Ion Cutting in wide band gap compound semiconductors:

Atomic processes in hydrogen-induced layers

Thermoevolution of nanovoids and formation of extended internal surfaces studied by positron annihilation spectroscopy

in GaN, ZnO, AlN

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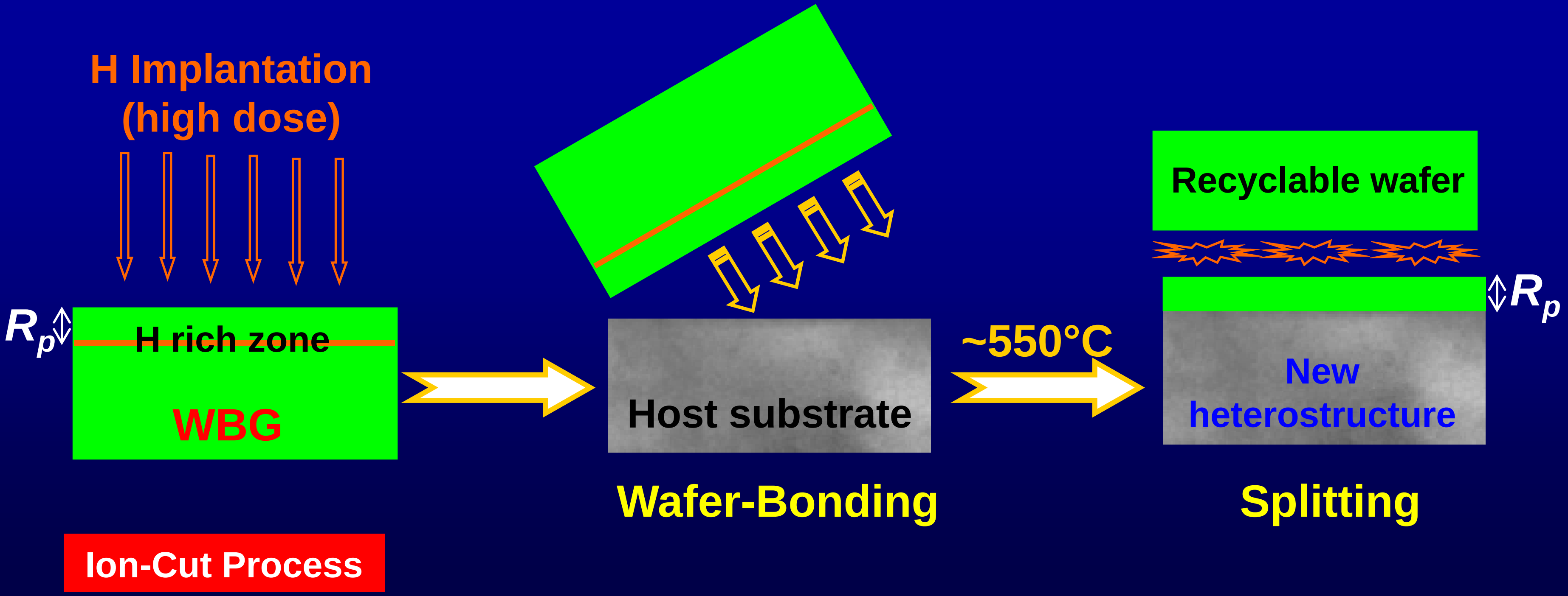
Motivation: Heterogeneous integration of WBG materials

Technological context: Hetero-epitaxial growth of WBG materials on foreign substrates leads unavoidably to the formation of growth-related defects such as dislocations, stacking faults and twins that occur to relax the strain which significantly limits the quality of the grown structures with undesirable impact on devices performance.

Our stratagem: Direct wafer bonding in combination with hydrogen ion-cutting is a promising stratagem to integrate bulk quality thin layers onto various host materials achieving a wide variety of heterostructures sometimes inconceivable by epitaxy. Having bulk properties, these new materials are very promising for a low cost fabrication of WBG-based devices such as phosphorous-free white LED and high performance laser diodes.



