First results from emission channeling lattice location experiments of ^{27}Mg in nitride semiconductors

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IS453 EC-SLI experiment

Emission Channeling with Short-Lived Isotopes

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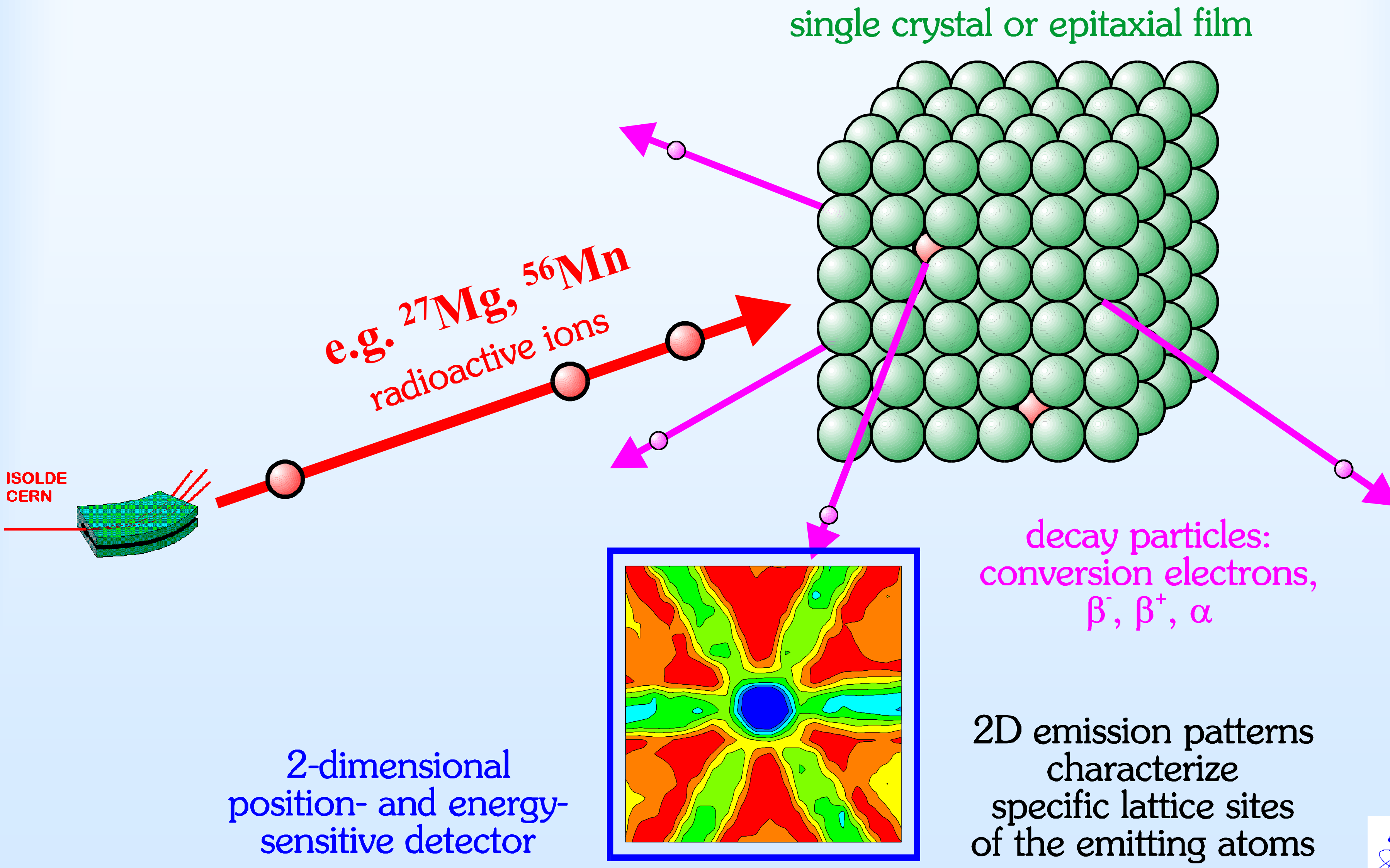
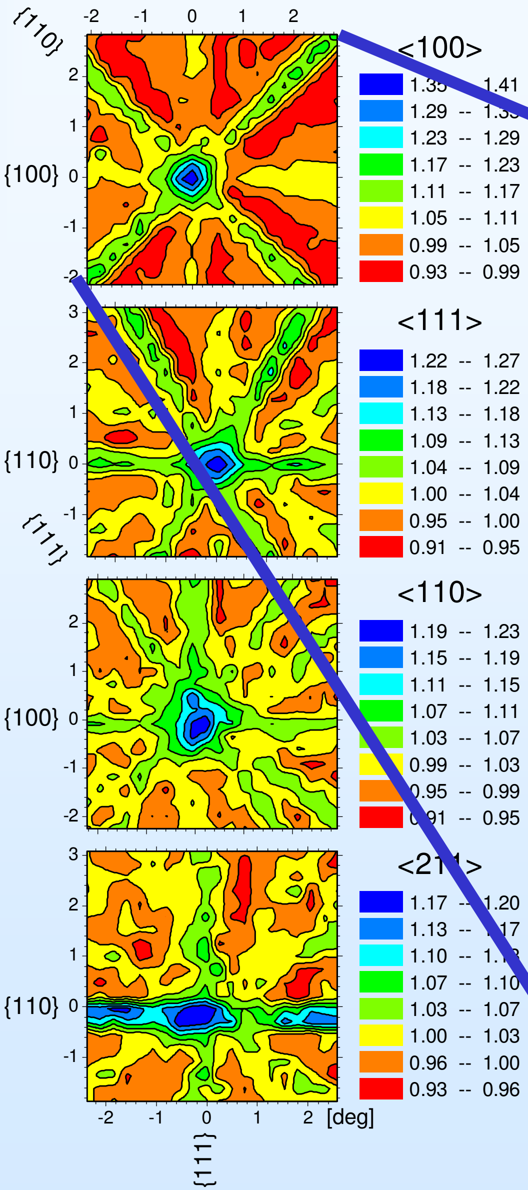
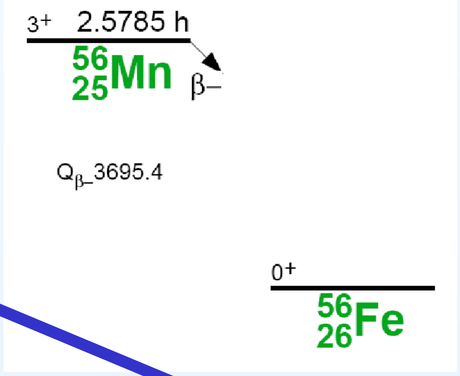
Emission channeling lattice location: basic principle



