Semiconductor physics group

LENS - Light and Electricity from Novel Semiconductors

Office: Kristen Nygårds hus (3.etg.)
Lab: MiNa-Lab

- Clean room (440 m^2) and
  9 char. labs

Status: >30 people

- 4-5 Prof's,
- 4 adm./engineers
- ~10 postdoc/researchers
- ~10 PhD's,
- ~5 Msc's,

- Currently 13 active externally funded + 1 infrastructure project
- 35 – 40 journal papers/year


ZONE 1

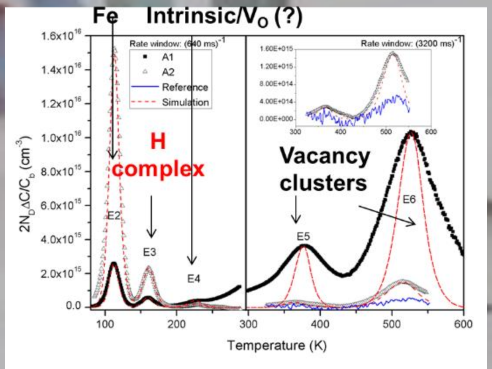

REMOVE
FOR BAKE OUT

Hva gjør en masterstudent på LENS?

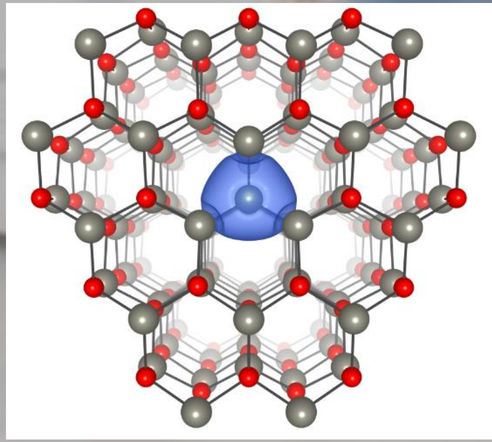
Lager materialer

Endrer egenskaper

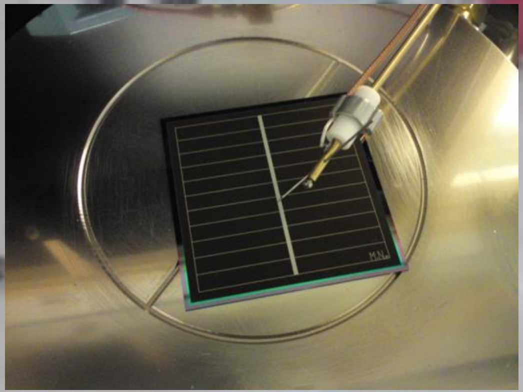
Karakteriserer



Analysere



Modellerer



Lager enkle komponenter

Halvlederfysikk / LENS

- Anvendelsesmotivert grunnforskning

Temaer:

- PV; Solceller, vannsplitting, etc
- Kvanteteknologi
- Lys fra faste stoffer (LED)
- Nanoteknologi
- Termoelektrisitet
- Sensorer (detektorer)
- Kraftelektronikk
- ...

Veilederteamet...

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Ion implantation
Ga2O3 for power electronics

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Solar cells
Silicon
Detectors

Justin Wells
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Quantum-spintronics
Photoemission spectroscopy
Synchrotron based char.

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Ga2O3 for power electronics
Quantum Technology
Novel solar cell materials

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Thin film growth
Solar energy conversion
Devices

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Solar Cells

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Photoemission spectroscopy
Synchrotron based characterization

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Theory / DFT

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Theory / DFT
Oxides

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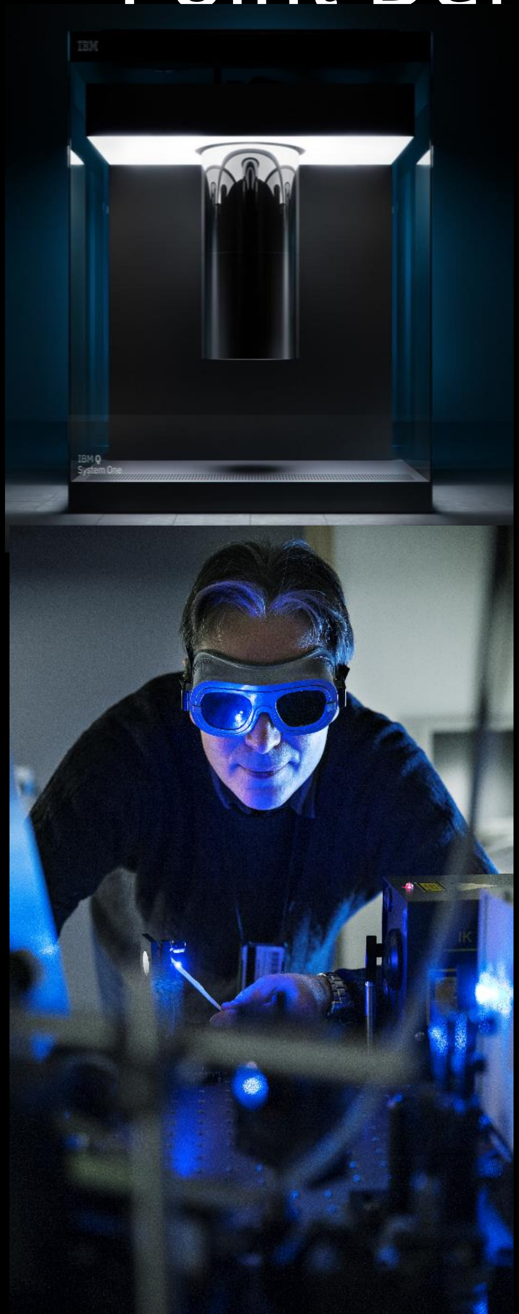
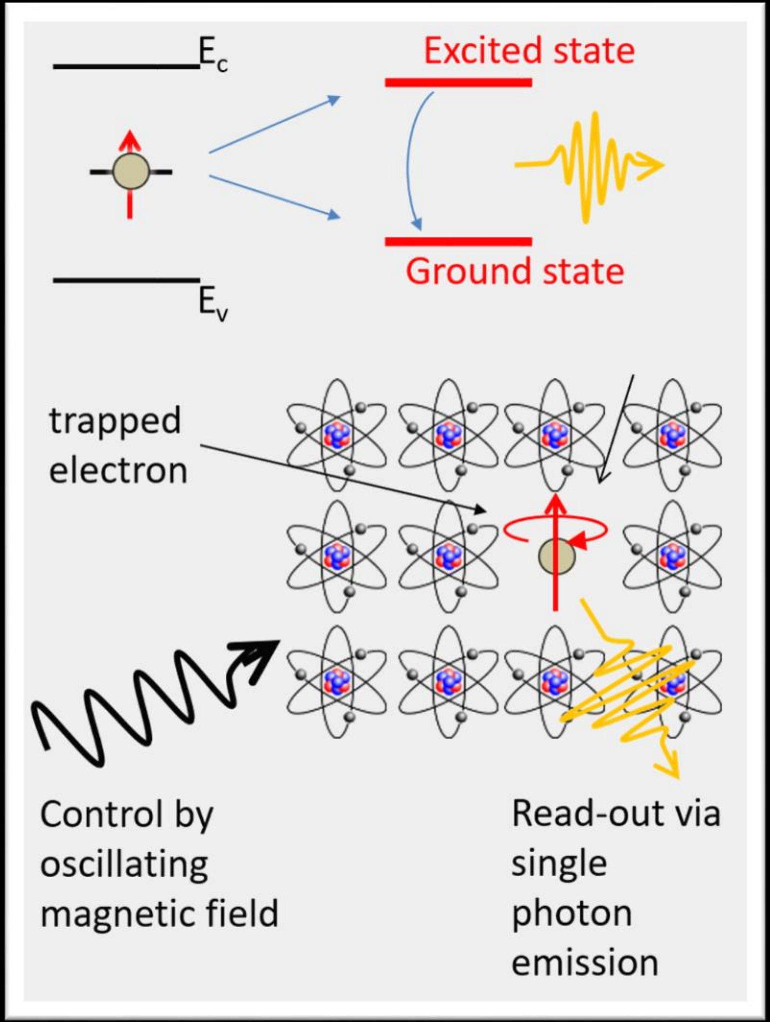
Photoluminescence
Quantum Technology

