



## Characterization of $\beta$ -Ga<sub>2</sub>O<sub>3</sub> and device fabrication

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# Characterization of $\beta$ -Ga<sub>2</sub>O<sub>3</sub>

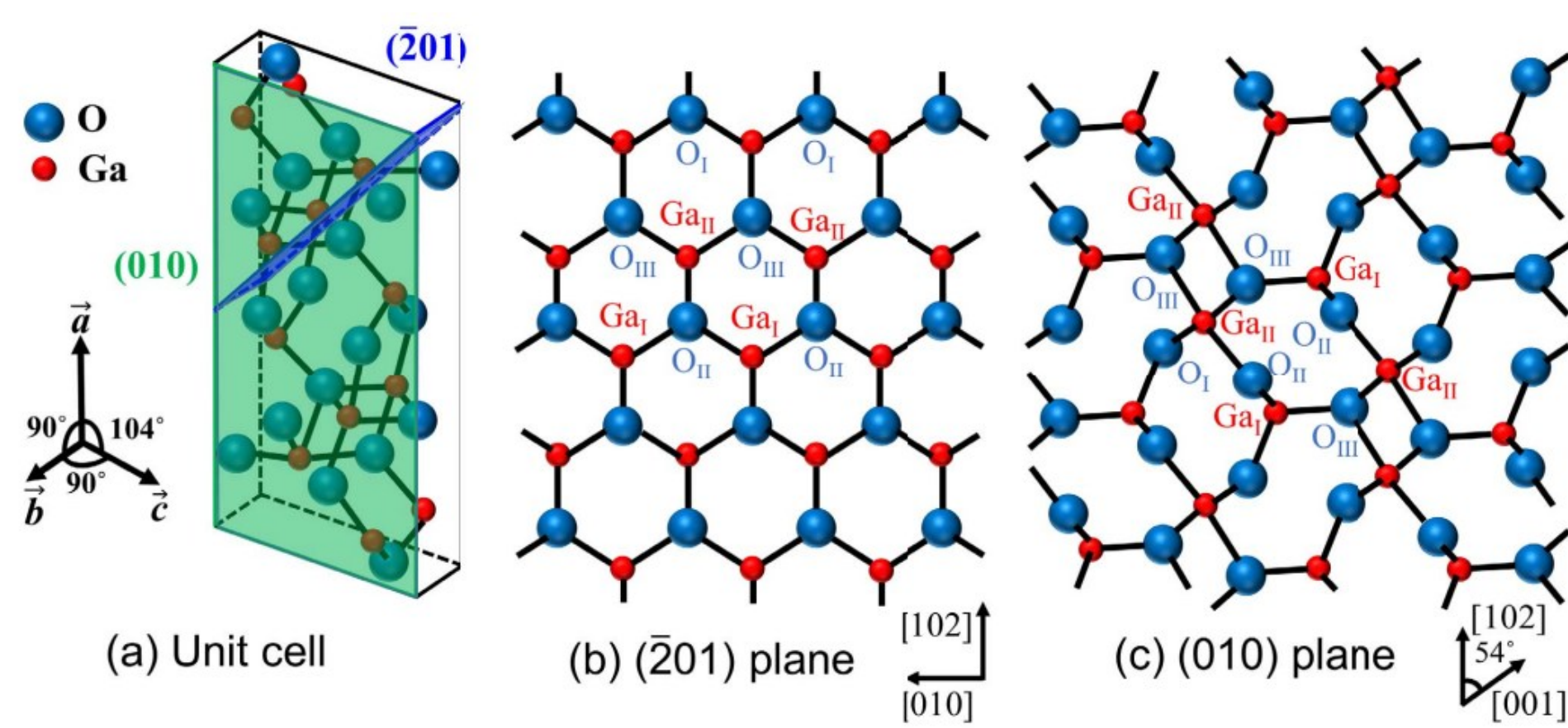
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## Introduction



Houqiang Fu et al, IEEE T-ED, 65, 2018

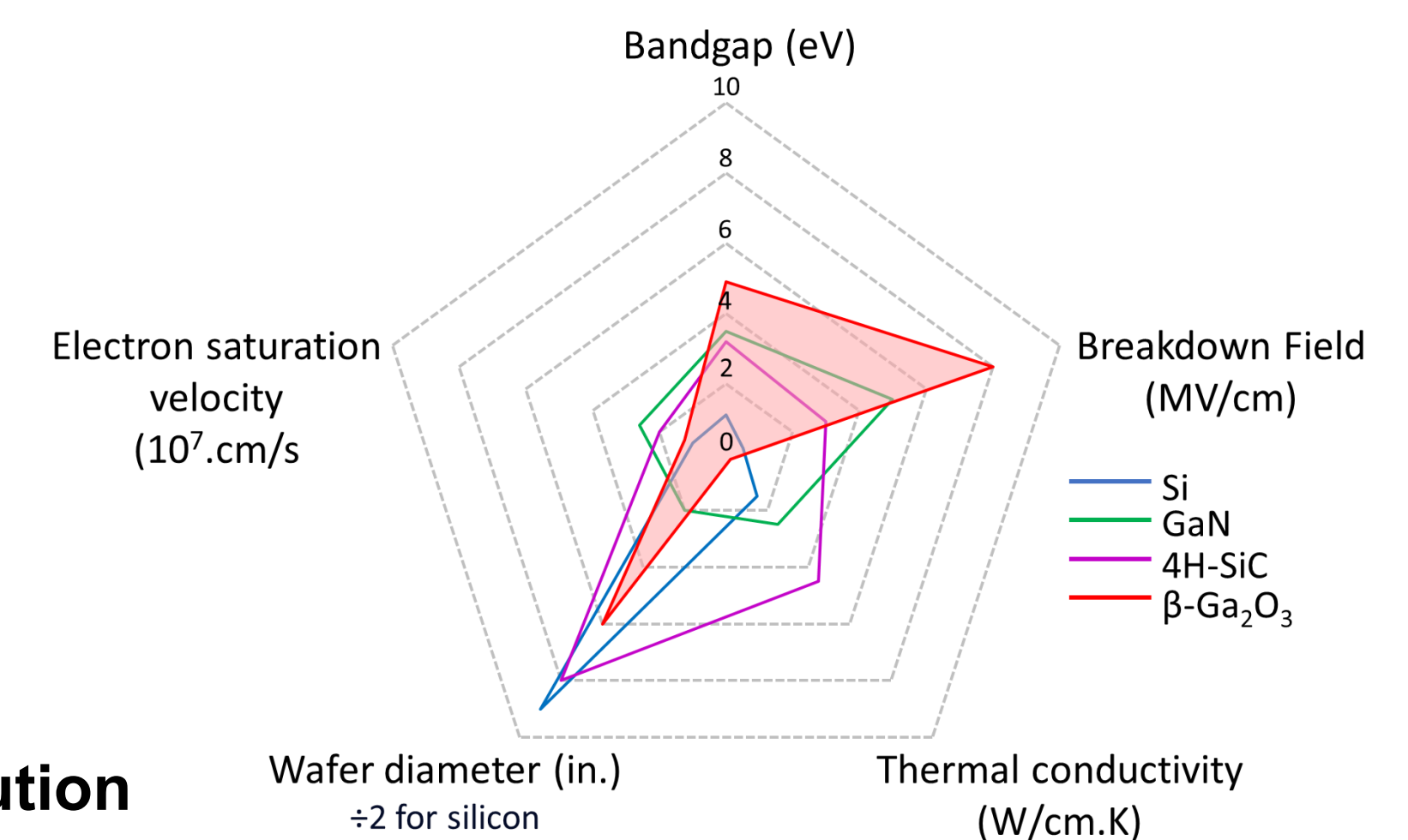
$\beta$ -Ga<sub>2</sub>O<sub>3</sub> : monoclinic lattice  $\rightarrow$  weak symmetry