Last year’s talk:
β^- emission channeling patterns from ^{56}Mn in GaAs



T_A=RT
as implanted



Arsenide

Univ. 56 Mn, EC On-line

One of the physics cases of EC-SLI proposal: Lattice location of Mg in nitride semiconductors

- Mg is the only technologically relevant acceptor in the nitride semiconductors GaN, AlN and possibly also in InN ($\rightarrow$ optoelectronics, blue and white LEDs)

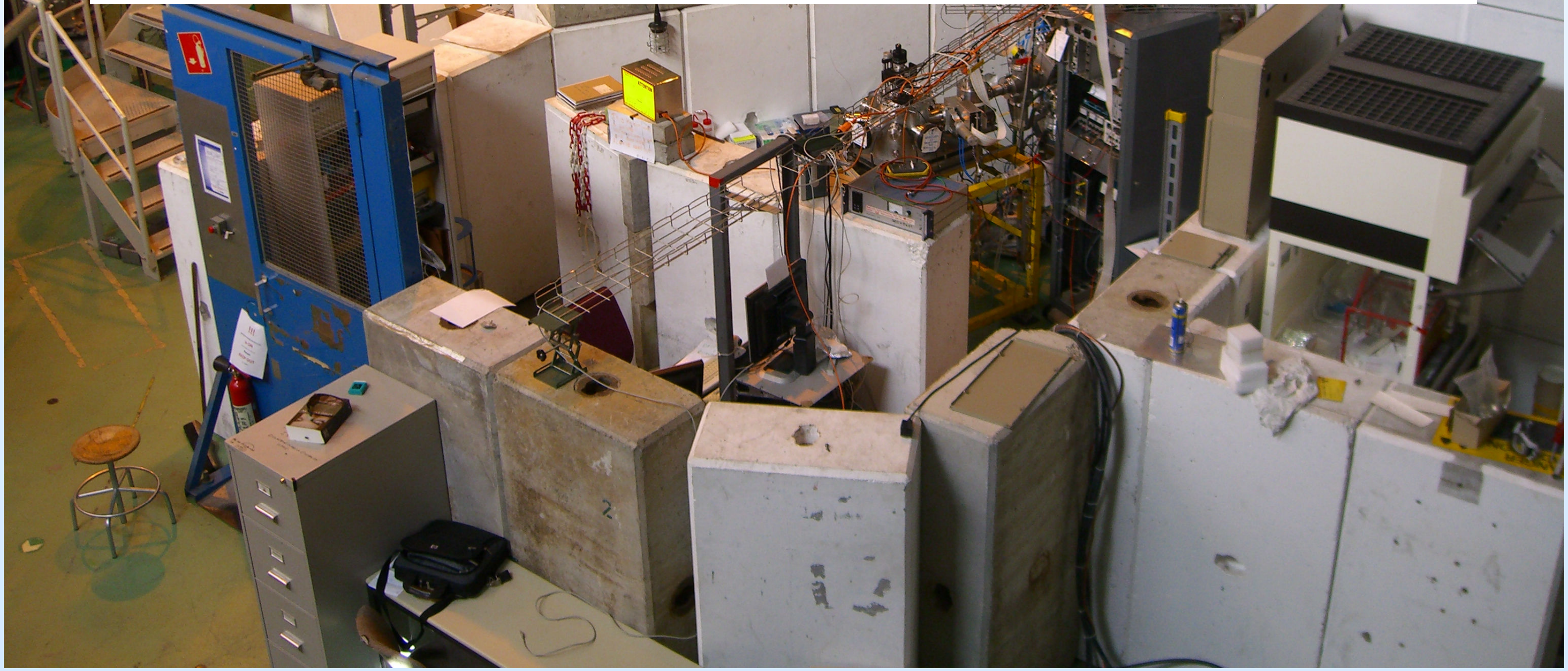
$\Rightarrow$ Knowledge on the lattice location of Mg is crucial for understanding the problems related to *p*-type doping of the nitride semiconductors (substitutional *vs* interstitial Mg)

Emission channeling lattice location experiments for Mg have been considered for more than 10 years, but available isotopes are difficult:

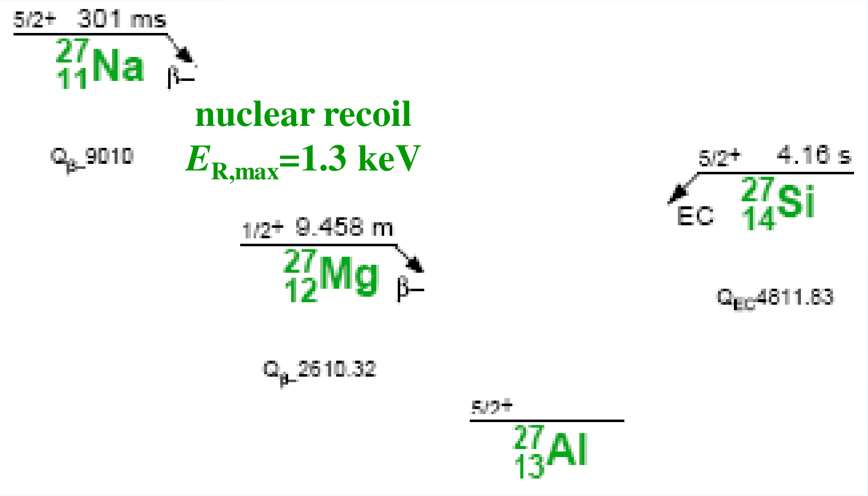
- ~~^{23}Mg (12 s) $\beta^+ \rightarrow$ ^{23}Na (stable): short-lived, requires on-line measurements, huge ^{23}Na contamination~~
- ^{27}Mg (9.5 min) $\beta^- \rightarrow$ ^{27}Al (stable): short-lived, requires on-line measurements, huge ^{27}Al contamination
- ~~^{28}Mg (21.7 h) $\beta^- \rightarrow$ ^{28}Al (2.2 min): β^- emission channeling patterns mixed with those of radioactive daughter~~

EC-SLI on-line setup coupled to GHM beam line

- On-line setup available and in use since 2007
- Equipped with fast position-sensitive Si pad detector that allows for data taking rates up to 3.5 kHz
- In August 2009 the setup was moved to GHM, occupying the space that was available following the removal of the PHOENIX ECRIS experiment
- Sept. 2009: First ^{27}Mg beam time, reduced to ~2.5 shifts only, due to Booster vacuum problems



