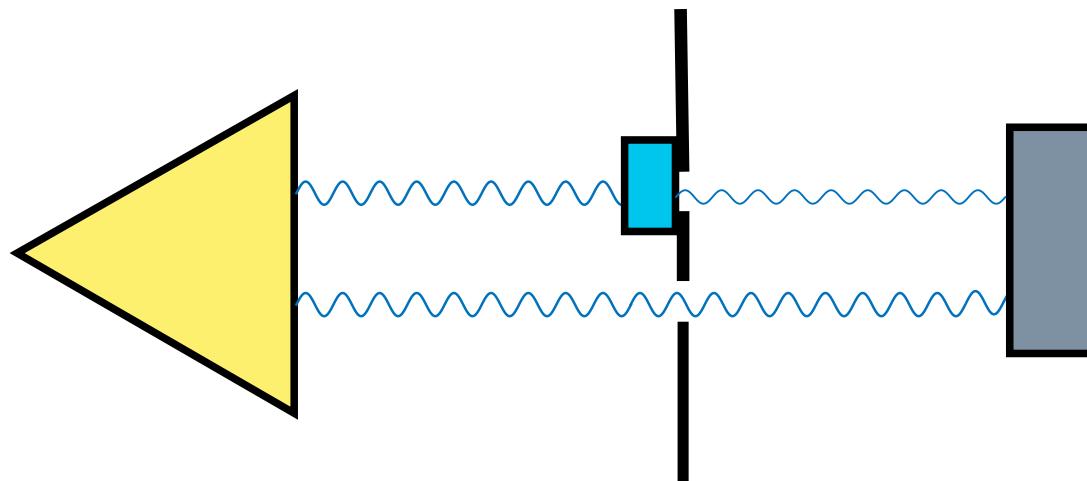


Indirect/direct doping, 10^{20} cm $^{-3}$

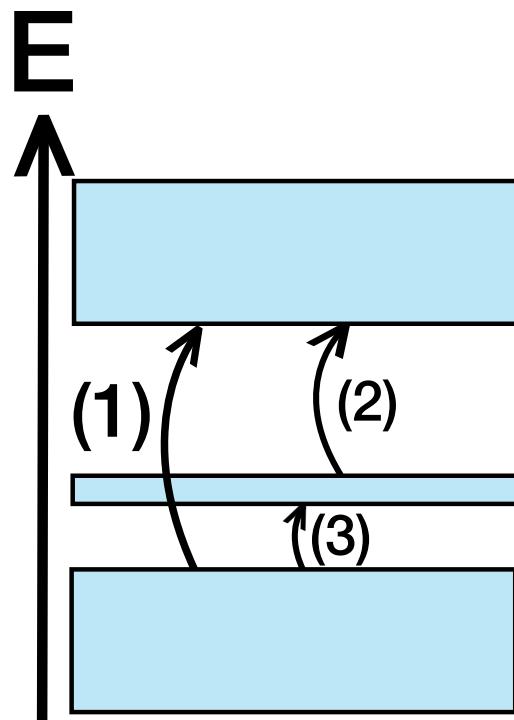


Absorption spectroscopy

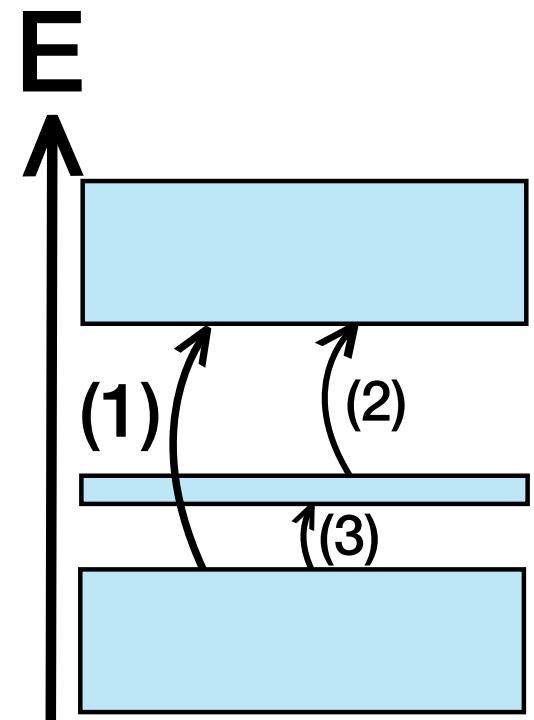
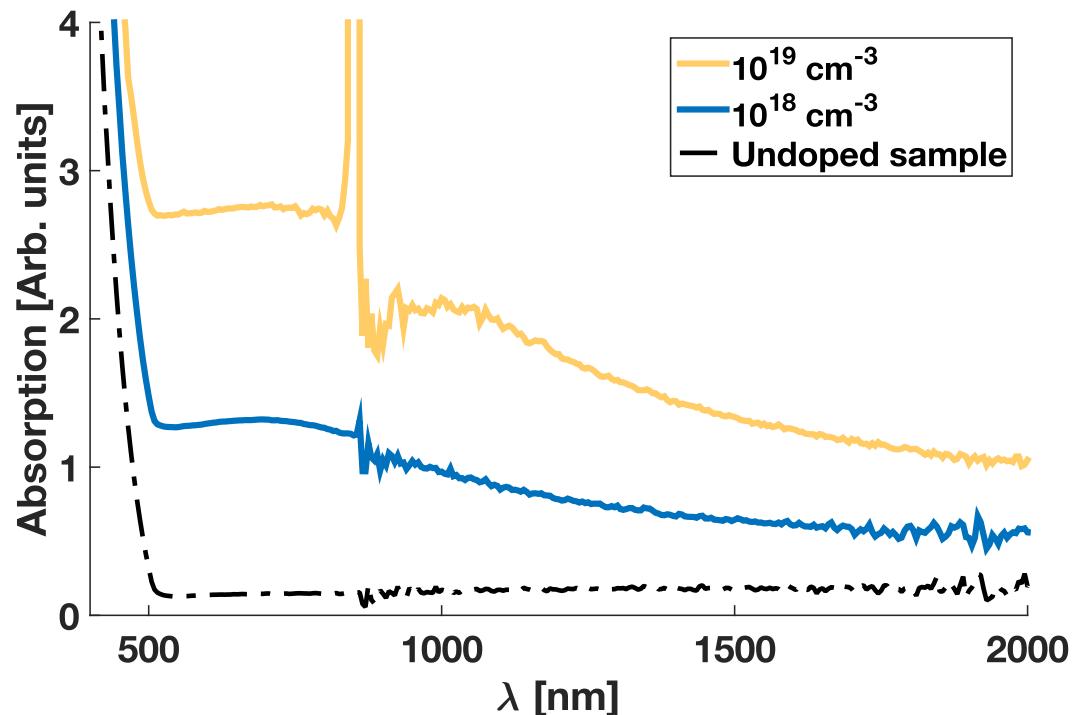
Absorption spectroscopy