Point Defects for Quantum Technology



The field of quantum technology (QT) aims to exploit the most exotic consequences of quantum mechanics for real-world applications within computing, communication and sensing. While many QT platforms use superconducting processors that require mK operation temperatures, extreme stability and are challenging to scale, **point defects in semiconductors** combine the potential for room-temperature qubit operation with nanoscale sensing and single-photon emitter (SPE) capabilities. The most famous qubit candidate, or SPE, is the NV center in diamond, but qubit candidates in more mature and industrially friendly materials were recently discovered. We study qubits in silicon and silicon carbide, and search for new SPEs in novel materials.



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Master projects

Silicon Carbide (SiC):

- Single photon detection from defects in SiC, Tooth peaks
- Nanopillars as waveguides for VSi emmision in SiC
- Stark effect of CAV, NV and VV in SiC
- Controlled formation (implantation) of single and ensamble SPE's in SiC

Silicon (Si):

- Demonstrating Single photon emission of W and C line in Si
- Revealing the origin of the SD lines in Si
- Stark effect of the G-center

Devices:

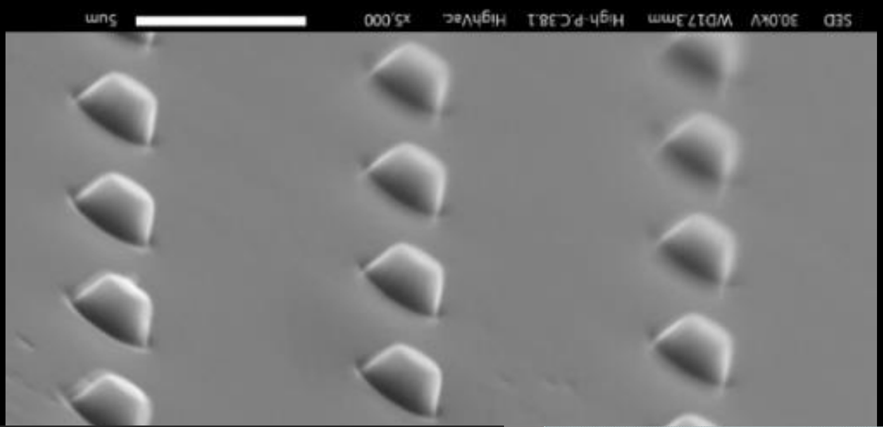
- Device prototype development using quantum defects in SiC
- Quantum sensors in SiC, imaging and electric field sensing
- Using Si based particle detectors as platofrm for quantum sensors

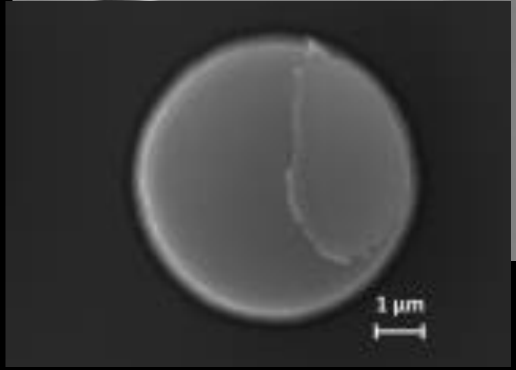
Materials exploration:

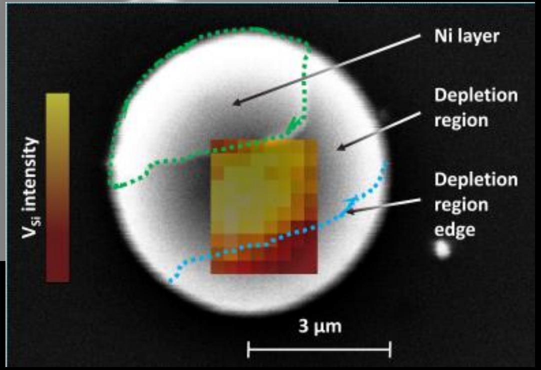
- Exploration of tomorrows materials for quantum technology

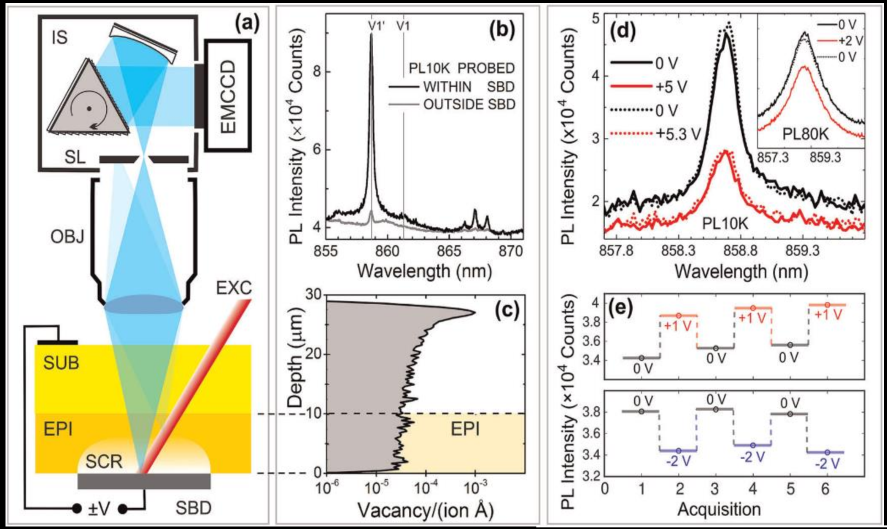
Theory:

- Quantum embedding, combining DFT and post-Hartree Fock methods
- Computational modeling (DFT) of quantum defects