Major Problem with mass 27 beams: ^{27}Al contamination

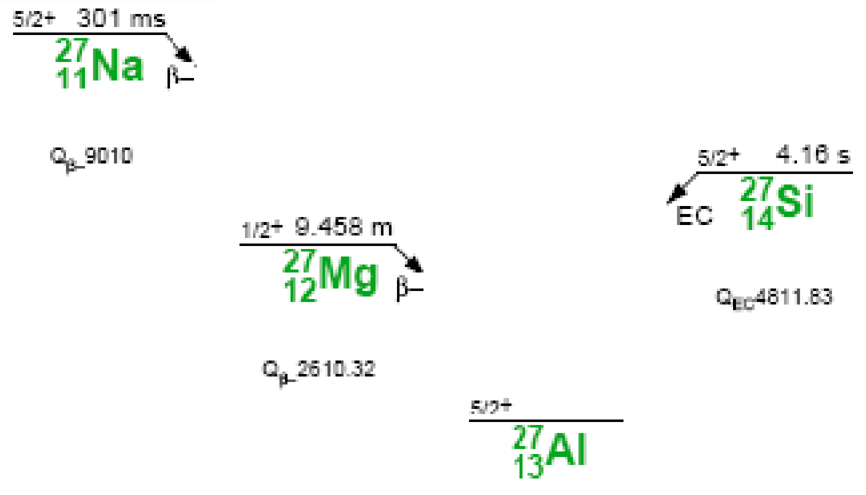


- **Normal target operating conditions (target 450 A, line 280 A, ~2000°C):** mass 27 beams from SiC-W or UC-W surface ionization targets dominated by stable ^{27}Al
- **SiC target # 409:**
- **~3.6 nA ^{27}Al or 2×10^{10} ions/s with NO protons on target**
  ~5 nA ^{27}Al or 3×10^{10} ions/s with ~1.5 μA protons ON
  while ^{27}Mg RILIS yields are around 5 pA or 3×10^{7} ions/s

⇒ **^{27}Al is thermally released contamination of target material**

⇒ **EC-SLI experiments with such a contamination are not feasible (single-crystalline samples would be destroyed during analysis)**

Major Problem with mass 27 beams: ^{27}Al contamination



- T_{boil} (Al) = 2450°C *vs* T_{boil} (Mg) = 1107°C

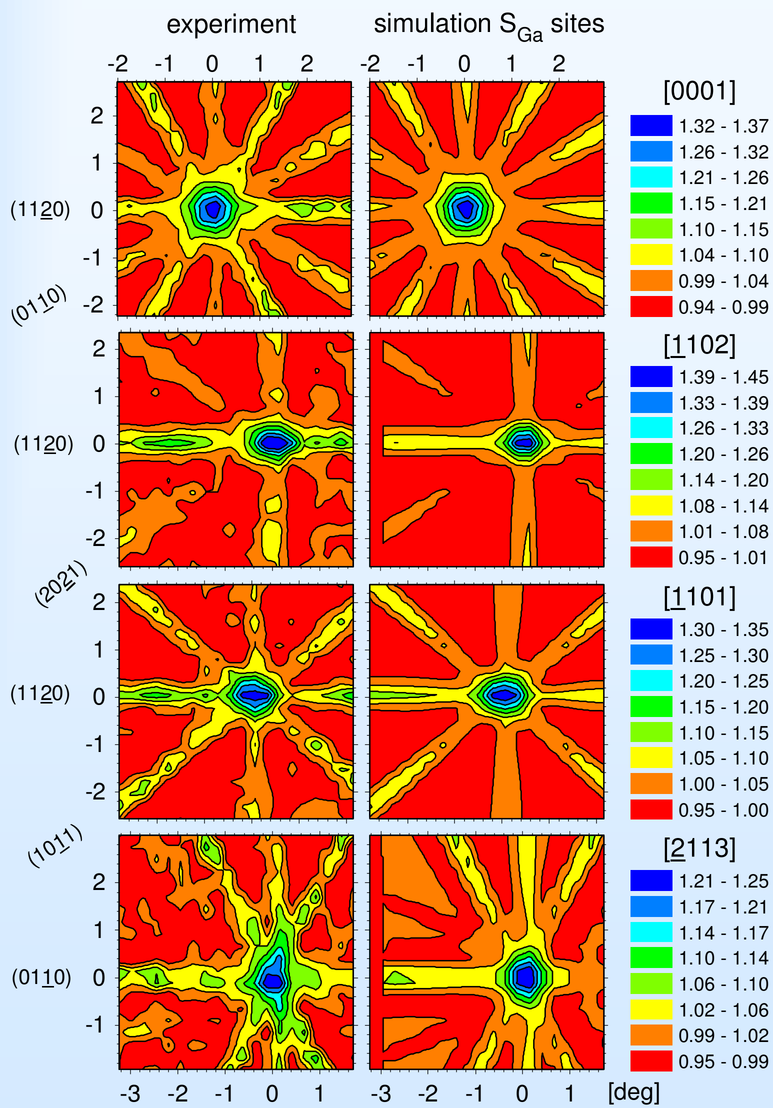
⇒ outdiffusion of Al from target can be reduced effectively by running the target under relatively cool conditions, with less severe losses for Mg