- Two different cell units : Ga<sub>1</sub>O<sub>4</sub> and Ga<sub>1</sub>O<sub>6</sub>
- Anisotropy of electrical and optical properties
- Applications in power devices and UV photodetectors

**Objectives :** Raman/PL characterization of  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> to better understand the effects of material defects and substrate orientation on  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> power devices electrical performance

➤ Identification of  $\beta$ -Ga<sub>2</sub>O<sub>3</sub>

➤ Defect & stress distribution



## Identification of substrates

Raman/PL measurements :  
Renishaw micro-spectrometer  
➤ Raman : laser 532nm and 325nm  
➤ PL : laser 325nm

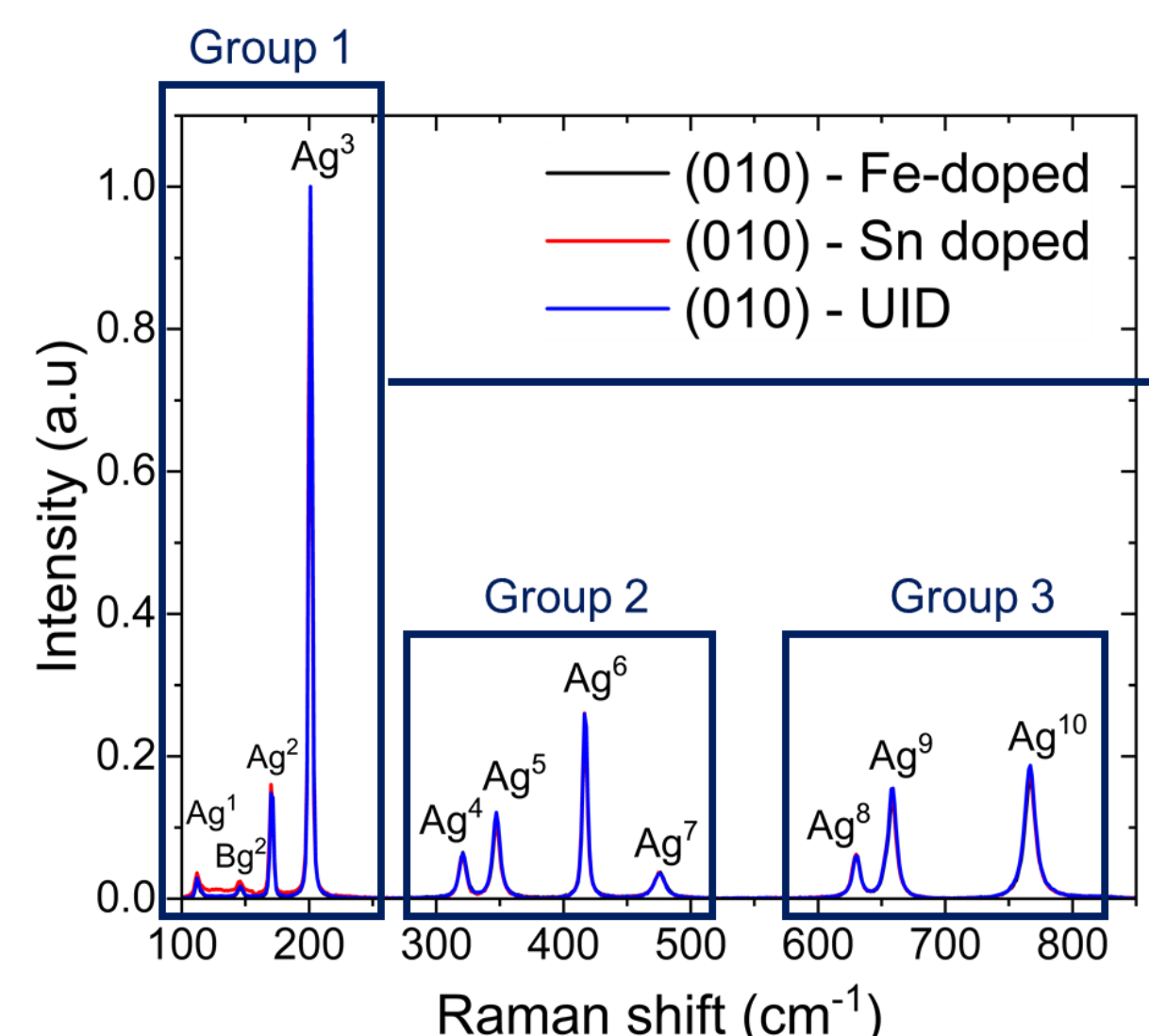


Raman spectra of  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> substrates with green laser

