

GAP(111)B-SE Surface for TMD epitaxial growth

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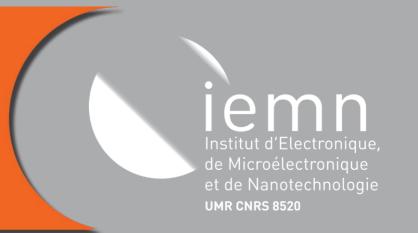
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GaP(111)B-Se SURFACE FOR TMD EPITAXIAL GROWTH



Niels Chapuis, Christophe Coinon, Dominique Deresmes and Xavier Wallart

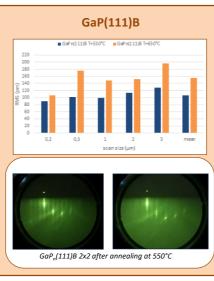
Univ. Lille, CNRS, Centrale Lille, Junia, Univ. Polytechnique Hauts-de-France, UMR 8520 - IEMN - Institut d'Electronique de Microélectronique et de Nanotechnologie, F-59000 Lille, France

Context

Over the past few years, 2D-Transition Metal Dichalcogenides (TMDs) have revealed great potential for optoelectronics and nanoelectronics devices, thanks to their optical and electronic properties, not encountered in other materials. They can be grown by van der Waals epitaxy allowing the use of materials with significant mismatch. Van der Waals epitaxy is usually performed on 2D substrates such as graphene, hBN or mica but 3D substrates can also be used after a proper surface passivation treatment, which for III-V semiconductor substrates has been applied successfully on GaAs(111) surfaces. Since rather high growth temperatures are needed in order to get high quality-TMD layers, GaP might represent an interesting alternative to GaAs considering its higher thermal stability. In this study, we present results relative to the preparation of n and p-type GaP(111)B surfaces and to their selenium passivation.

Atomic Force Microscopy and RHEED

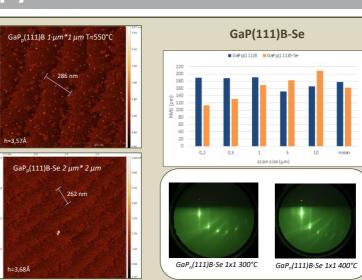






- Increase of deoxidation temperature from 550°C to 650°C reduces the dots concentration.
- Material nature homogeneous all over the surface

 In both cases, atomic steps clearly.
- In both cases, atomic steps clearly resolved although not straight