H Implantation (high dose)

R_p

H rich zone

WBG

Host substrate

~550°C

Recyclable wafer

R_p

New heterostructure

Wafer-Bonding

Splitting

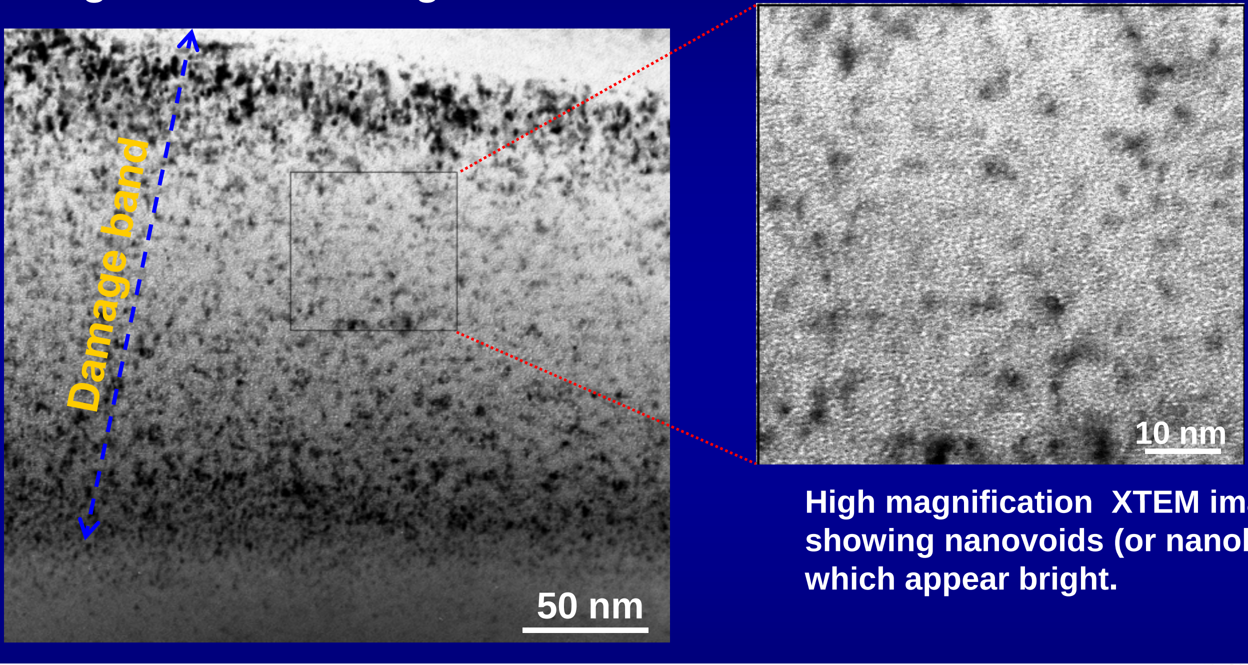
Ion-Cut Process

Motivation: Understanding basic mechanisms of ion-cut process

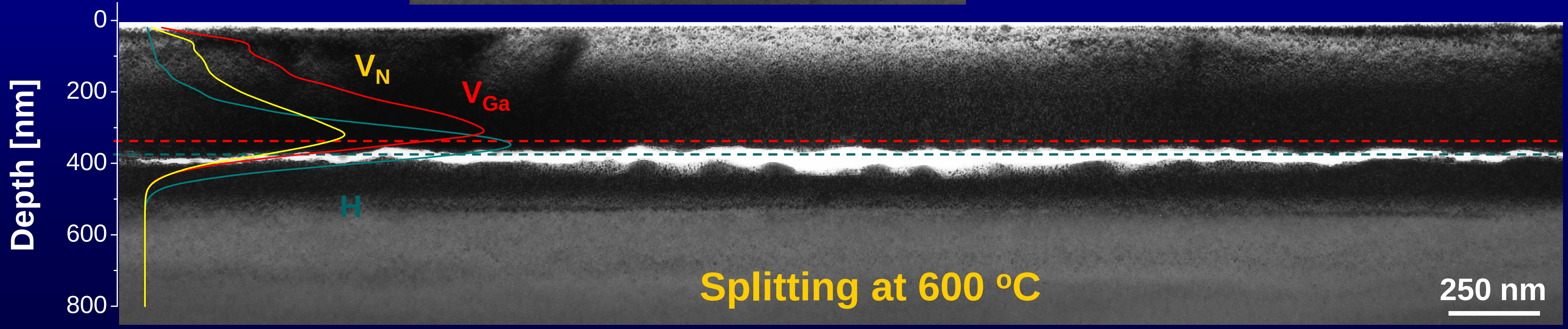
Objective: In order to draw a precise mechanistic picture of H-induced splitting of WBG materials a deep investigation thermal evolution of H-defect complexes is required

Example: **H-induced splitting of free standing GaN**

As-implanted GaN:
2.6×10^{17} H^+/cm^2 at
50 keV



High magnification XTEM image showing nanovoids (or nanobubbles) which appear bright.