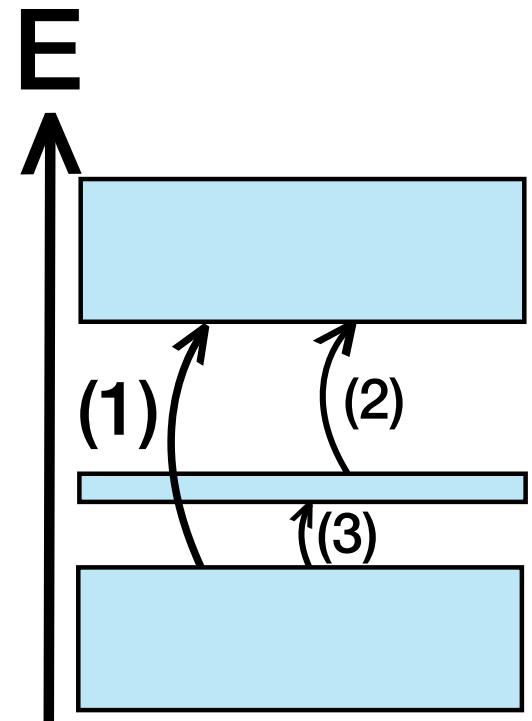
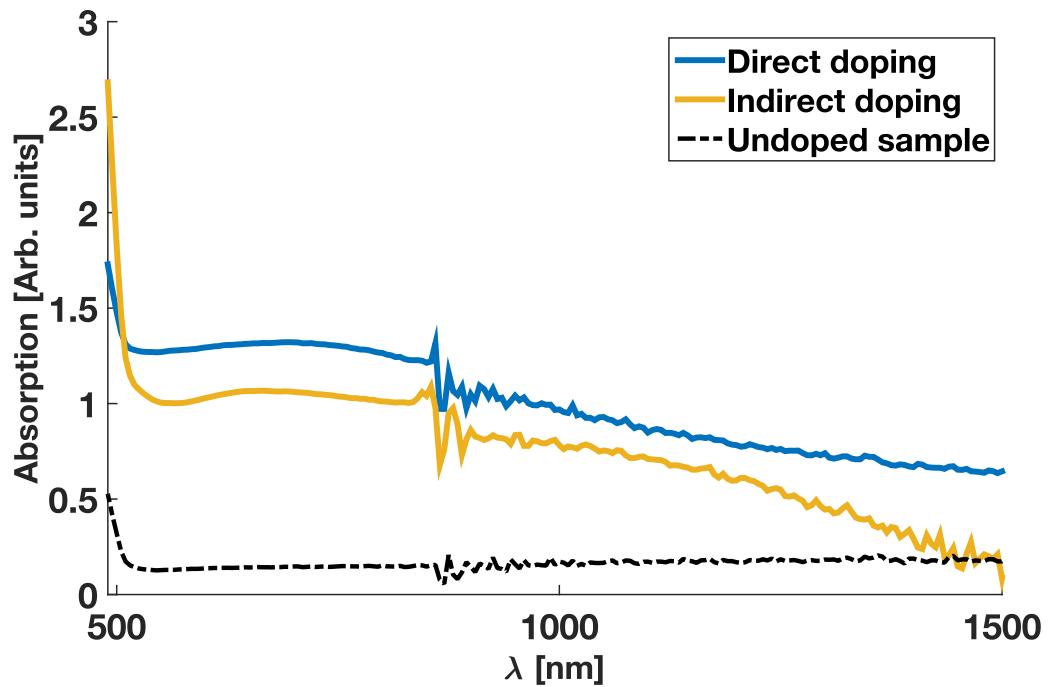
Absorption spectroscopy