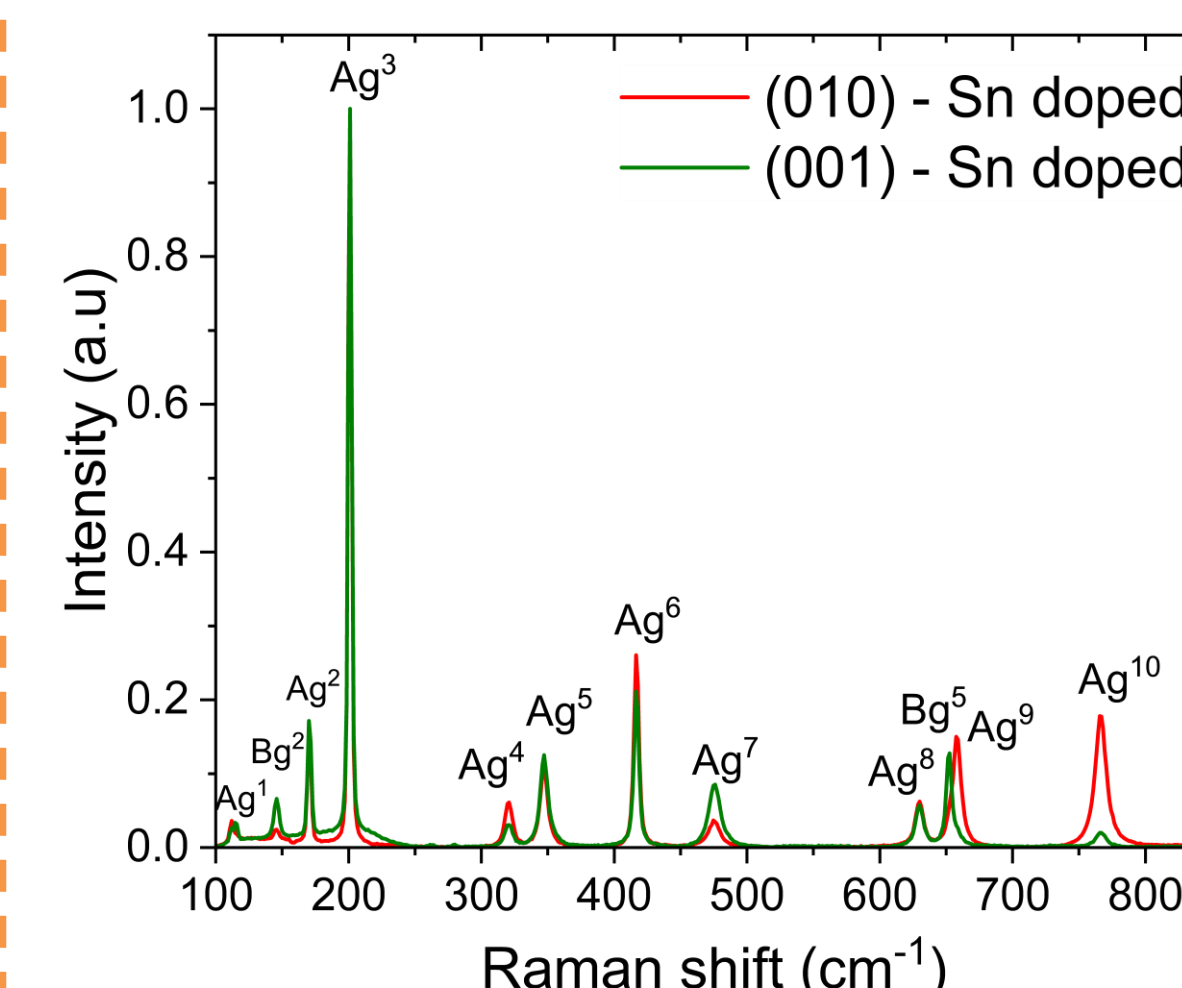
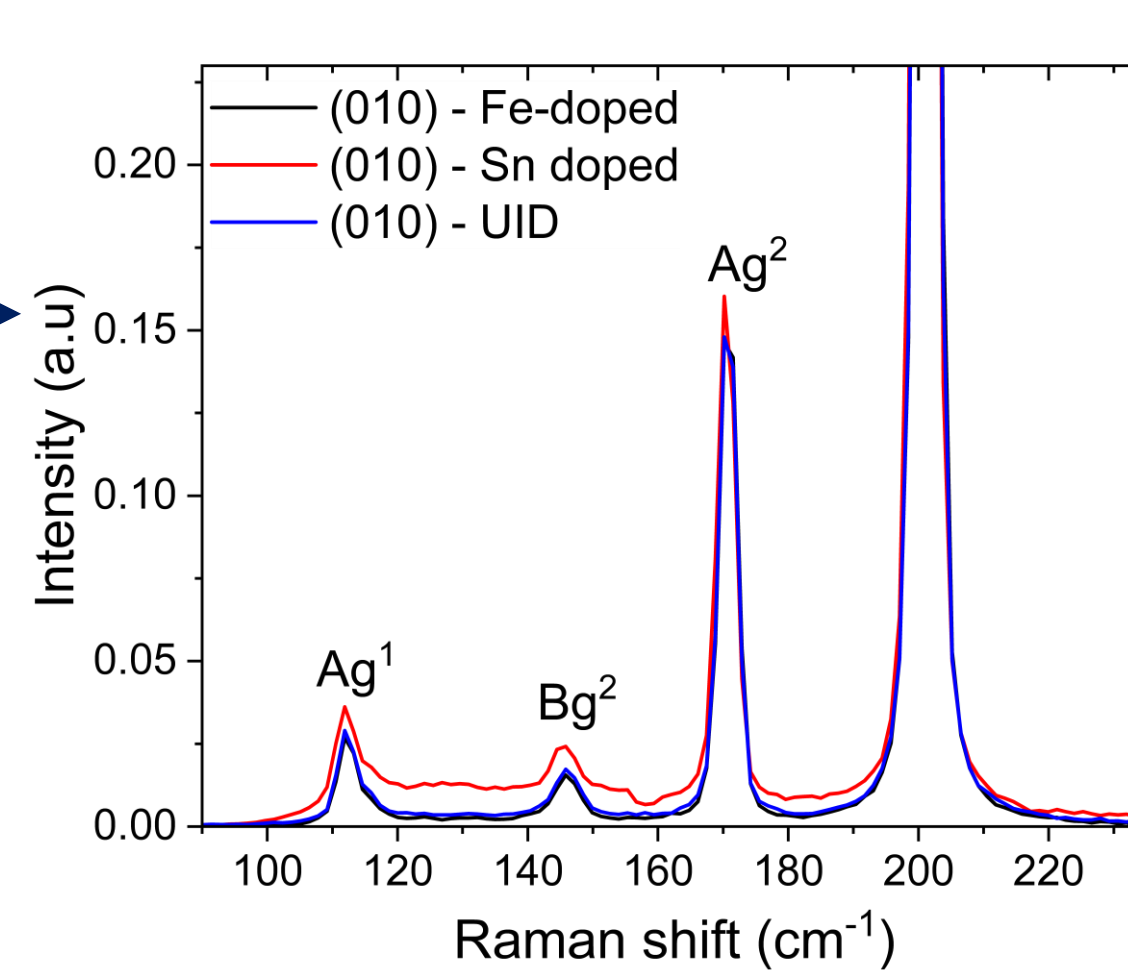
➤ Three different groups of Raman peaks