Methodology

We are using a wide variety of experimental techniques in order to address different aspects of H-defect interactions leading to extended internal surfaces

Experimental Techniques:

1- Cross section transmission electron microscopy: Study of post-implantation structural and morphological changes;

2- Rutherford backscattering spectrometry in channeling mode: Characterization of displacement fields and strain build-up induced by thermal annealing of implanted substrate;

3- Elastic recoil detection analysis: Implanted gas depth profile and quantification of its amount as a function of thermal annealing;

4- Fourier Transform Infrared Spectroscopy: Identification of H-defect complexes induced by H implantation and their evolution during sub-surface cleaving process.

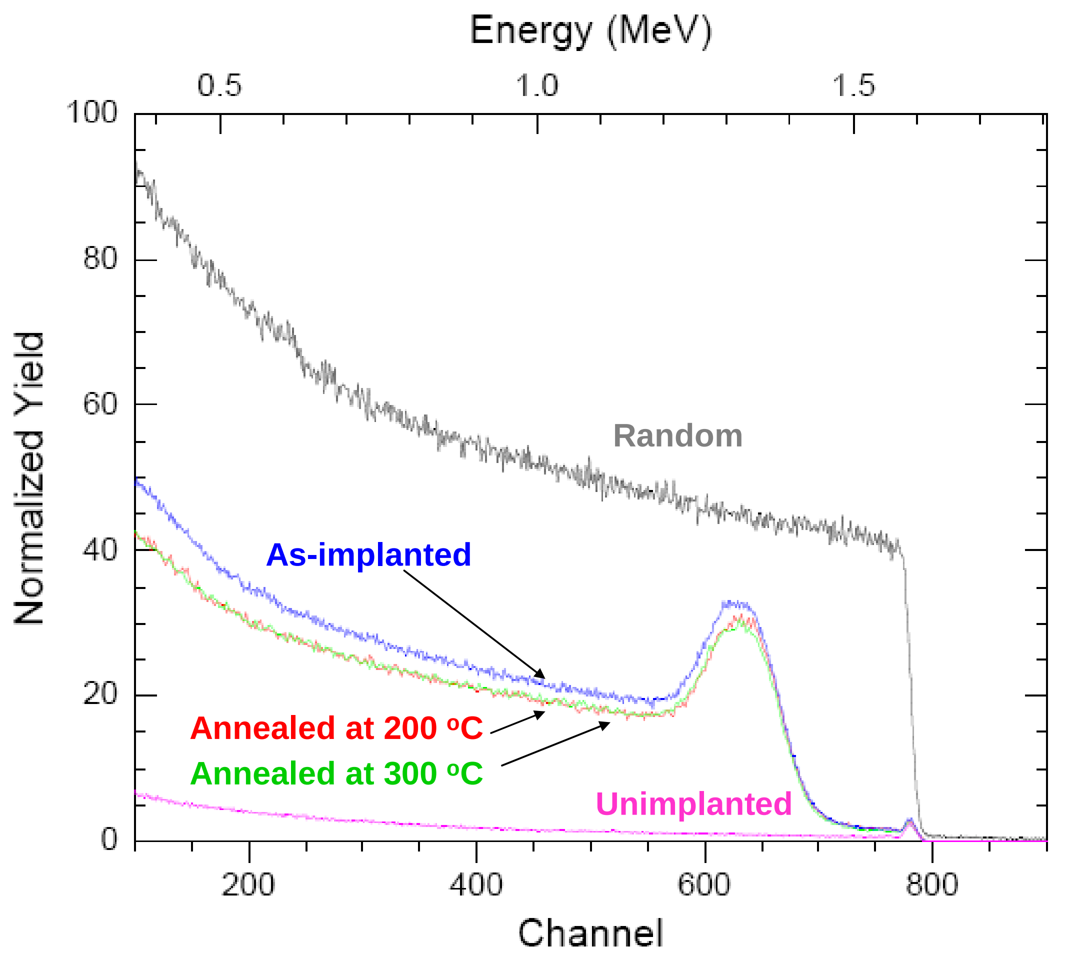
5- Positron annihilation spectroscopy: To probe open volumes and vacancy clusters induced by H implantation and their thermal evolution.