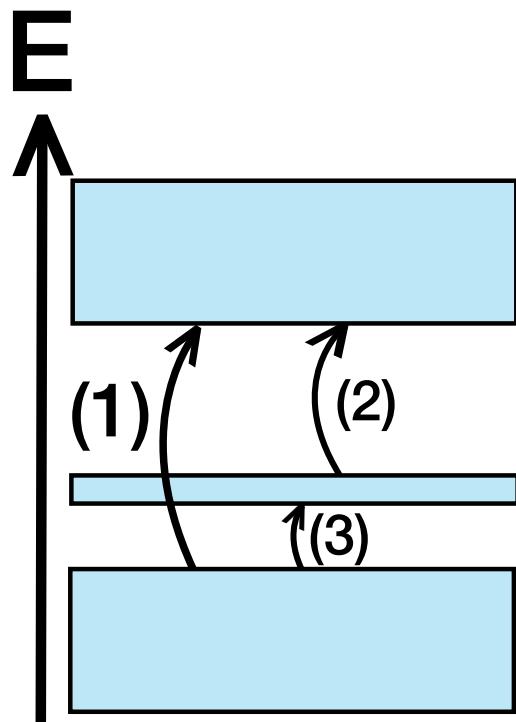
Absorption spectroscopy



Absorption spectroscopy

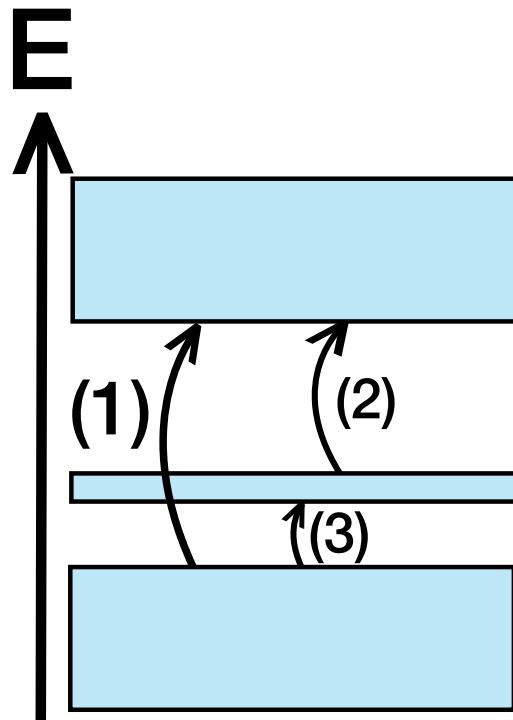


Fermi level



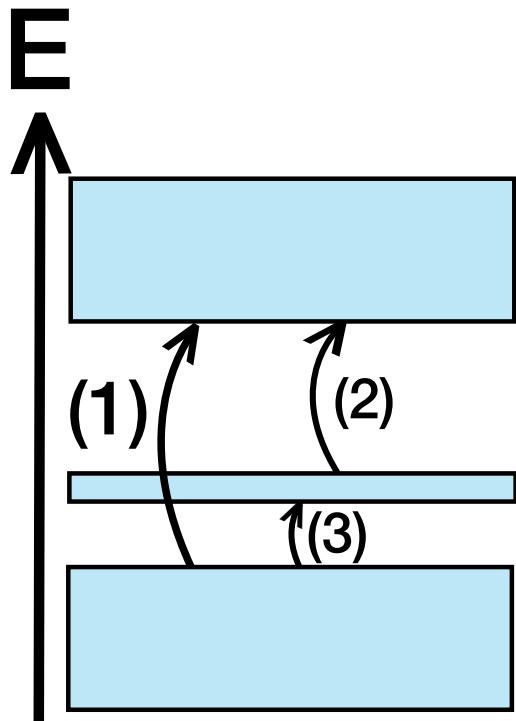
Fermi level

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



Fermi level

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



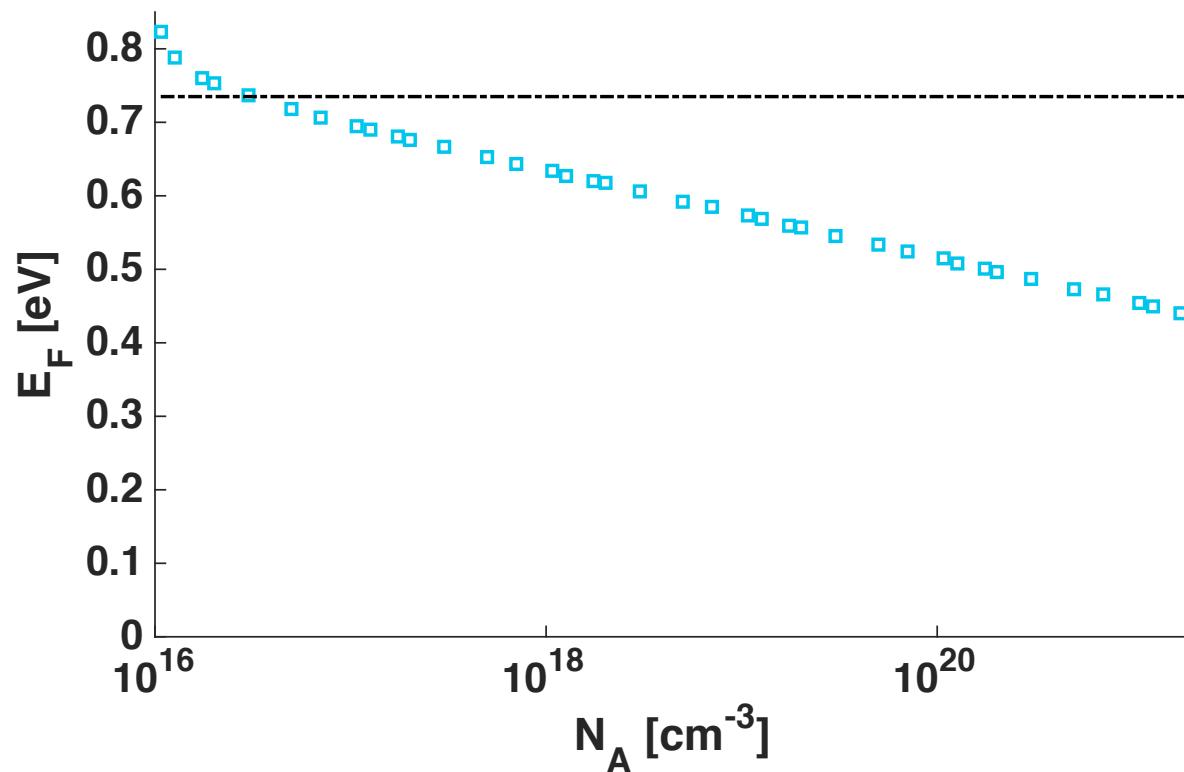
$$p \gg n$$

$$N_D^+ \approx N_D$$

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

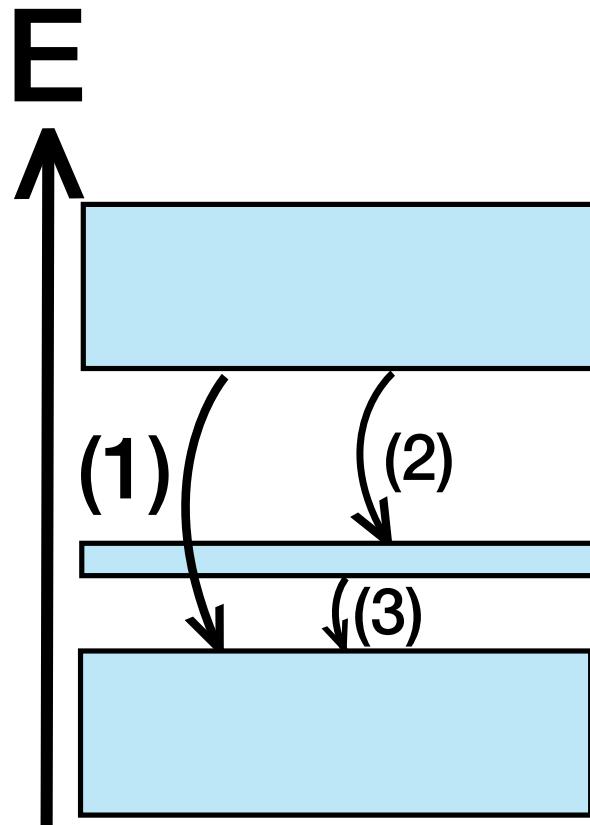
$$N_A^- = \frac{N_A}{1 + 2e^{\frac{E_A - E_F}{kT}}}$$