⇒ With target 220 A, line 250 A, estimated temperature 1000-1200°C with proton beam on target, we obtained around 2-5 pA of ^{27}Al, ~0.3 pA or 2×10^6 ions/s of ^{27}Mg (estimated from ~1500 Hz count rate of detector)

⇒ **Reduction of factor ~1000-2500 for ^{27}Al, factor ~15-20 for ^{27}Mg**

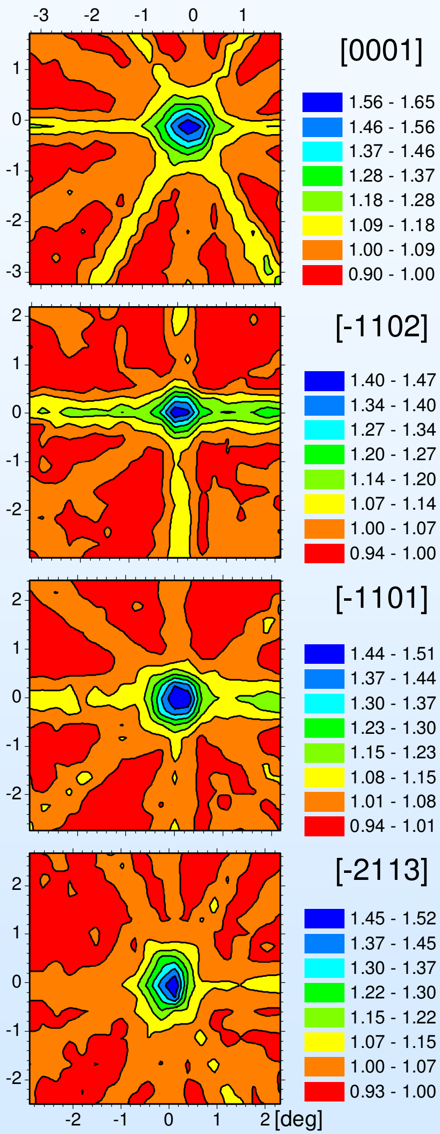
β^- emission channeling patterns from ^{27}Mg in GaN

T_A=RT as-implanted



- ^{27}Mg+ ^{27}Na implanted (~10^{11} cm^{-2} per pattern on 1 mm beamspot)
- beam off ⇒ emission channeling patterns measured from ^{27}Mg β^- particles only
- preliminary fit results (not corrected for background, inaccurate depth profile):
  ~30% ^{27}Mg on substitutional Ga sites,
  possible Mg interstitial fraction 5-10% on hexagonal H or O sites
- Relatively high β^- endpoint energy of ^{27}Mg causes quite narrow channeling effects, improved angular resolution would help

β^- emission channeling patterns from ^{27}Mg in AlN



T_A=RT
as implanted

- emission channeling patterns measured from ^{27}Mg β^- particles
- qualitative result:
  ^{27}Mg on substitutional Al sites
- Assessment of possible interstitial sites will require comparison to simulations (not yet available)

Conclusions

- despite considerable problems, the first ^{27}Mg run of EC-SLI was successful
- removing the stable ^{27}Al contamination is just about feasible for EC-SLI experiments but needs to be improved
- ^{27}Mg occupies mostly substitutional Ga sites in GaN and substitutional Al sites in AlN

Future plans:

- simultaneous implantation and measurement up to 900°C (requires aluminized mylar foil in front of detector)
- improve angular resolution by factor of 2 by increasing distance of detector to sample (loss of factor 4 in solid angle!)
- lattice location of ^{27}Mg in InN
- ^{27}Mg lattice location experiments will be subject of PhD thesis of Ligia Amorim (IKS Leuven)