➤ Low influence of doping on the spectra :  
small variation for Sn doping (type n)

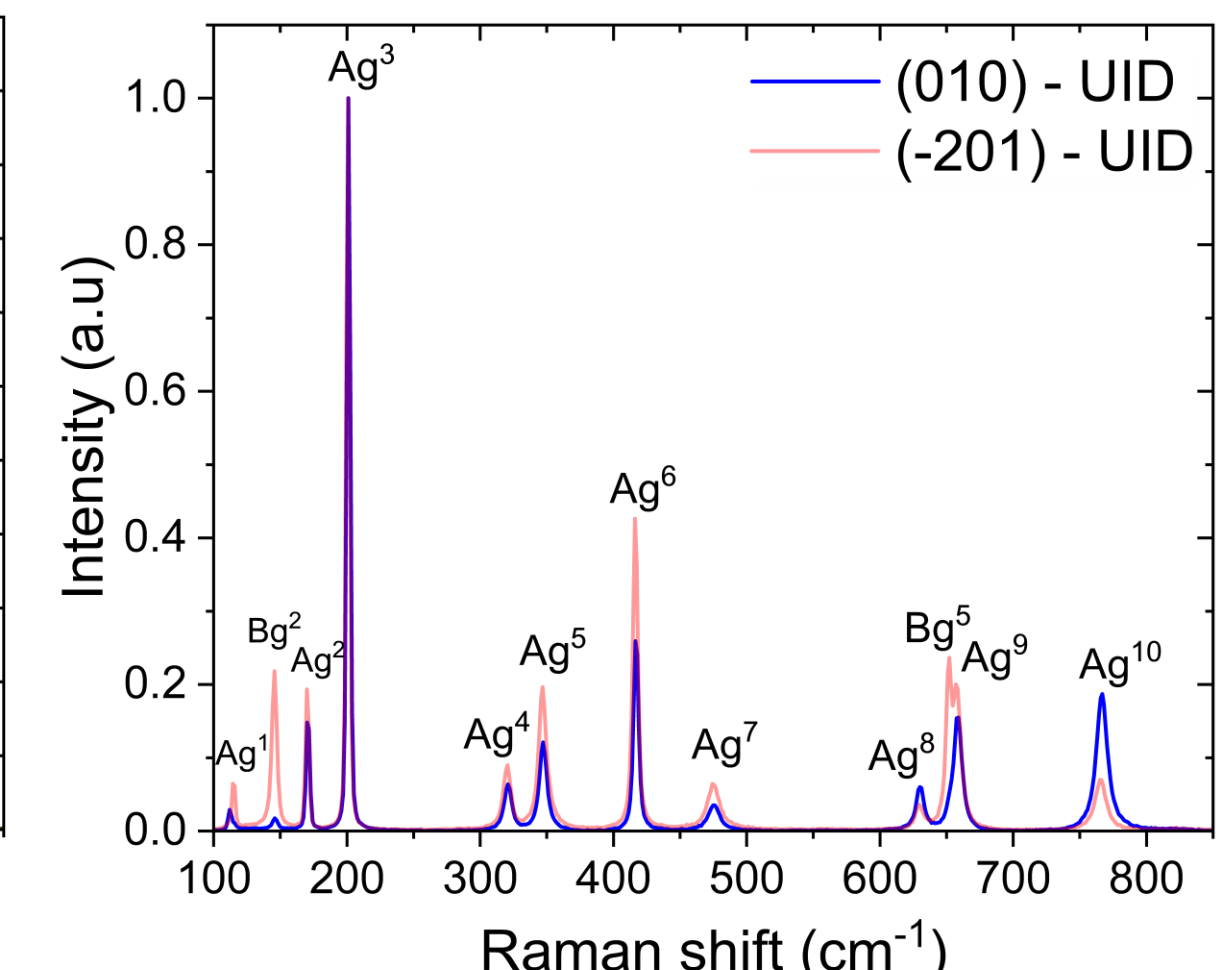
➤ The orientation of the substrate affects the Raman spectra  
➤ The stress influences the position of the Raman peaks