Fermi level

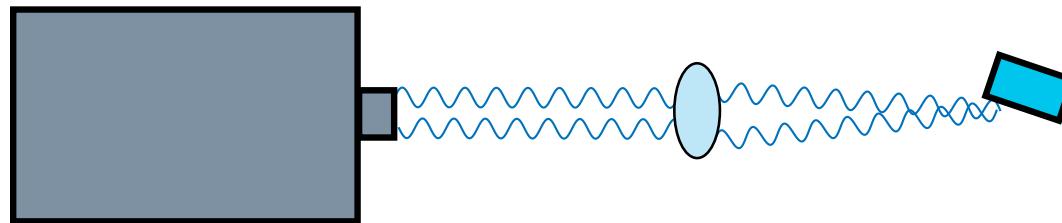


Photoluminescence spectroscopy

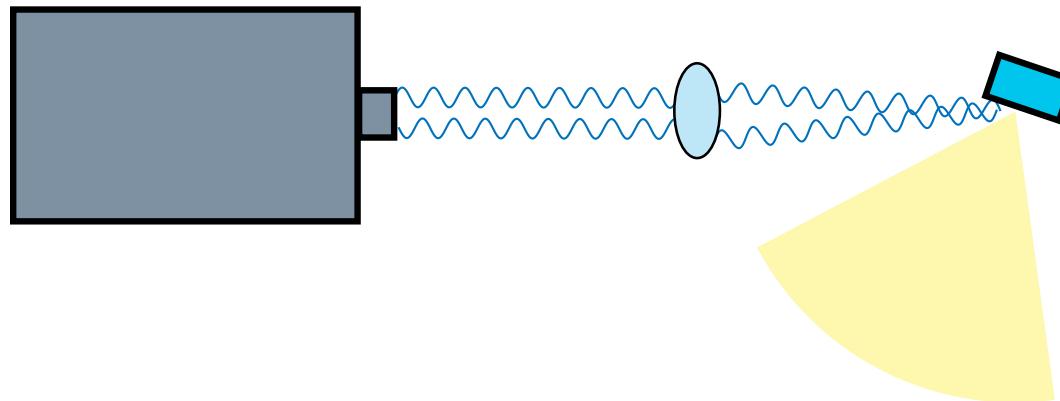
Photoluminescence spectroscopy



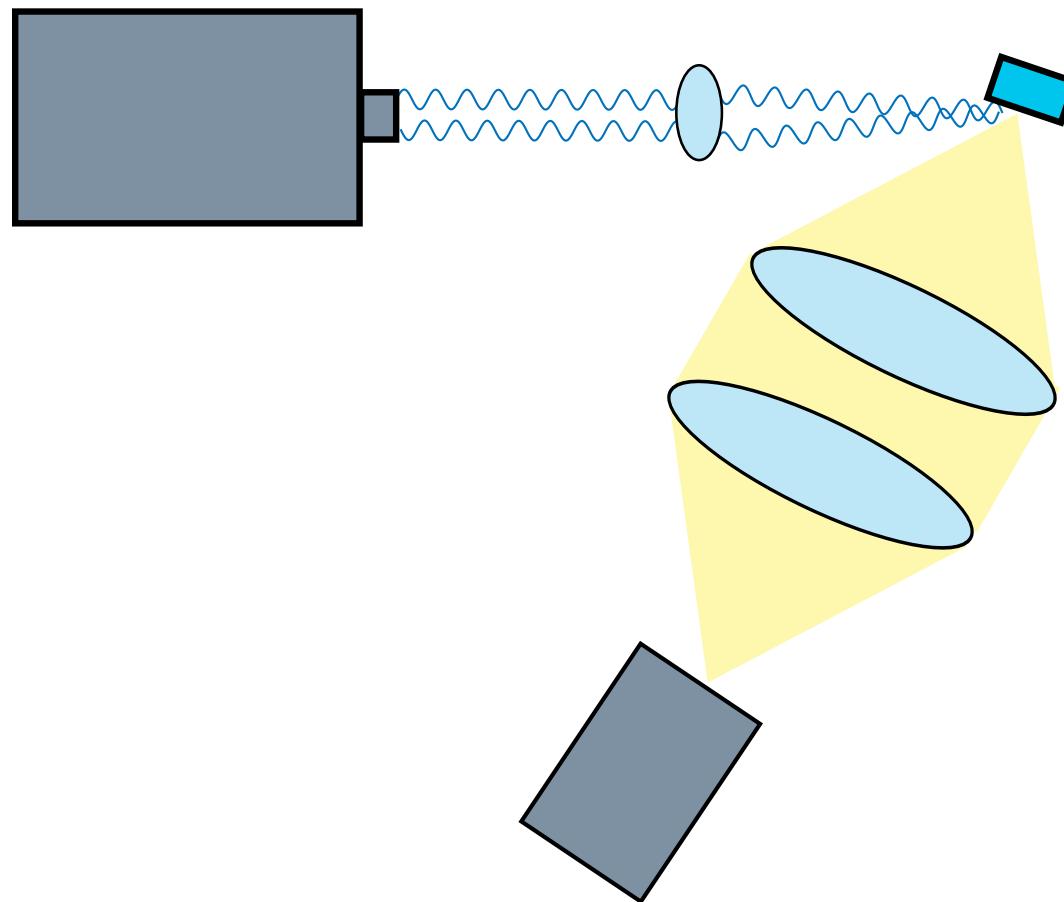
Photoluminescence spectroscopy