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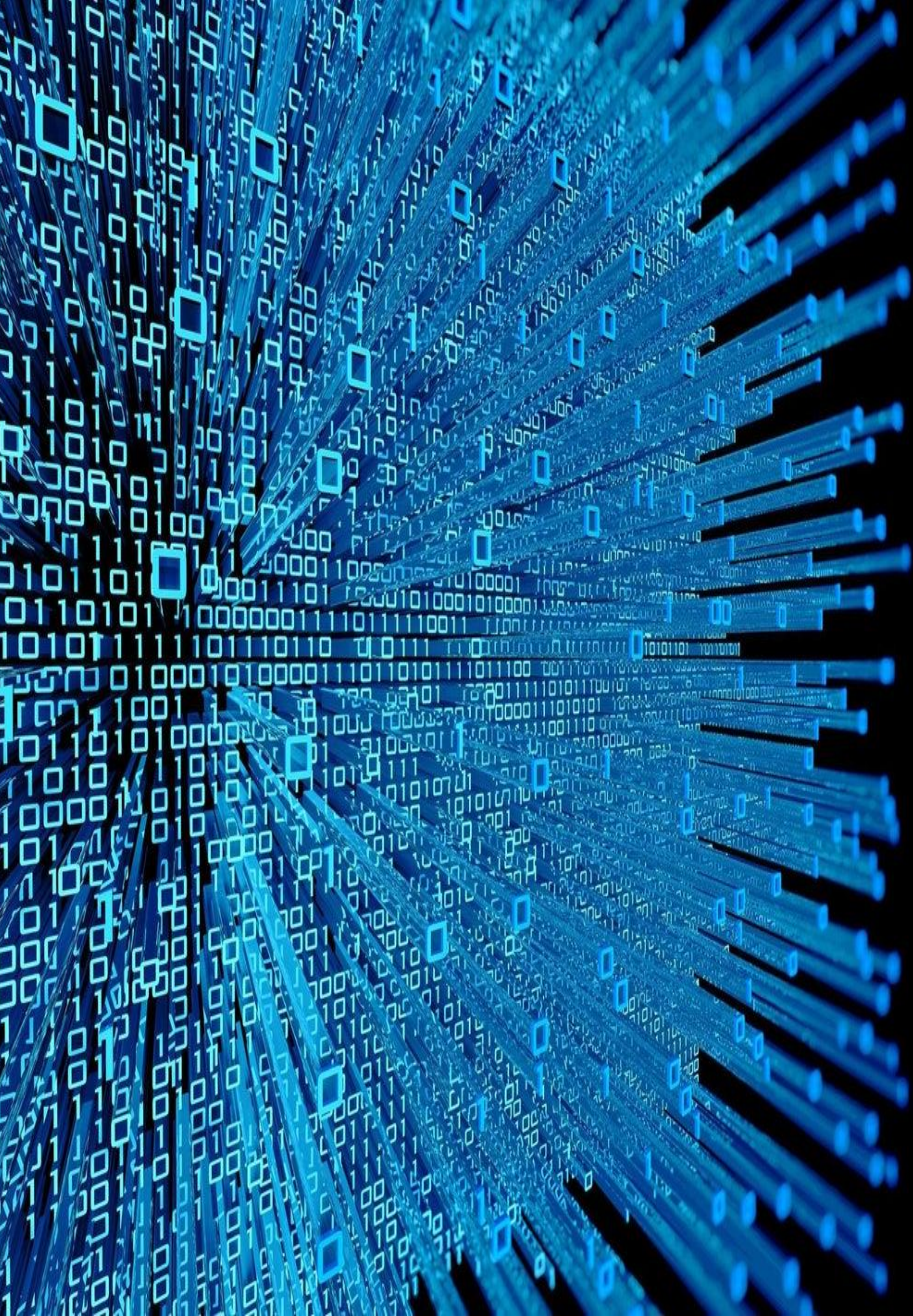
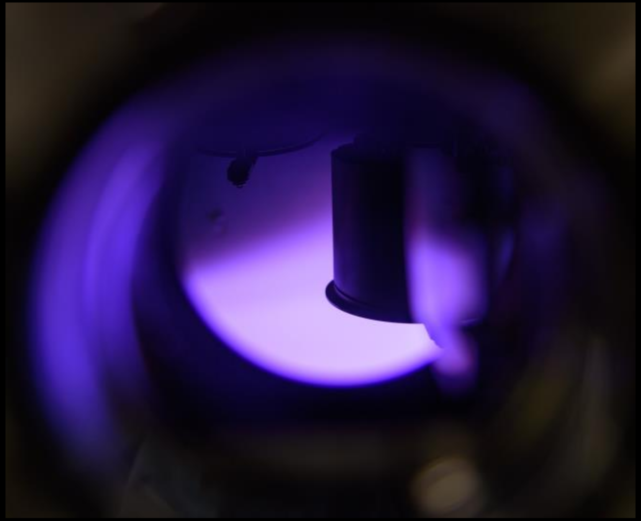


Example of master project:

Exploration of tomorrow's materials for quantum technology

Objective: Experimental fabrication of materials predicted to obtain promising properties for the use in semiconductor quantum technology.

How: Thin film deposition by magnetron sputtering of materials identified by theoretical calculations. The project will focus on obtaining high-quality material enabling the probing of single-photon source defects.
This will be an experimental project.



Interested? Contact us!

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Vegard S. Olsen

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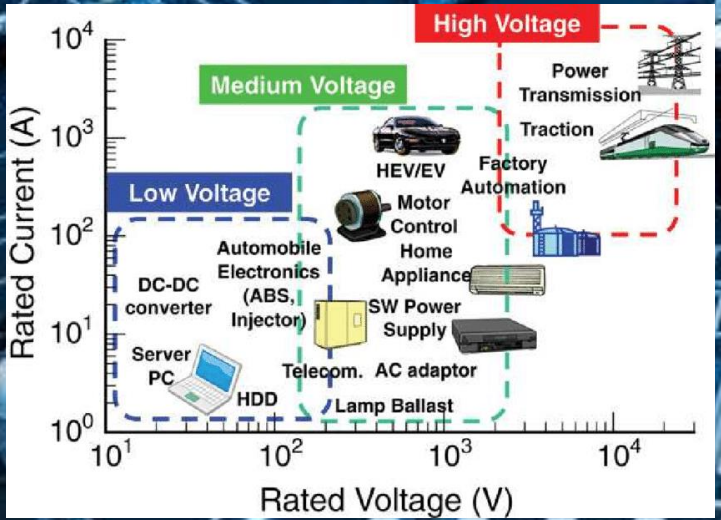
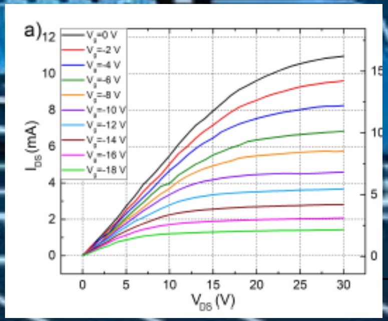
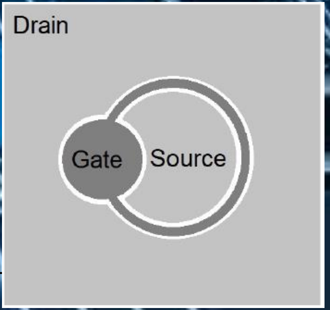
Ga_2O_3 for power electronics

Power electronics (PE) play an important role in the collection, delivery and storage of energy, and is a key enabler for energy efficiency, renewable energy and smart grids. PE converters are found in about 40% of electrified technology for applications ranging from handheld devices through electric vehicles to offshore windmill parks. β-Gallium oxide (Ga_2O_3) is emerging as a viable candidate for certain classes of power electronics, solar blind UV photodetectors, solar cells, and sensors with capabilities beyond existing technologies due to its large bandgap.
Thus, Ga_2O_3 provides a platform for studying fundamental semiconductor properties, but in a material of massive technological and scientific interest. It is a research field where The LENS/Semiconductor physics group is internationally strong!