Substrates with different types of doping

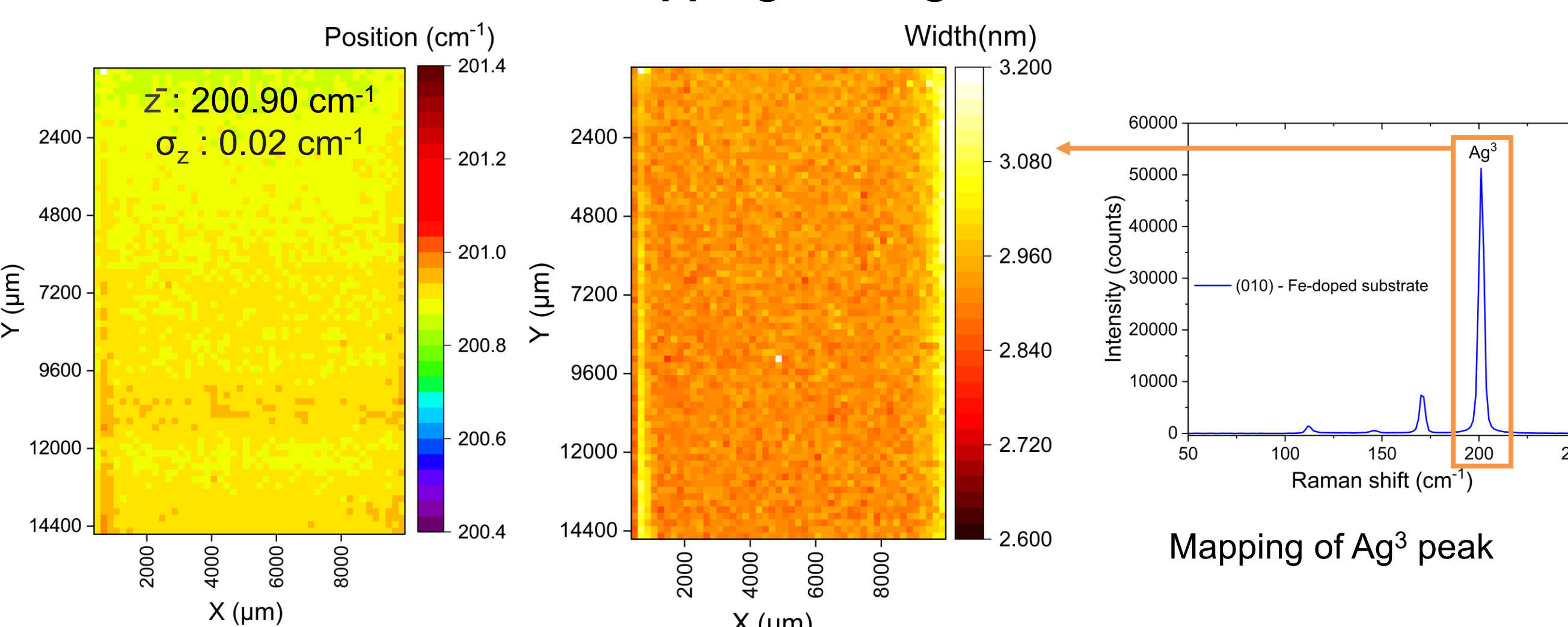


Different orientations of substrates



## Defect and stress distribution in substrates

Raman mappings with green laser

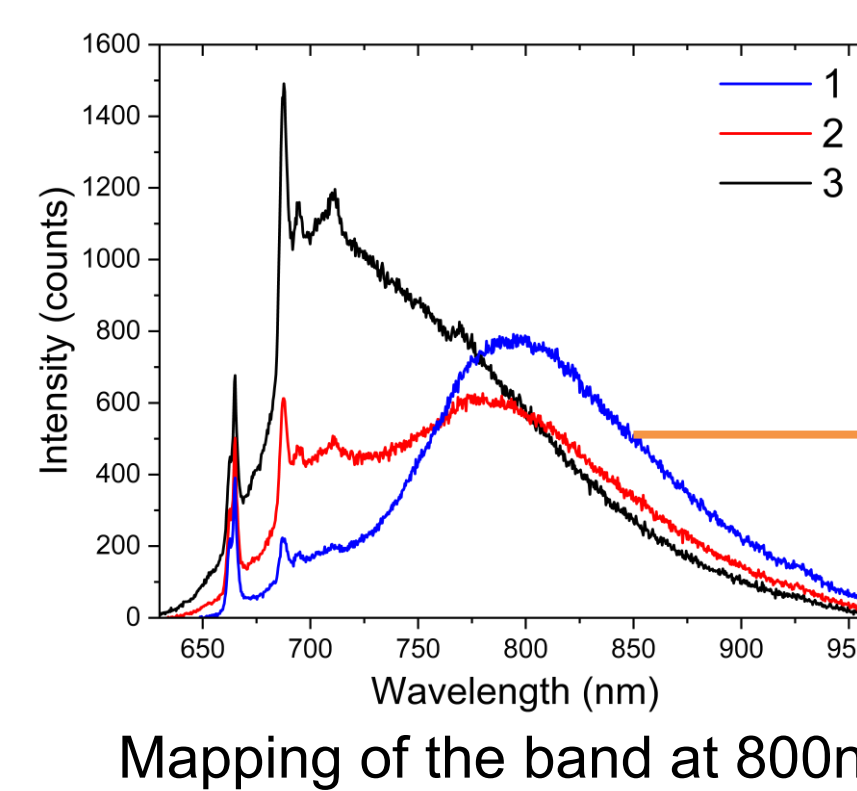
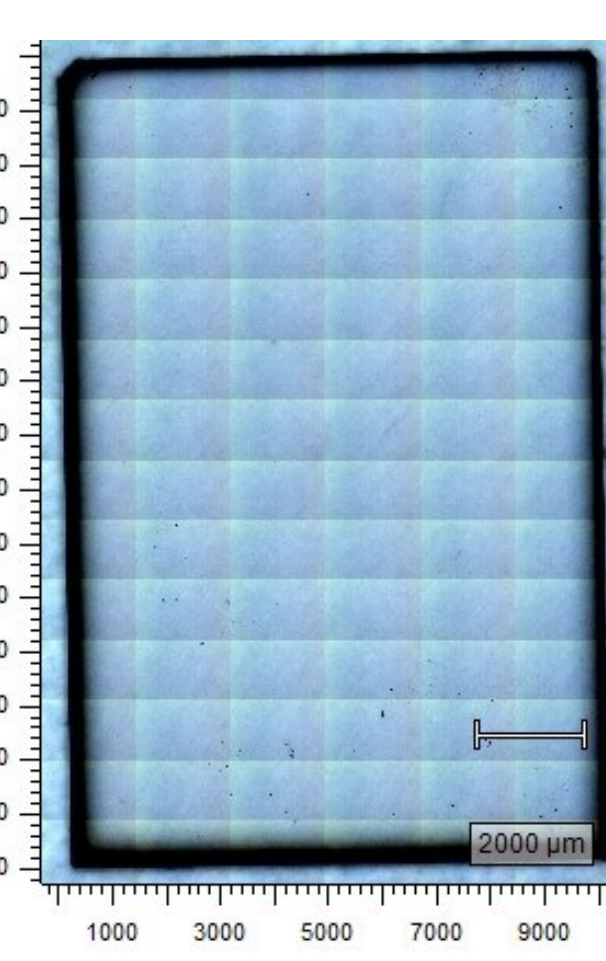


Raman measurements :

- The Ag<sup>3</sup> peak position shift ( $\Delta\omega$ ) can be expressed as a function of tensile stress ( $\sigma_T$ ) within the sample by the formula :  $\Delta\omega = -0.33\sigma_T$
- Relative homogeneous stress in the substrate
- Some stress at the borders of the sample