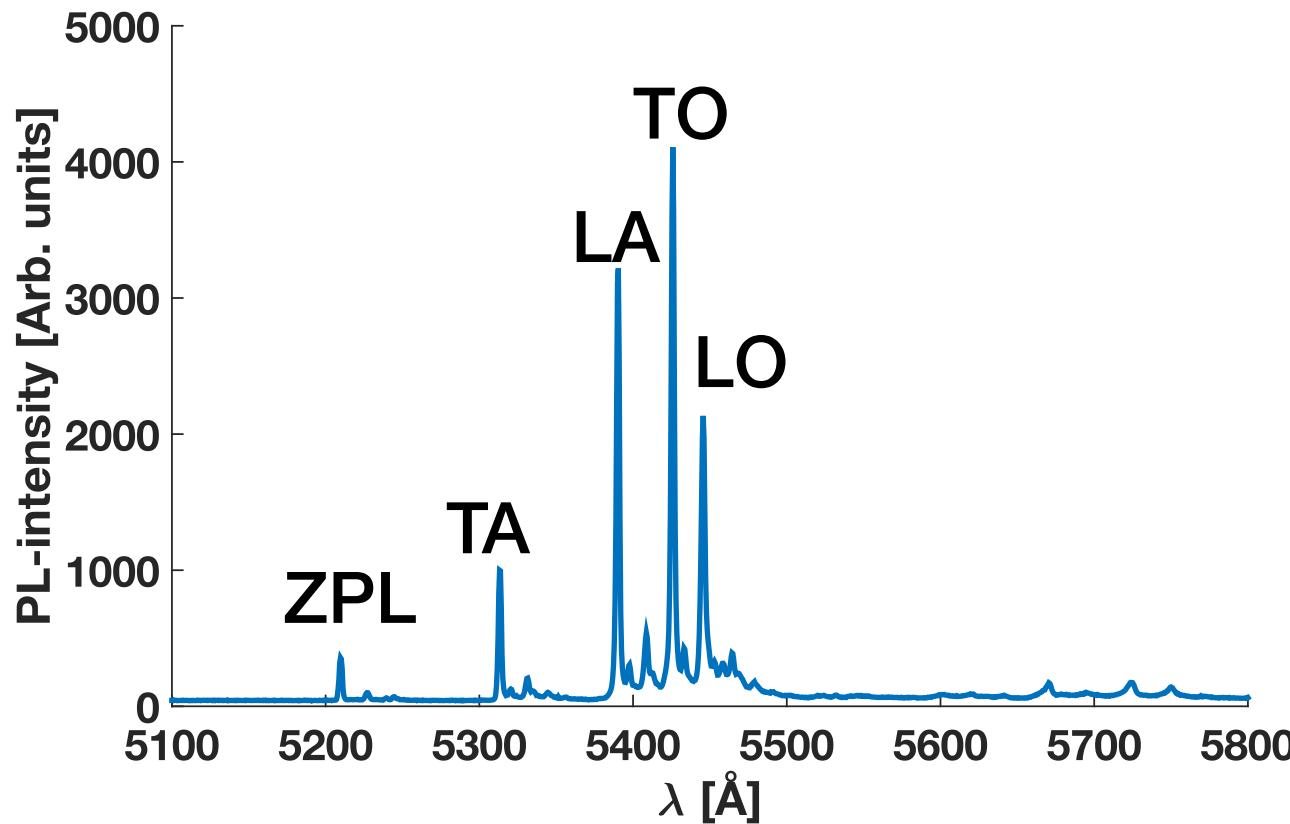
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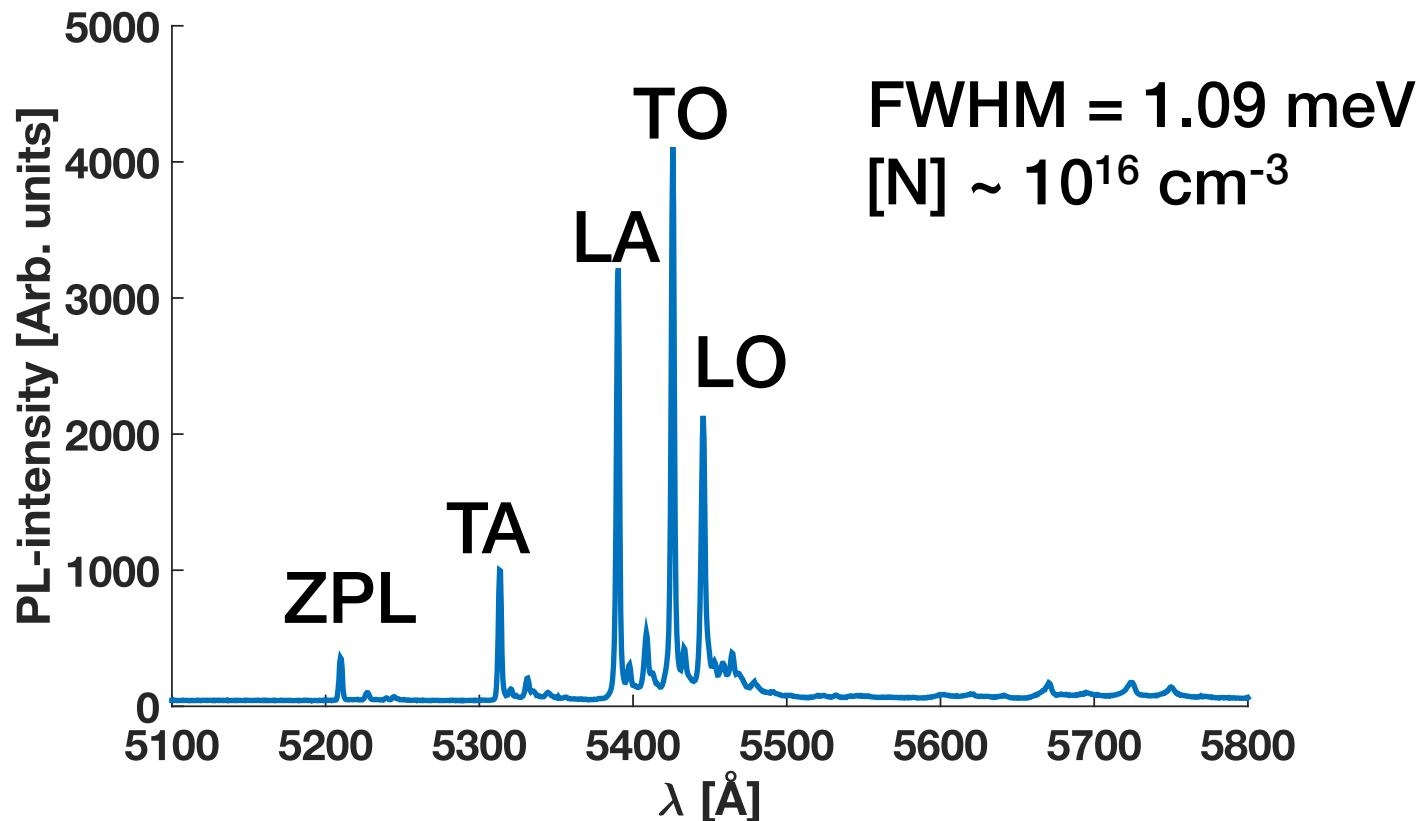
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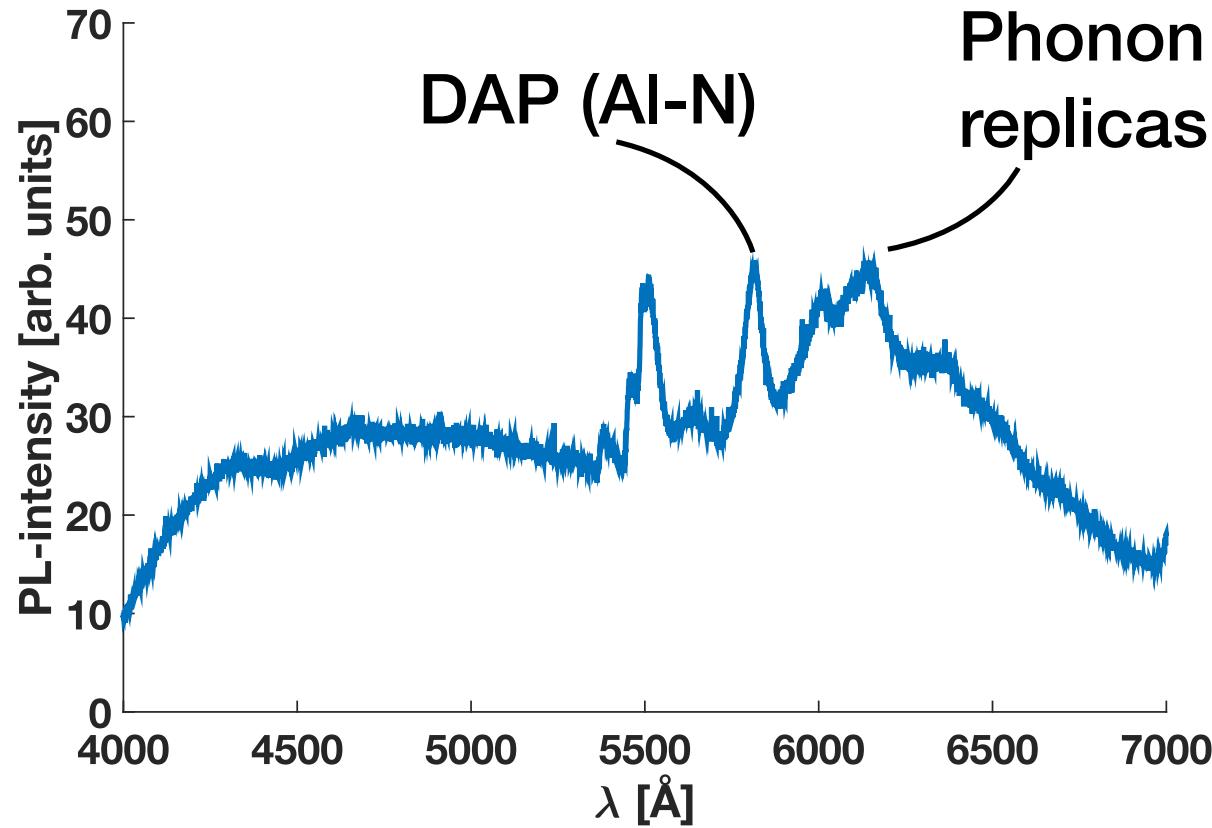
Photoluminescence spectroscopy