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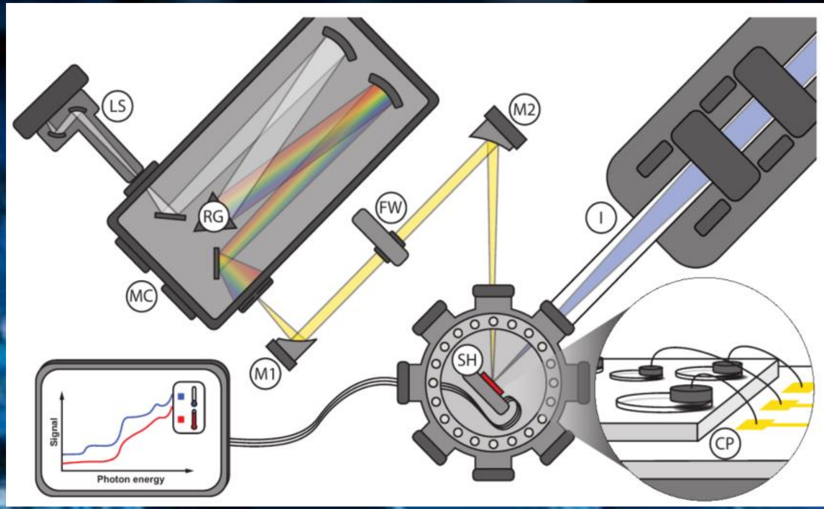
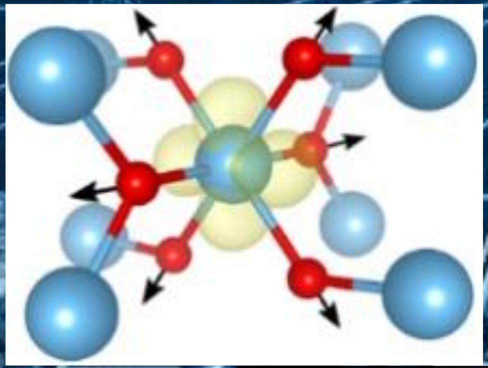
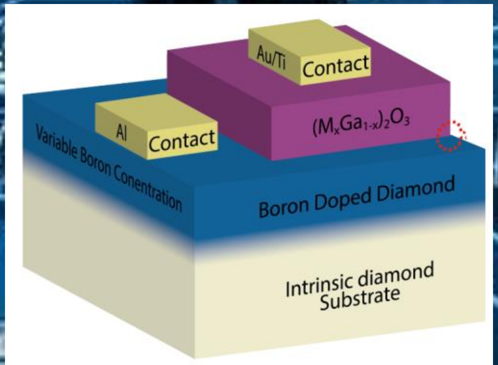
Master projects

- Diamond and Gallium Oxide Interfaces for Power Electronic Devices
- Ion beam modification and doping in Ga_2O_3
- Studying solid state diffusion of dopants and impurities in Ga_2O_3
- Characterizing electrically active defects in Ga_2O_3
- Theoretical modeling of dopants and recombination centers
- MOSFET device fabrication







Our master projects can be focused on growth, characterization or application, or they can be more theoretically (computationally) oriented.

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Example: Diffusion and defects in Ga2O3

- Studying solid state diffusion of dopants and impurities in Ga_2O_3

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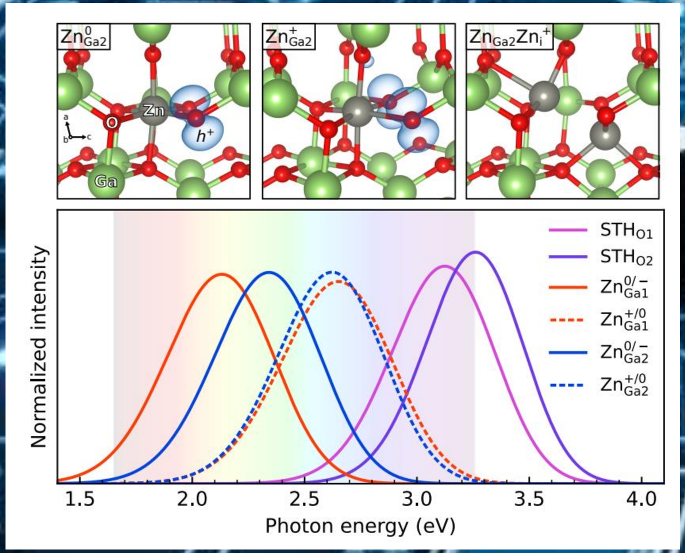
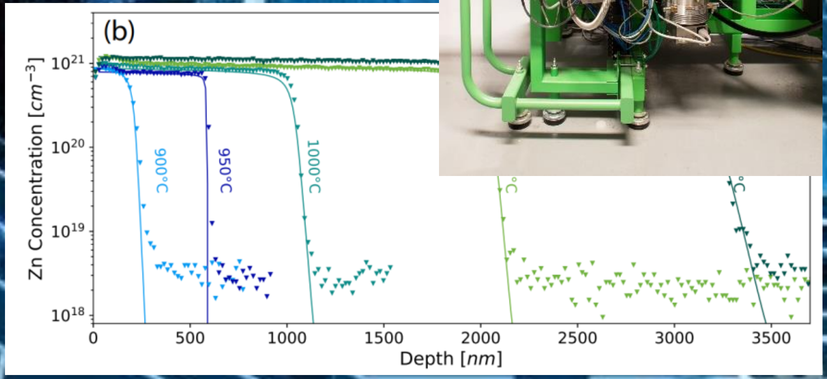
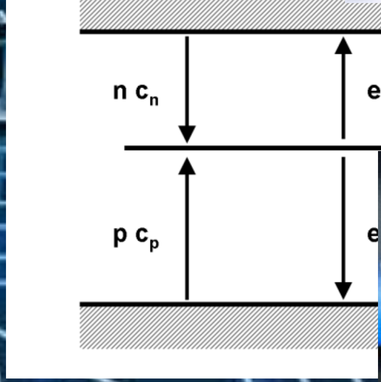
Teoretisk (DFT) modellering



SIMS og numerisk modellering



Elektrisk og optisk karakterisering



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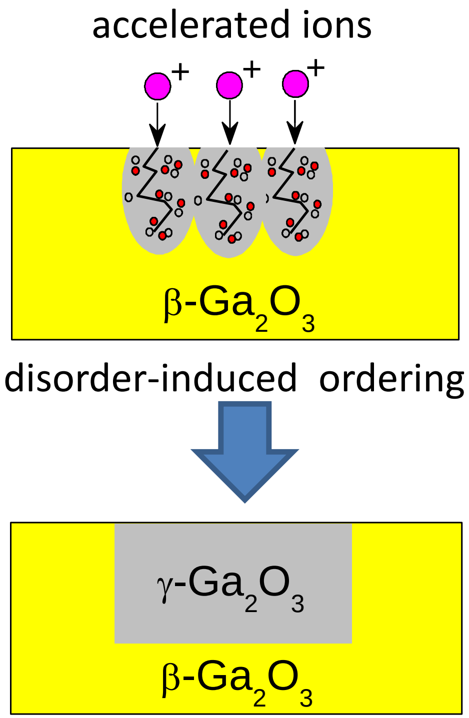
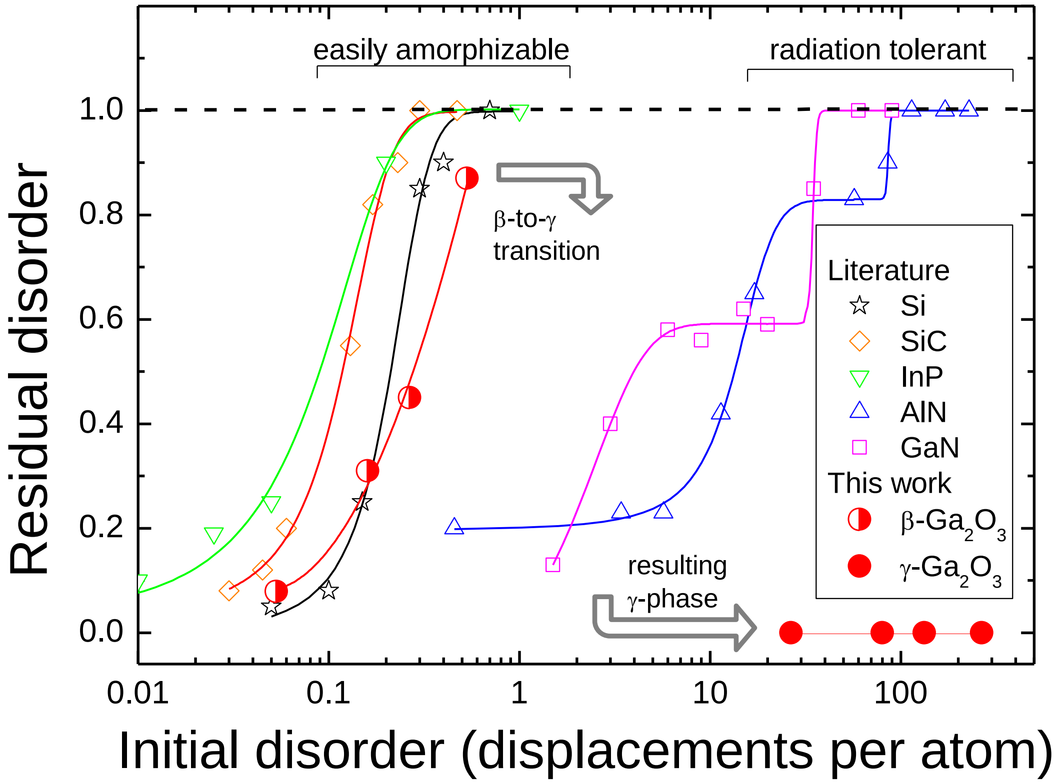
Universal radiation tolerant semiconductor