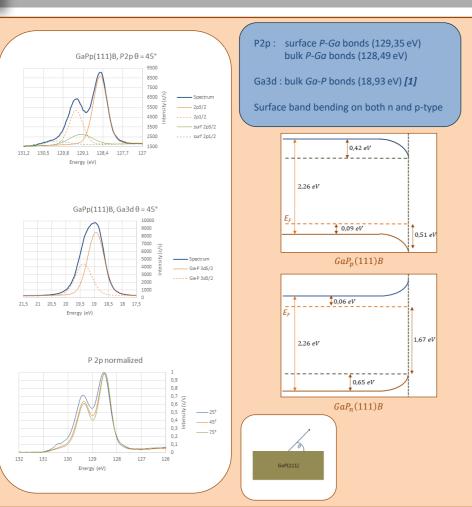


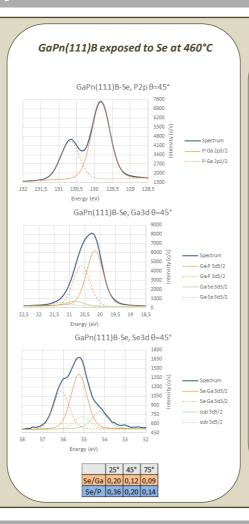
Selenium exposure From 250°C to 700°C

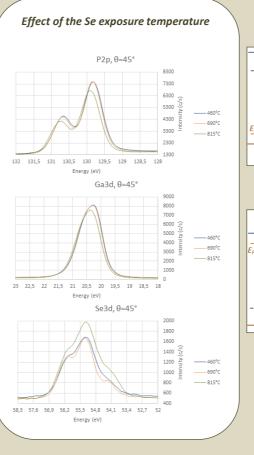
Se BEP: a few 10-6 T

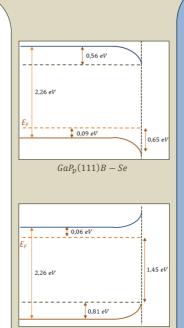
- The RHEED pattern changes from a 2x2 to a 1x1 one
- Above 750°C degradation of the Rheed pattern
- The surface topography and rugosity remain stable after the Se treatment
- Atomic steps are still visible

X-ray and UV Photoelectron Spectroscopy









 $GaP_n(111)B - Se$

Se exposure

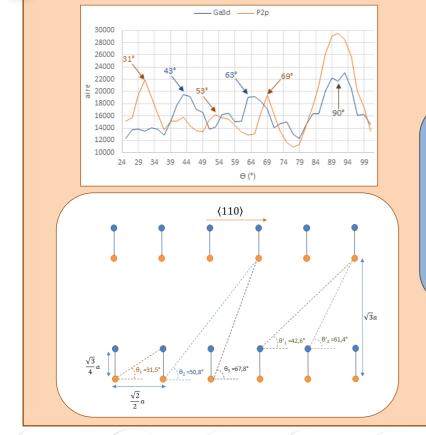
- Surface *P-Ga* bonds in P2p disappear
- Ga-Se bonds (20,8 eV) appear in Ga3d [2]
 2 chemical environments In Se3d [3]
- Surface *Se-Ga* (55,3 eV) - Sub-surface *Se-Ga* (54,3 eV)
- Angular variation of the Se/Ga and Se/P intensity ratios indicative of Se in the surface region
- → presence of selenium in the top and second P surface layers
- Effect of exposure temperature
 Ga3d and P2p similar for temperatures up to 690°C, reduced and shifted at 815°C
 Clear enhancement of the sub surface Se-Ga bonds component in Se3d at 815°C
 Spotty Rheed pattern (not shown) at 815°C indicates surface morphology degradation at this temperature

→ GaP(111)B-Se stable up to roughly 700°C

- Slight increase of the band bending after Se treatment (+0,15 eV) regardless of the doping condition
 - → No effective electronic passivation
- [1] Y. Suzuki et al 2004 Appl. Surf. Science 235, 260-266 [2] G. D'Olimpio et al. 2020 Adv. Funct. Mater. 30, 2005466 [3] C González et al 2004 J. Phys.: Condens. Matter 16, 2187

X-ray Photoelectron Diffraction

 φ along $\langle 110 \rangle$



X-ray photo-diffraction for polar angles between

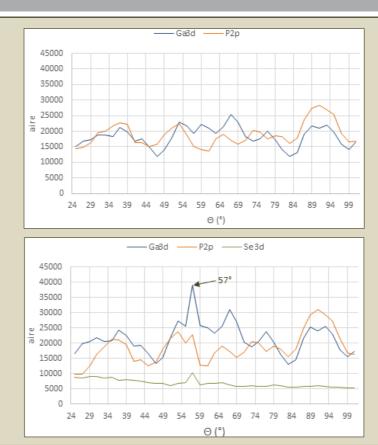
25° and 102° performed along <110> azimuthal

• P2p intensity enhanced at 31°, 53°, 69° and 90°

• Ga3d intensity enhanced at 43°, 65° and 90°

direction for GaP_n(111) substrates.

→ Consistent with a GaP(111) B surface within a simple diffusion model





 φ along $\langle 112 \rangle$

Ga3d and P2p profiles similar before and after

direction on GaP_p(111)B substrate and

GaP_n(111)B-Se

enhanced at 57°)

Se treatment
 Se3d intensity profile rather flat (only slightly

→ Se mainly present at the top surface layer