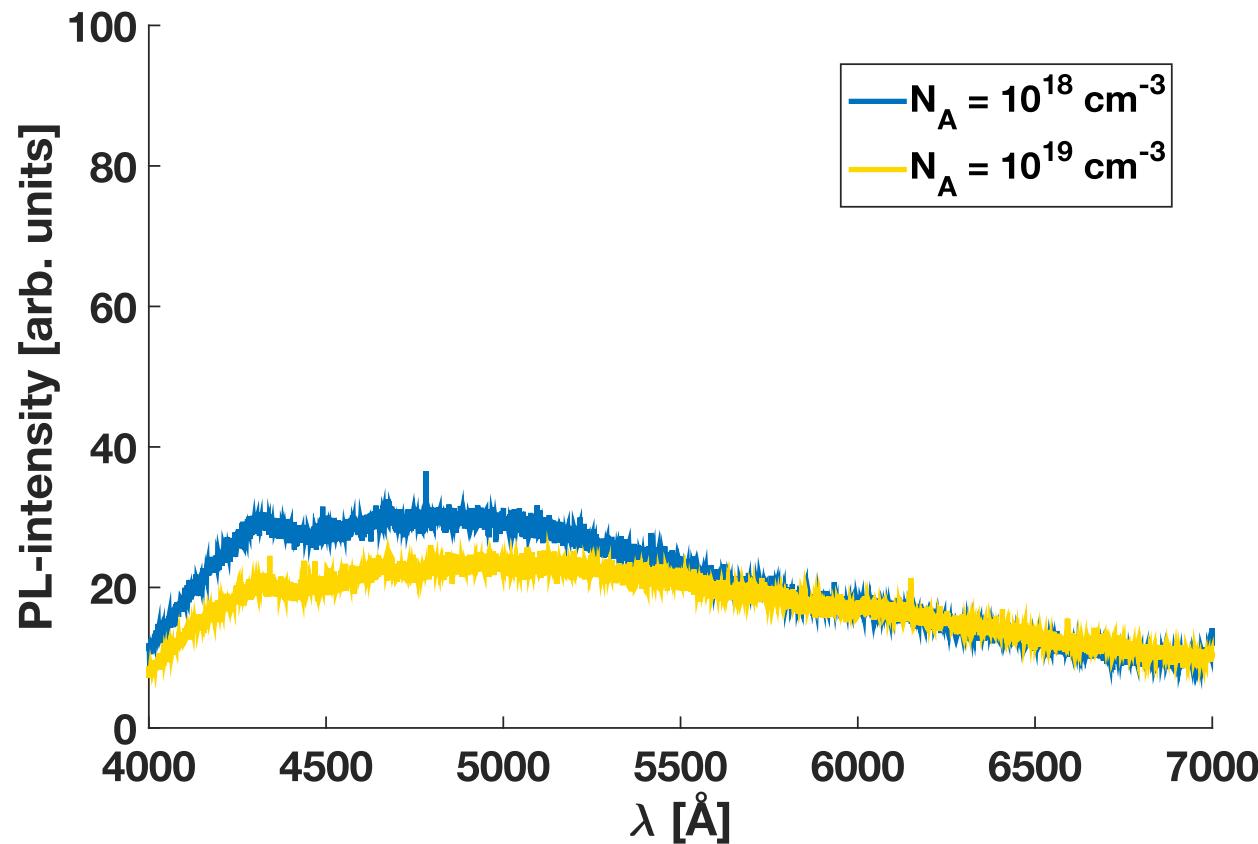
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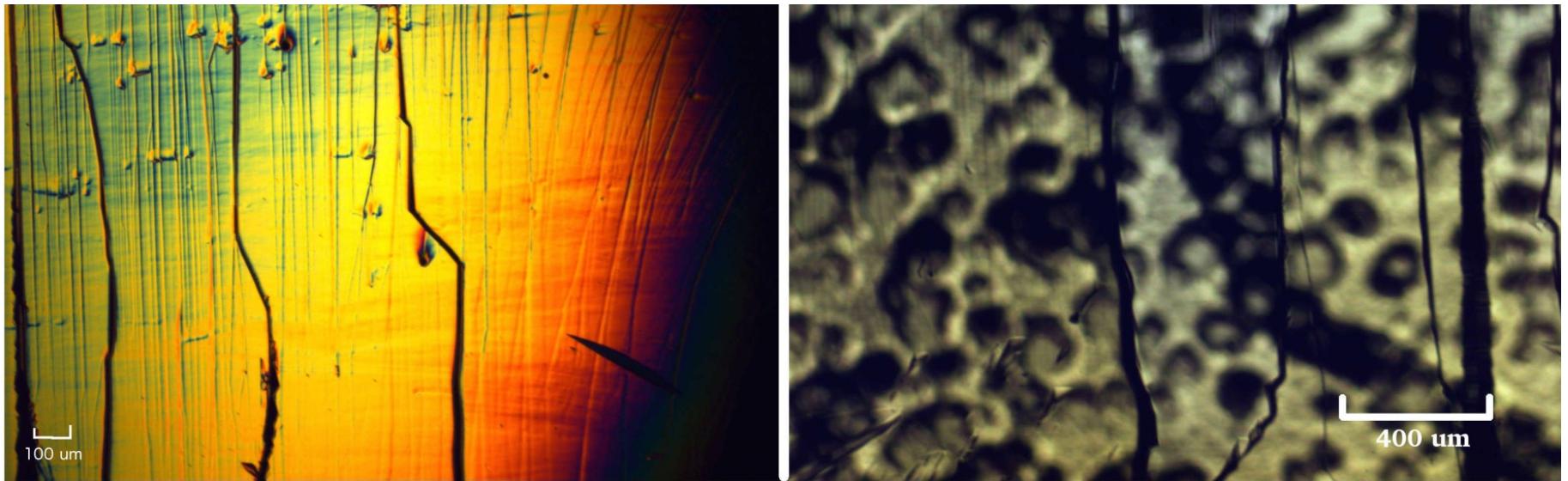
Photoluminescence spectroscopy