We discovered, what we called, universal radiation tolerant semiconductor and already got some publicity, see the interview in the NewScientist (https://www.newscientist.com/article/2367286-crystal-impervious-to-radiation-could-be-used-in-spaceship-computers/) and got an offer to test our sample for the Gateway space project (https://www.nasa.gov/gateway/overview)

Andrej Yu. Kuznetsov
andrej.kuznetsov@fys.uio.no





This unique radiation tolerance of Ga_2O_3 is because of fascinating disorder-induced ordering phase transition!

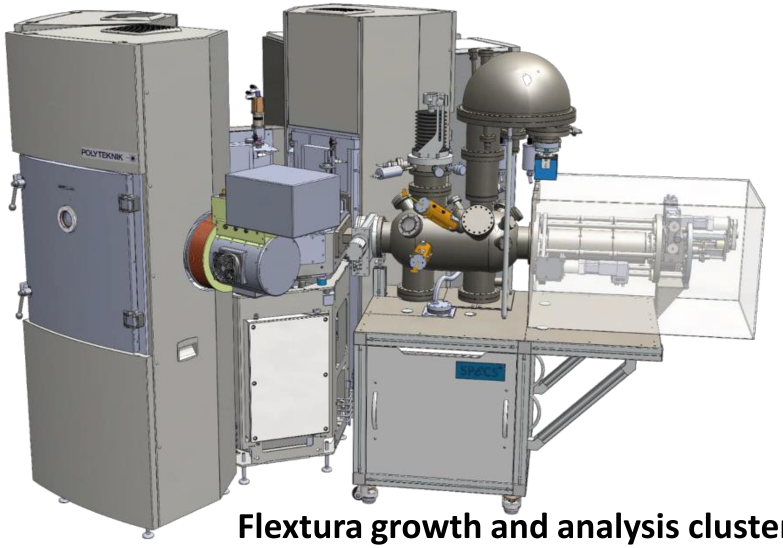
Come to us to do your master project on this amazing material!!

Simon Cooil

Ultra-wide Bandgap Materials for the Next Generation of Power Electronics – Diamond and Ga_2O_3

Characterising interfaces

- Thin film deposition using state of the art tools.
- Materials characterisation using photoelectron spectroscopy and electron diffraction.
- Hands on experiments!



Flextura growth and analysis cluster.

(DOPED)

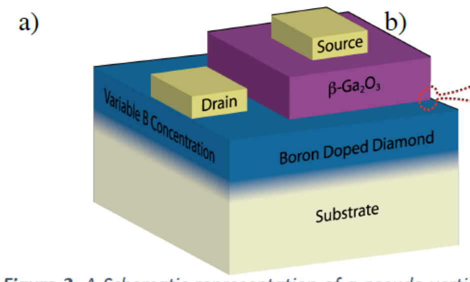
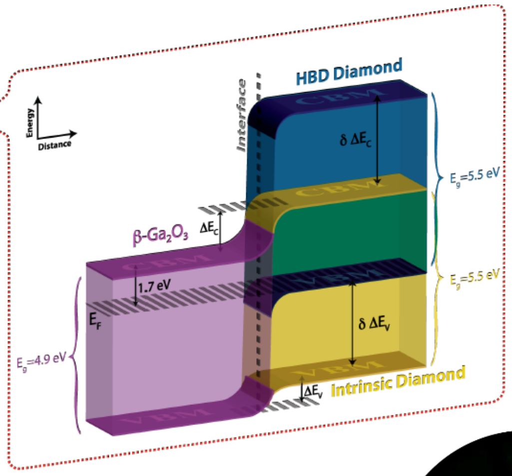
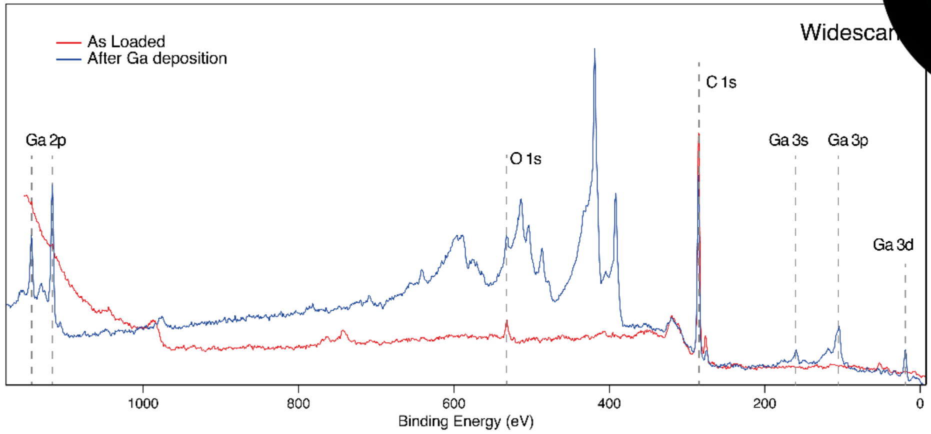
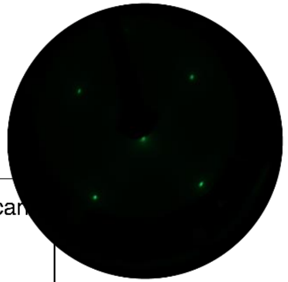


Figure 2. A Schematic representation of a pseudo-vertical p-n heterojunction comprising $_{n}$-β-Ga_2O_3/ $_{p}$-Diamond grown on intrinsic diamond substrate is shown in a). A schematic diagram of the band alignment between β-Ga2O3 and Diamond showing the large variation in conduction/valance band offsets available by tailoring the boron concentration in diamond.