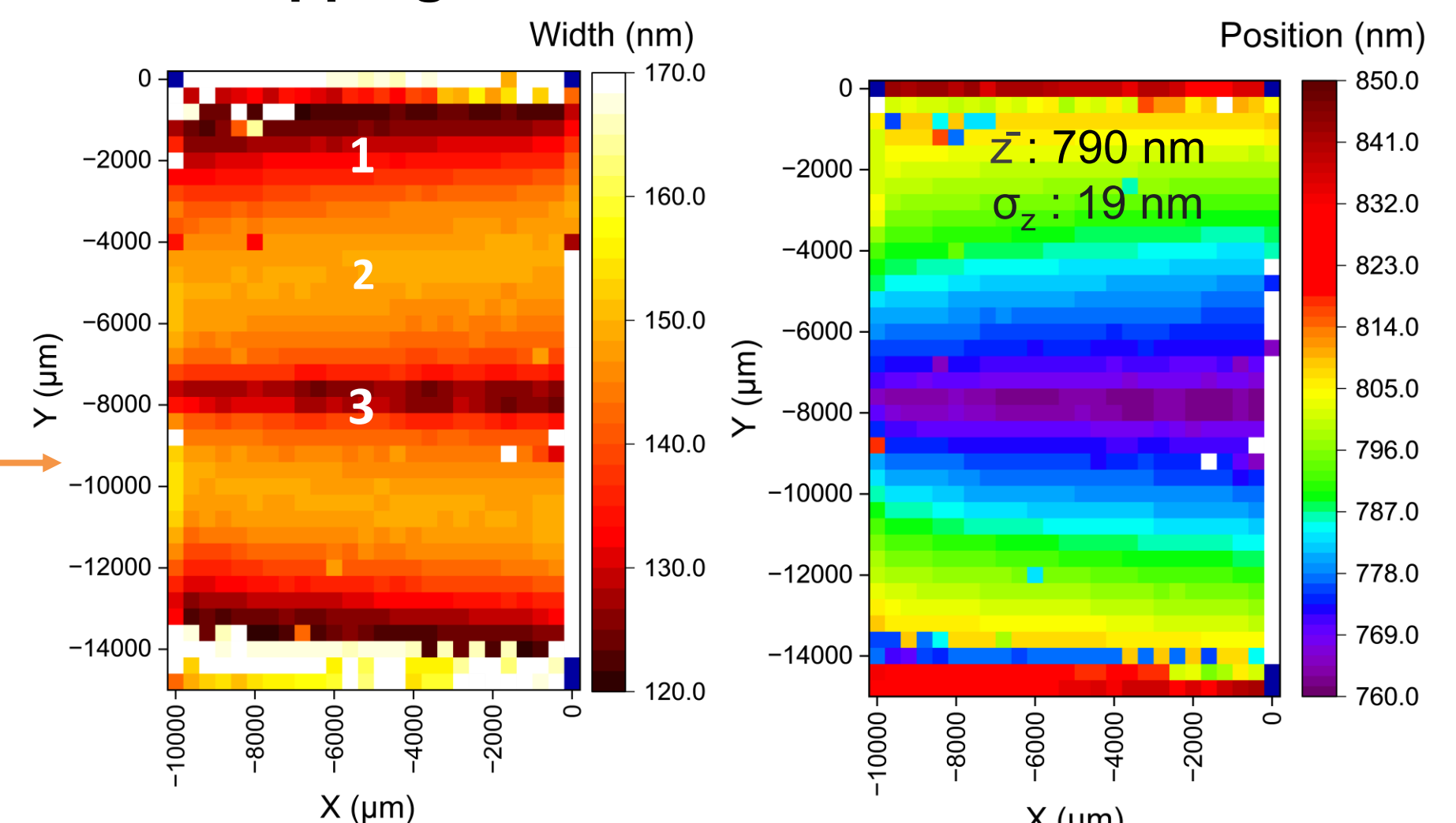
(Noriyuki Hasuike et al, JJAP, 62, 2023)