Photoluminescence spectroscopy



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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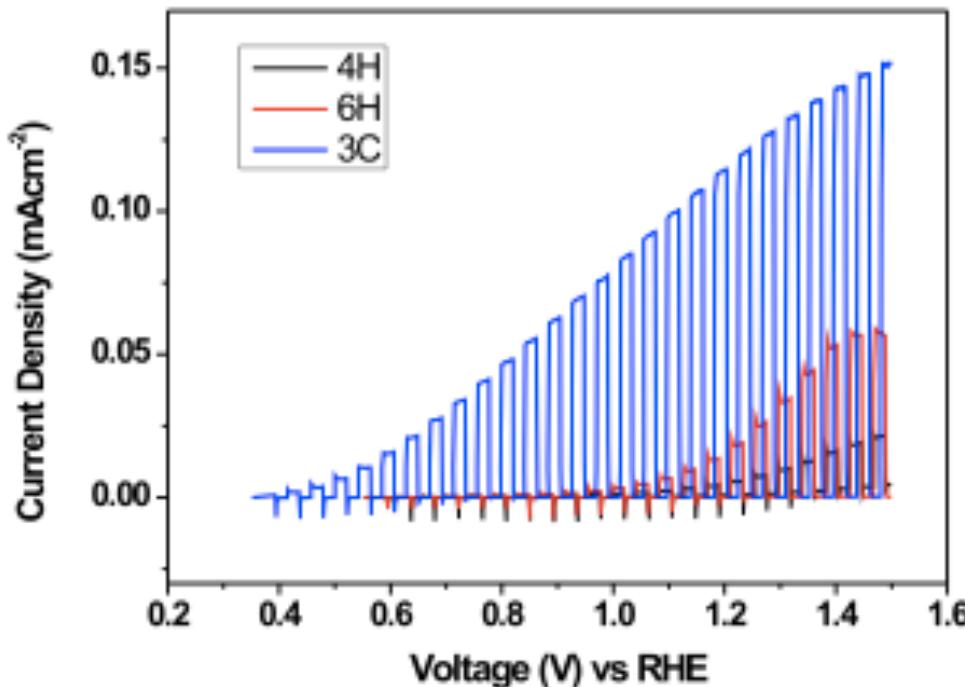


Fig. 3. Current-potential curves using n-type 3C-SiC, 6H-SiC and 4H-SiC as photoanode in 0.1M NaOH under chopped AM1.5G illumination.