Characterisation with XPS/UPS

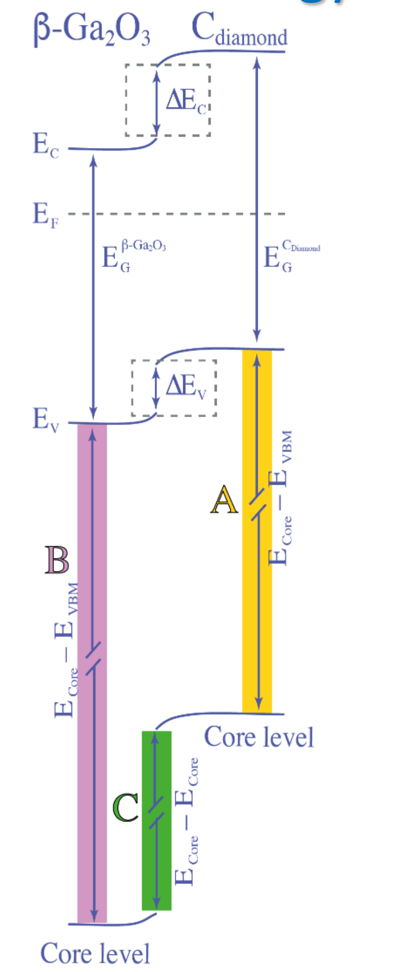




LEED

156 eV

Methodology

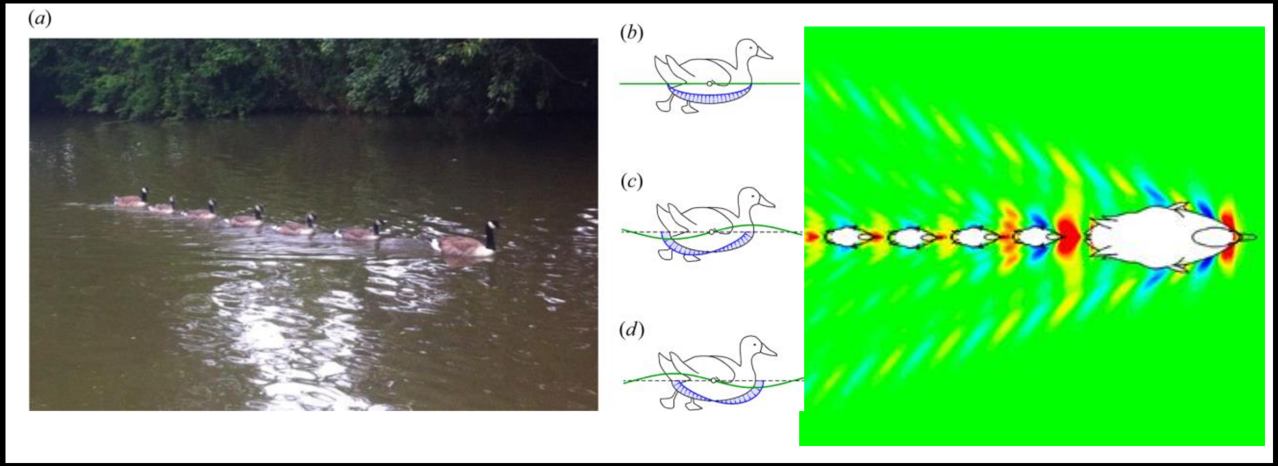


$$\Delta E_V = \boxed{A} + \boxed{C} - \boxed{B}$$

$$\Delta E_C = E_G^{\beta\text{-}Ga_2O_3} + \Delta E_V - E_G^{C_{Diamond}}$$

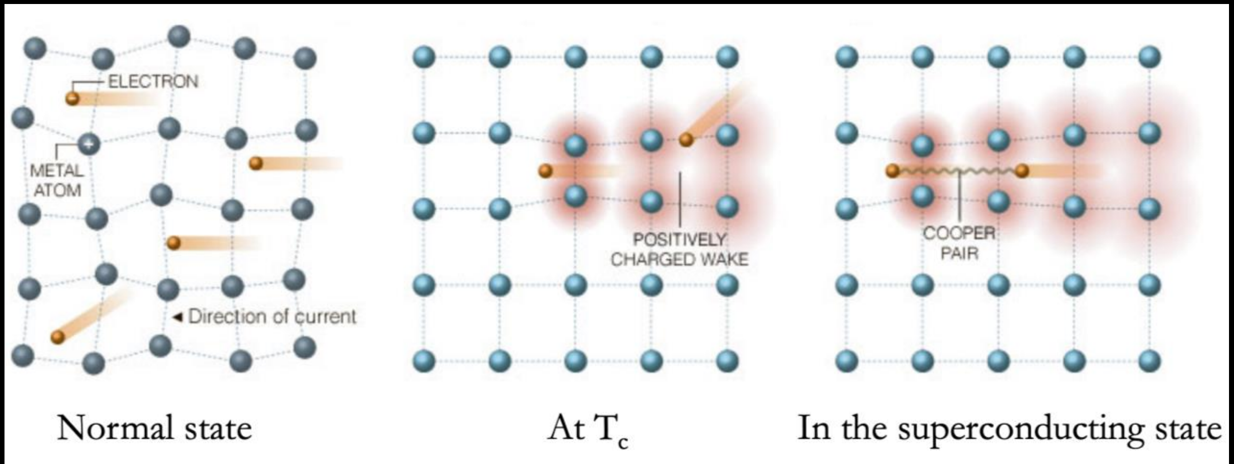
Electron-boson interactions for ultra-low-power technology — *the general concept*

1) Many-body interactions and the Ig-Nobel prize (Sept 2022)



"Wave-riding and wave-passing by ducklings in formation swimming": the resistance to motion for ducks in formation is independent of the number of ducks.

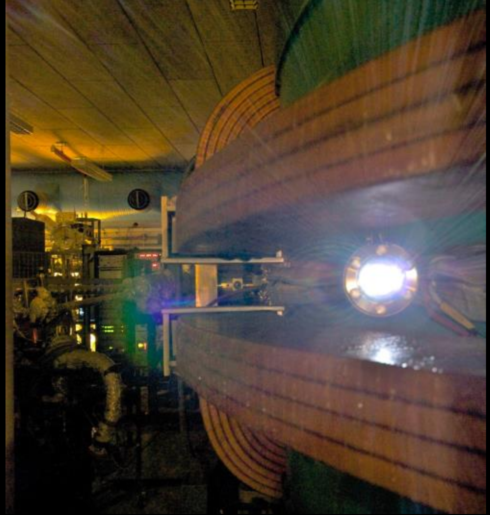
2) Electron-phonon coupling as a driver of superconductivity:

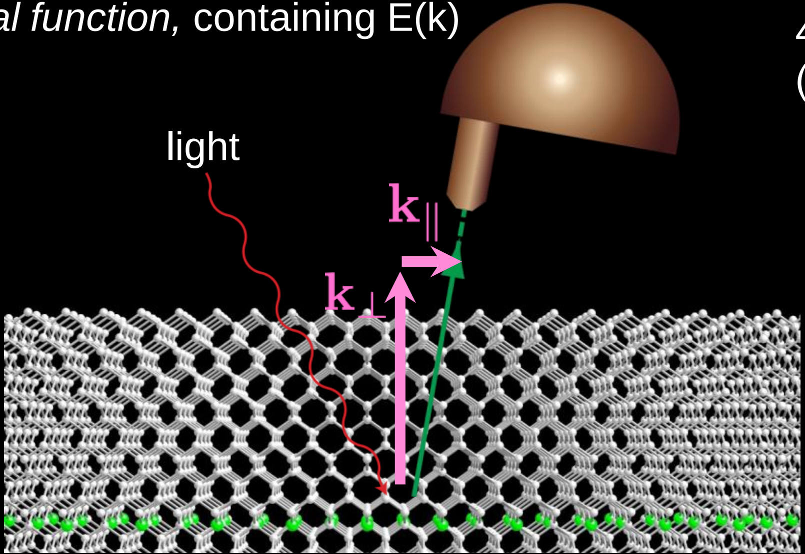


$$T_c \approx \frac{\omega_{log}(K)}{1.20} \exp\left(-\frac{1.04(1+\lambda)}{\lambda - \mu^*(1+0.62\lambda)}\right)$$