This ensemble of techniques cover most of the critical factors involved in ion-cut process. However, there is still a need to probe qualitatively the vacancylike complexes which seem to play the major role.

Methodology - RBS

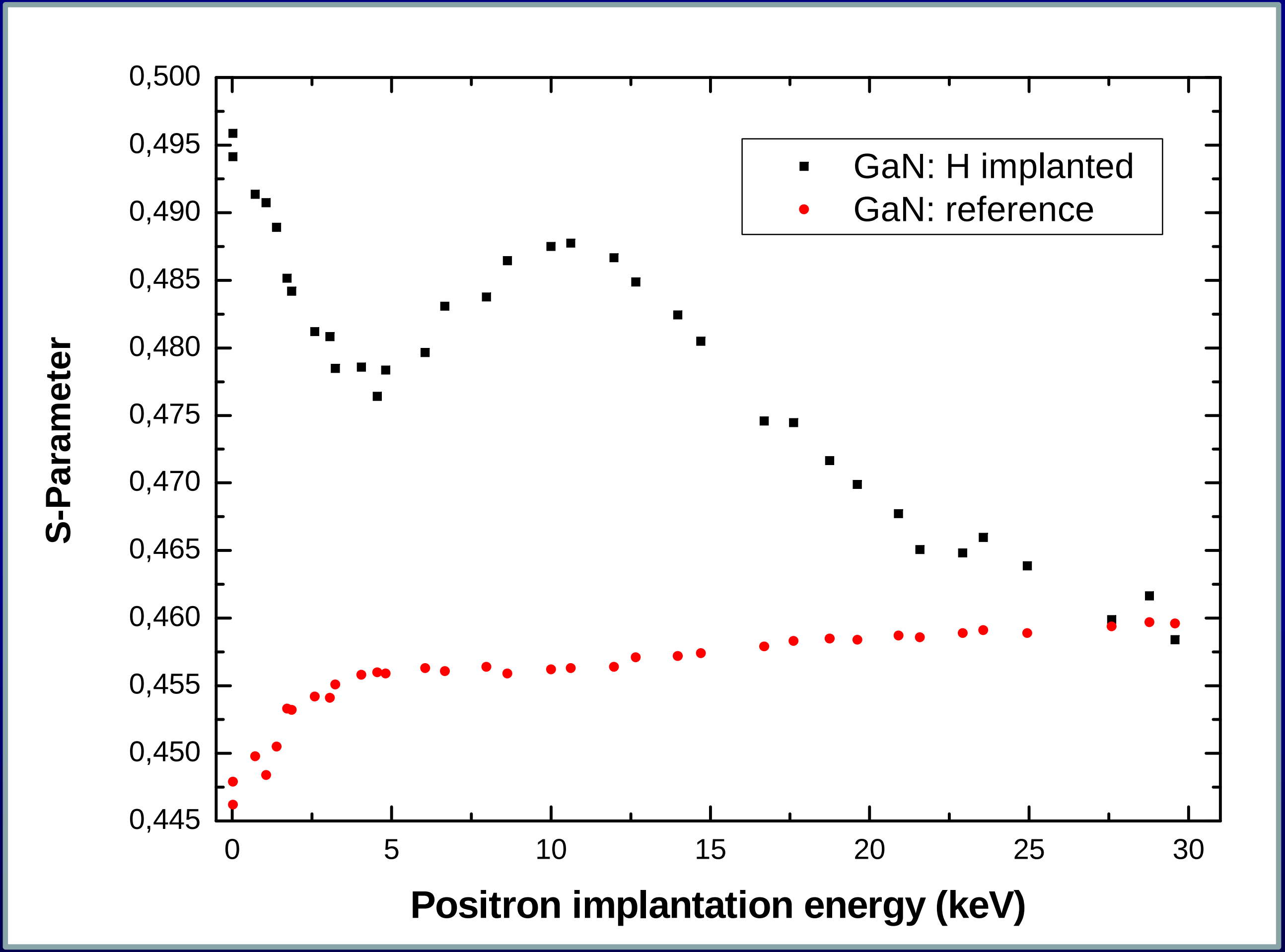
An annealing Rutherford backscattering was performed and can be compared to PALS.