Fe-doped  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> substrate



Mapping of the band at 800nm

PL mappings with UV laser

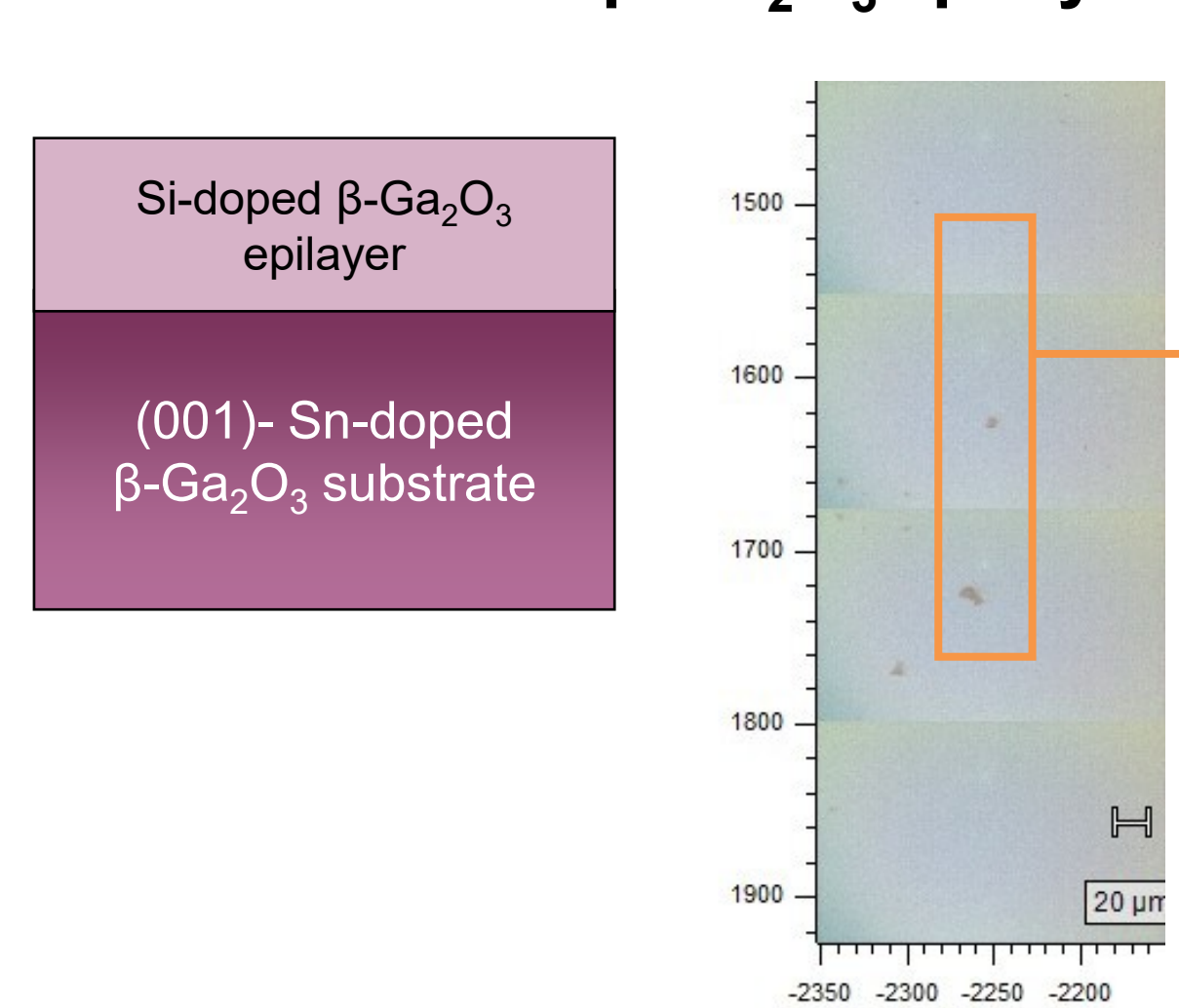


PL measurements : inhomogeneous distribution of defects

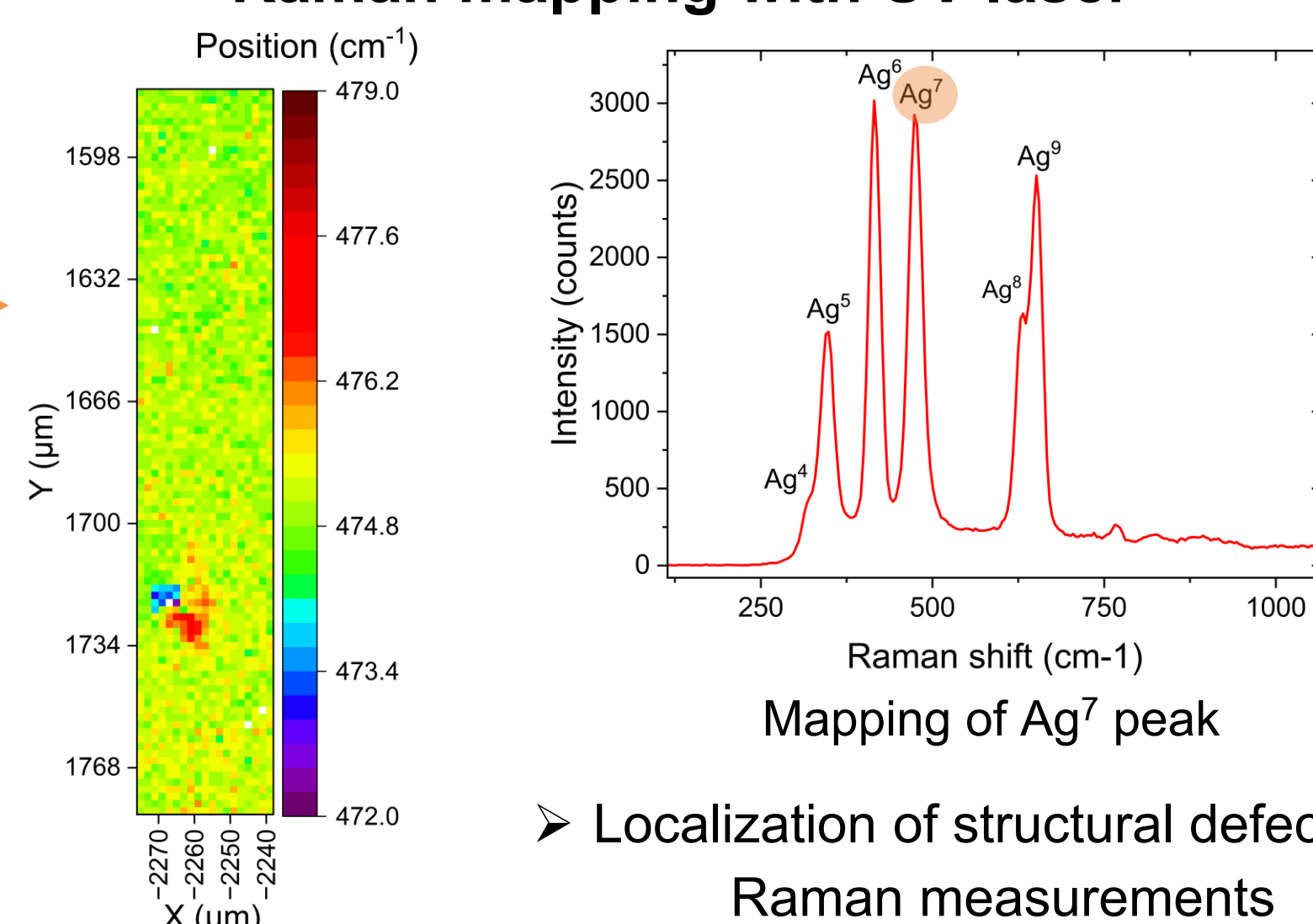
- Red luminescence  $\rightarrow$  Cr<sup>3+</sup> impurities or DAP recombination N<sub>O</sub>-V<sub>O</sub>
- The band at 800nm is thinner and blue-shifted at the center of the sample