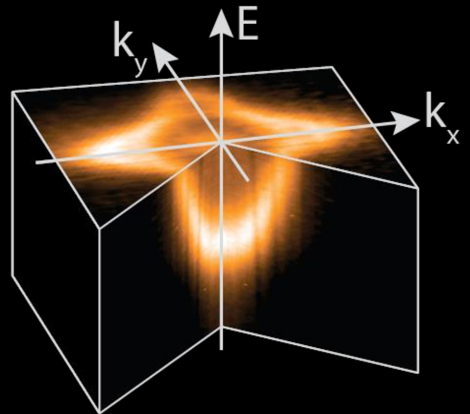
McMillan/Allen formula
λ = change in effective mass

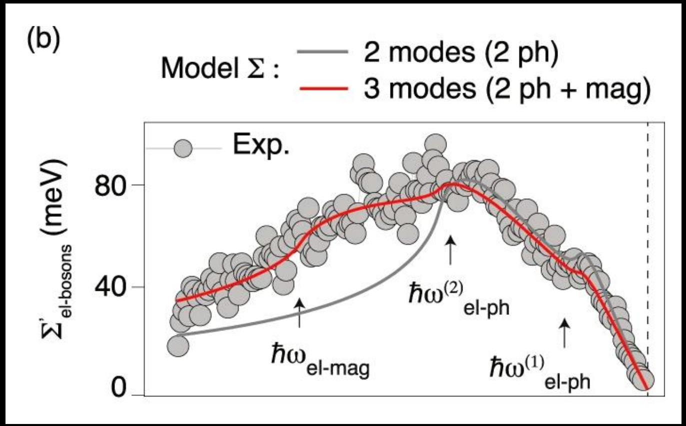
3) Momentum resolved photoelectron spectroscopy:
gives us the electron *spectral function,* containing E(k)





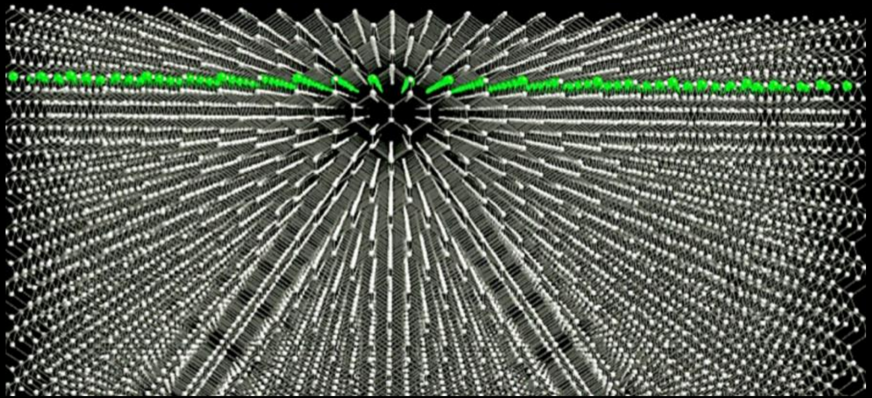
4) From the *spectral function* we can extract parameters (including λ) and understand the interaction strength





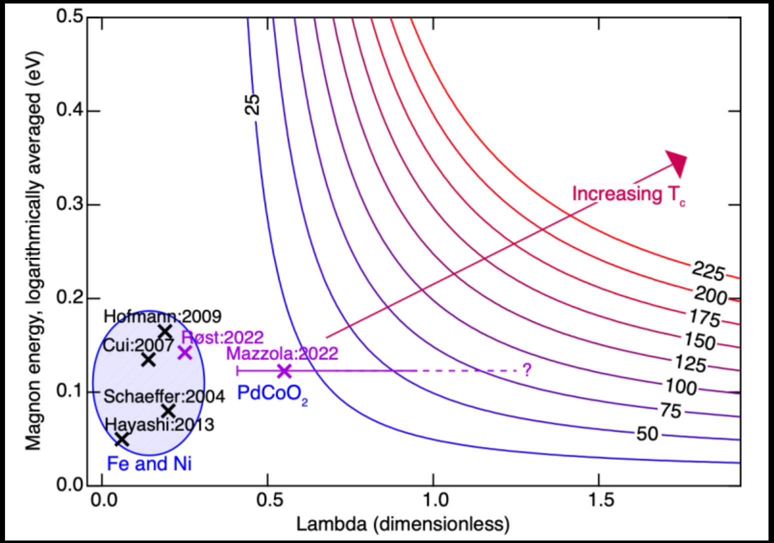
Electron-boson interactions for ultra-low-power technology — *the master projects*

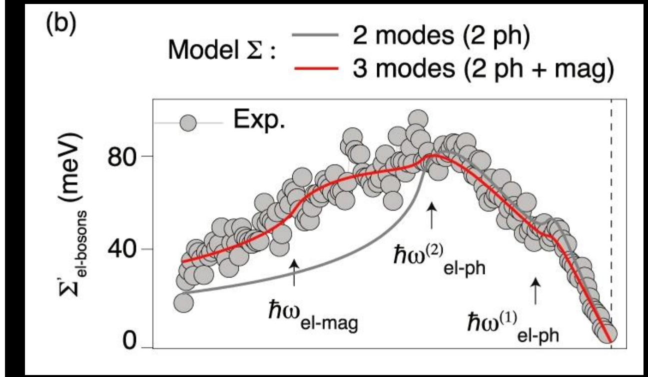
1) Grow and characterise a range of high quality samples, i.e. 2D materials, 2D structures in silicon



2) Perform photoemission measurements at home and at synchrotron sources

3) Perform analysis of the the photoemission data to extract the coupling, and how λ depends on material properties (like doping, magnetisation, etc)





4) Develop models for the spectral function (collaboration with theory)

Interested? Then contact us — we can be quite friendly! [Justin.wells@fys.uio.no]

REFERENCES: Yuan, Z., et al., *Wave-riding and wave-passing by ducklings in formation swimming*. doi:10.1017/jfm.2021.820
McMillan W.L., *Transition Temperature of Strong-Coupled Superconductors* https://doi.org/10.1103/PhysRev.167.331
Allen P.B. and Dynes R.C., *Transition temperature of strong-coupled superconductors reanalyzed*. https://doi.org/10.1103/PhysRevB.12.905
Mazzola F. et al., *The Sub-band Structure of Atomically Sharp Dopant Profiles in Silicon.* https://doi.org/10.1038/s41535-020-0237-1
Mazzola et al., Tuneable electron--magnon coupling of ferromagnetic surface states in PdCoO2. https://doi.org/10.1038/s41535-022-00428-8

Solar cells: Silicon

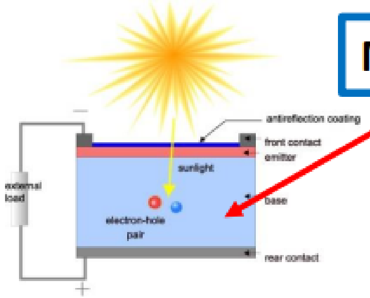
Project:

SUSOLTECH
The Norwegian Research Centre for Sustainable Solar Cell Technology

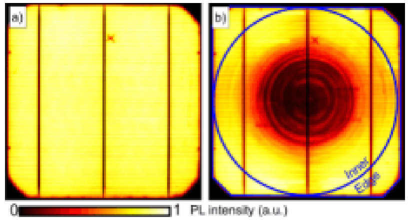
Collaborator:

IFE

Eduard Monakhov
eduard.monakhov@fys.uio.no



Material quality!