Implantation: energy 50 keV, fluence 2.6x10^{17} H/cm^2



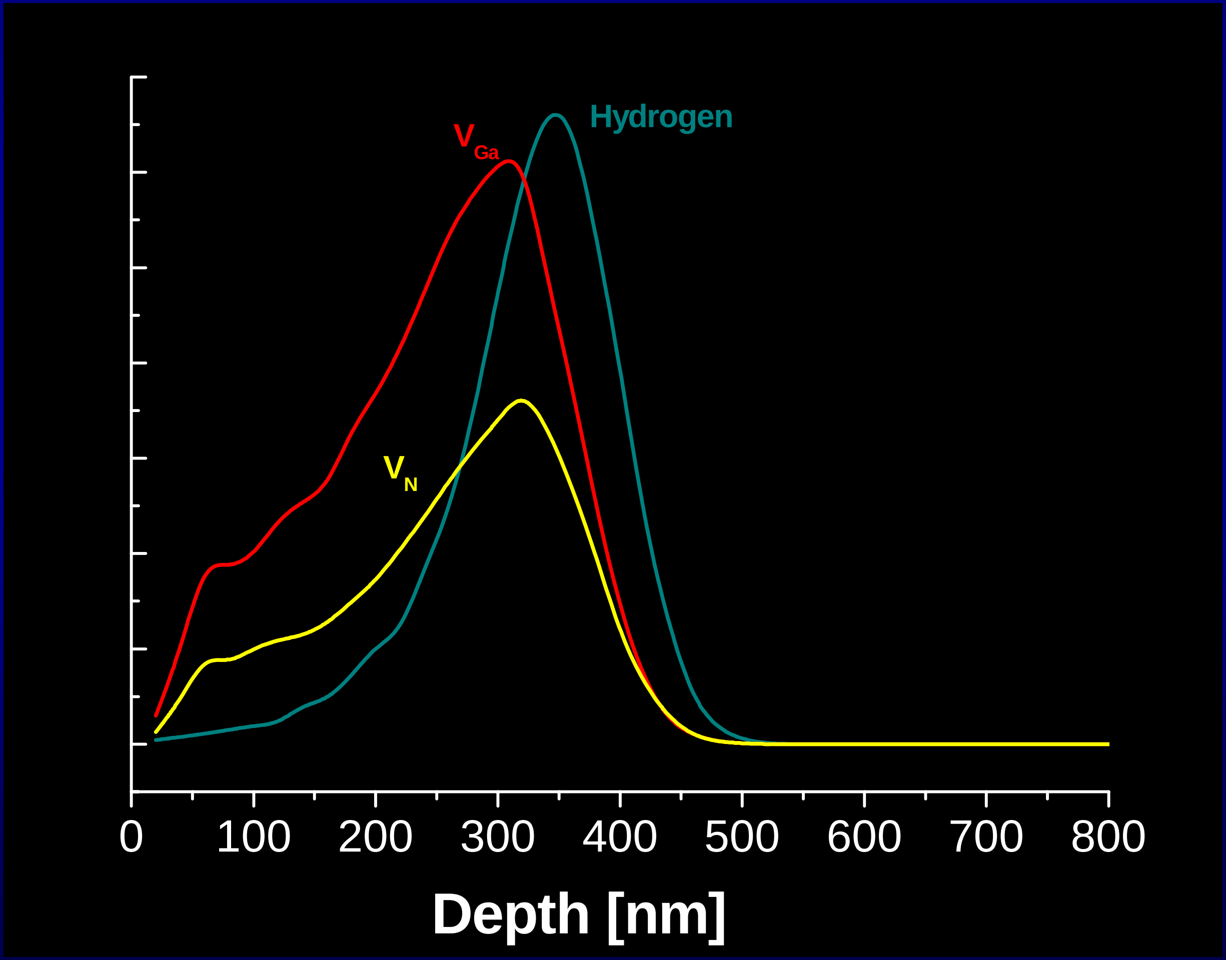
Methodology - DOBS

- **Slow positron DOBS of implanted GaN sample: results show strong defect signal**
- **50 keV protons and 2.6x10^{17} H/cm^{2}**



Methodology - DOBS

- SRIM simulations: defect layer at about 350 nm
- DOBS profile much deeper: defect diffusion?



Experiments at PLEPS @ FRM-II – The working Plan

- **Annealing of GaN layer after H implantation for 2 different heating rates**
- **about 12 annealing steps up to 800°C (in-situ annealing possible?)**
- **2 samples with different annealing rates = 24 energy scans (about 15 spectra each)**
- **How about DOBS at the PLEPS system?**

talk available @ http://positron.physik.uni-halle.de