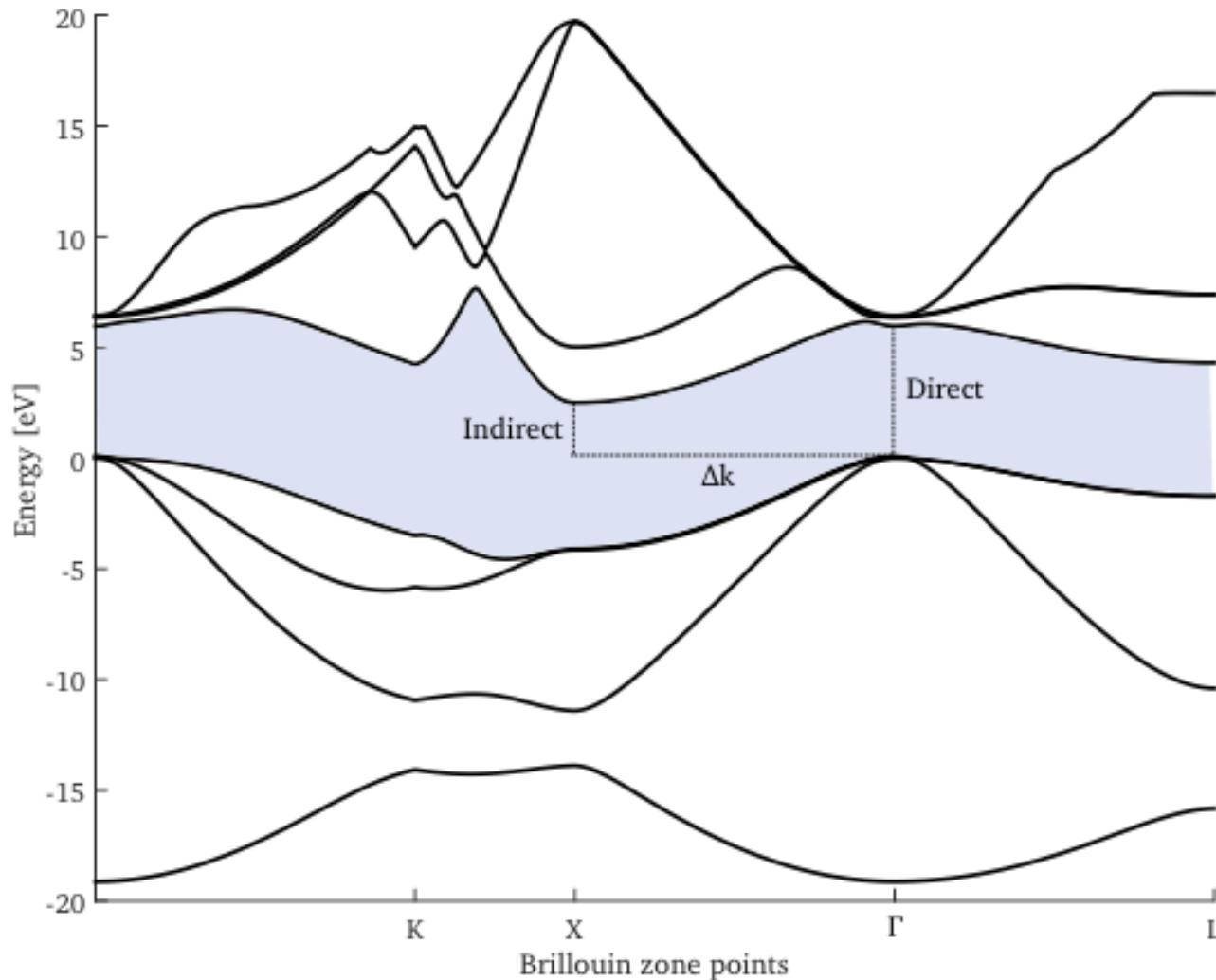
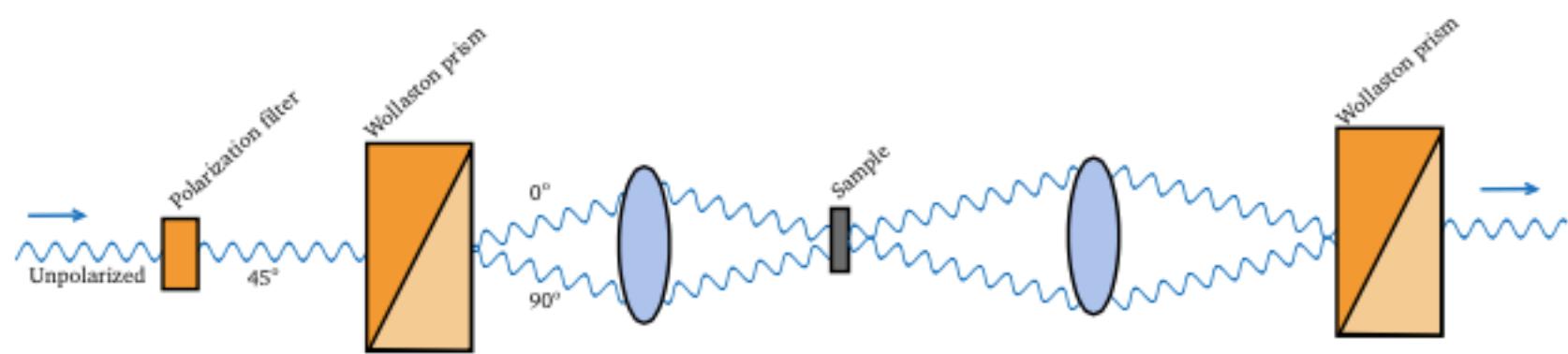


Table 2.3: Binding energies for some of the most common SiC dopants.

Element	Dopant type	$E_{D/A}$ [meV]	Reference
N	Donor	57	[13]
B	Acceptor	735	[5]
Al	Acceptor	257	[13]



	Temp. [°C]	Time [h:min]	Thickness [μm]	Doping [cm^{-3}]	Mode	Seed
D1				10^{18}	Direct	Yes
D2	1825	2:30	350	10^{18}	Direct	Yes
D3	1825	3:00	360	10^{18}	Direct	Yes
D4			440	10^{19}	Direct	Yes
D5	1825	2:30	320	10^{19}	Direct	Yes
D6				10^{20}	Direct	Yes
D7	1825	2:30	220	10^{20}	Direct	Yes
D8	1825	2:30	380	10^{18}	Indirect	Yes
D9	1825	2:30	380	10^{20}	Indirect	No

	Temperature [°C]	Time [h:min]	Sample thickness [μm]	Terrace coverage [%]
S1	1825	4:00	700	40
S2	1850/1925	0:30/1:00	800	20
S3	1850/1925	0:30/1:00	800	
S4	1850/1925	0:30/1:00	900	30
S5	1875/1925	0:15/1:00	800	50
S6	1925	1:00	700	20
S7	1925	1:00	700	