18% 14%

We do: Electrical and optical measurements on silicon

Relevant for industry:

DYNATEC
Dynatec

NorSun
NorSun

norwegian crystals
Norwegian Crystals

REC
SOLAR'S MOST TRUSTED
REC Solar Norway

SINTEF
SINTEF

Solar cells: Tandem cells

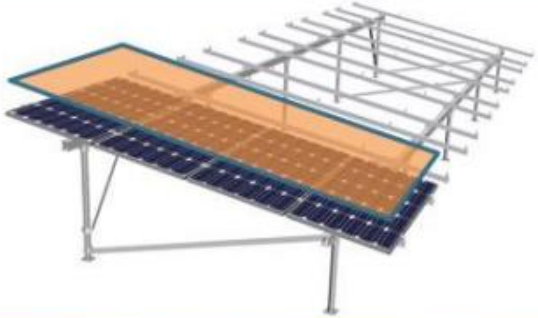
Project:

SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

Theoretical limit for Si-cell (Shockley–Queisser limit): ~30%

Theoretical limit for Si-based tandem: ~45%



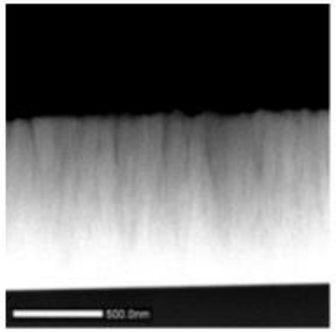
Material system:

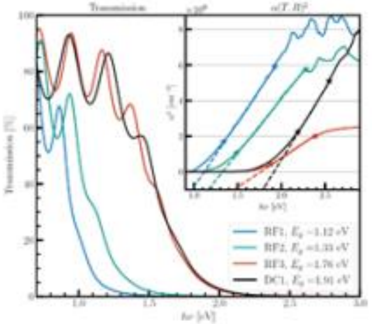
28 Ni 58.693 Nickel	29 Cu 63.546 Copper	30 Zn 65.38 Zinc

+

7 N 14.007 Nitrogen	8 O 15.999 Oxygen

=





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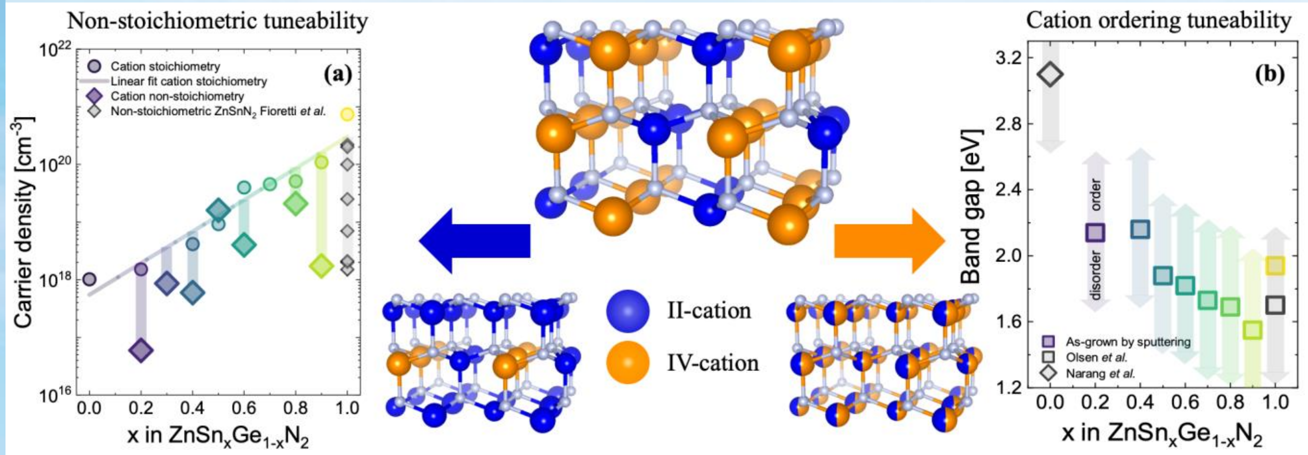
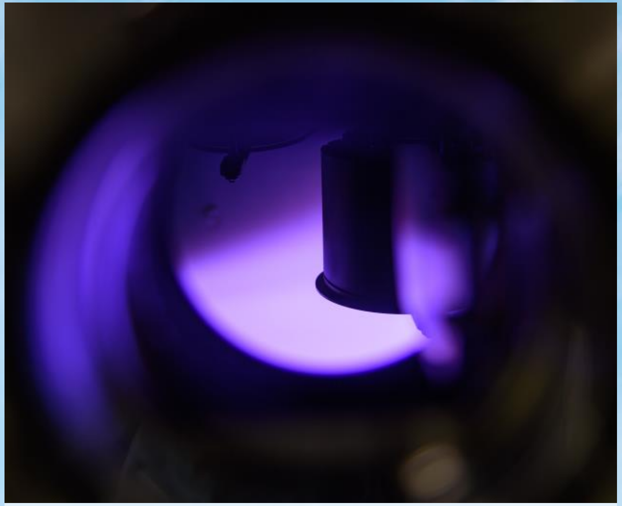
We do: Synthesis, electrical and optical measurements

Development of earth-abundant novel solar cell materials

Target: Tailor the structural, optical and electrical properties of II-IV-N_2 to for potential use in tandem solar cells, focusing on $ZnSnGeN_2$ alloys.

How: Explore the tuneability of functional properties of $ZnSnGeN_2$ through experimental growth and characterization.





Growth: Magnetron sputtering
Characterization: XRD (structural), UV-Vis (optical), Hall effect (electrical), XPS (chemical) and UPS.

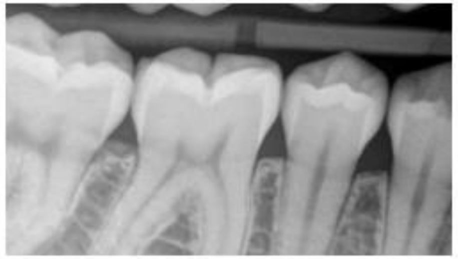
If you want to take part in the solar energy research at UiO, and learn how to operate some of the most advanced instruments at UiO MiNaLab on a daily basis: contact me at v.s.olsen@smn.uio.no
Info about UiO MiNaLab: QR code

SCAN ME

Sensors & detectors

Collaborator:

SINTEF

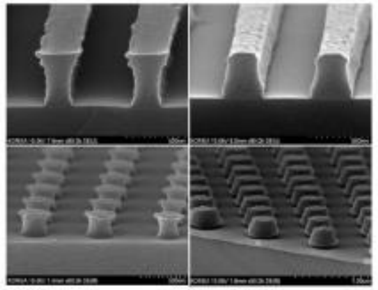


X-ray imaging

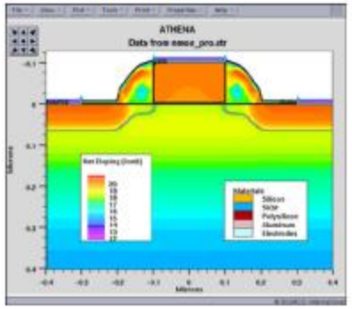
Radiation therapy

We do:

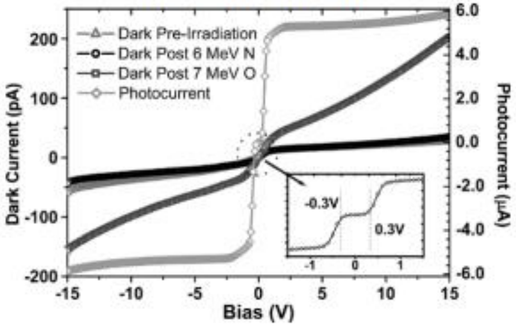
Making devices



Simulations



Measurements



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