## Defect identification in epitaxial layers

Defects in  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> epilayer

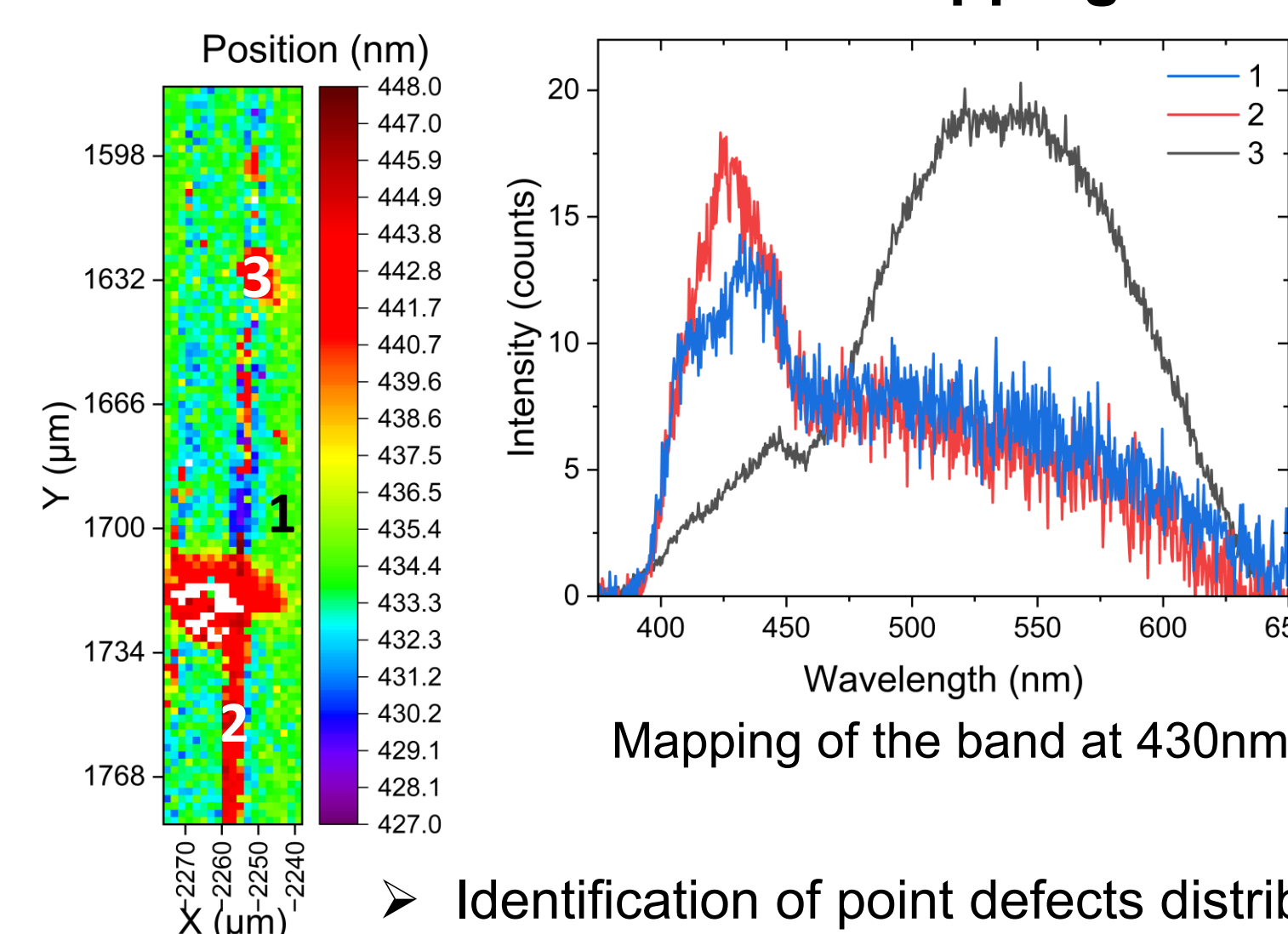


Raman mapping with UV laser



➤ Localization of structural defects with Raman measurements

PL mapping with UV laser



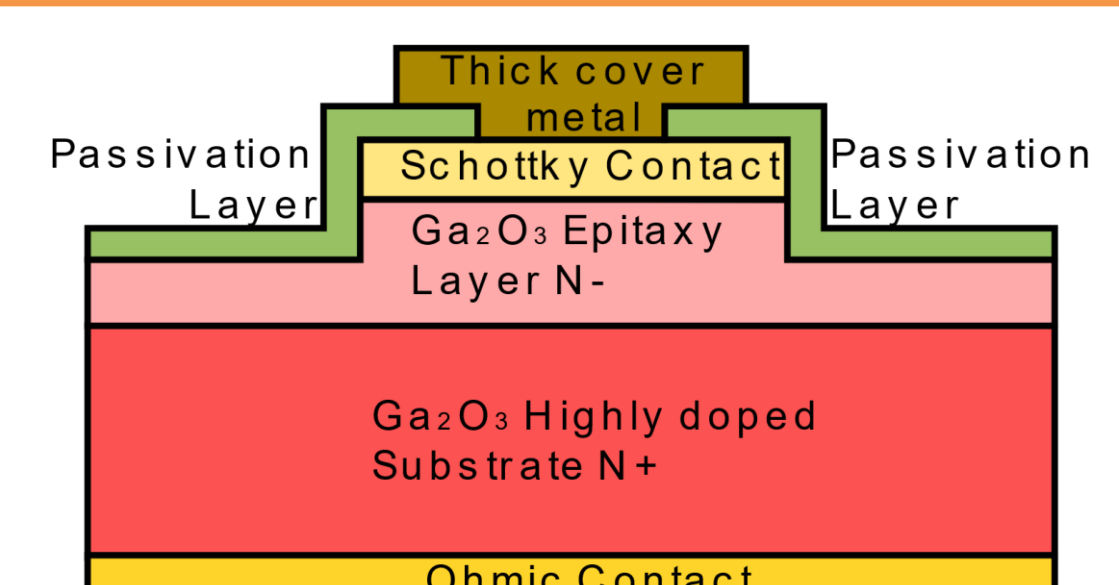
- Band around 425nm  $\rightarrow$  divacancy ( $V_{Ga} + V_O$ )<sup>1-</sup>
- Green luminescence : divided opinion in the literature  $\rightarrow$  Ga or O vacancy or a still unknown extended defect

➤ Identification of point defects distribution along the defect with PL measurements

## Conclusion and perspectives

- $\beta$ -Ga<sub>2</sub>O<sub>3</sub> monoclinic lattice leads to the weak symmetry of the crystal  $\rightarrow$  the orientation of the substrate affects the Raman spectra
- Doping has little to no effect on Raman measurements
- Stress at the border of the substrate can be identified with Raman mapping
- PL measurements allow the location of point defects within the samples that are not visible with Raman

**Future work :** conception of a Schottky diode in  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> to study the effects of material defects on electronic devices performances



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