Secondary ion mass spectrometry (SIMS) analysis of PIN and NIP structures grown on (113)-oriented diamond

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Diamond ➡ tremendous physical properties ➡ considered to be the ultimate semiconductor for high power electronics ➡ awaited to endure high electric fields with low leakage current ➡ candidate of choice for high voltage and high temperature power electronics

(113) orientation ➡ Lying in between (100) and (111) ➡ stable growth orientation during CVD[1] & could allow obtaining enlarged crystals ➡

Boron doping (LSPM): p⁺ enlarged[2] free-standing plates with quality equivalent to (100)[3]

&

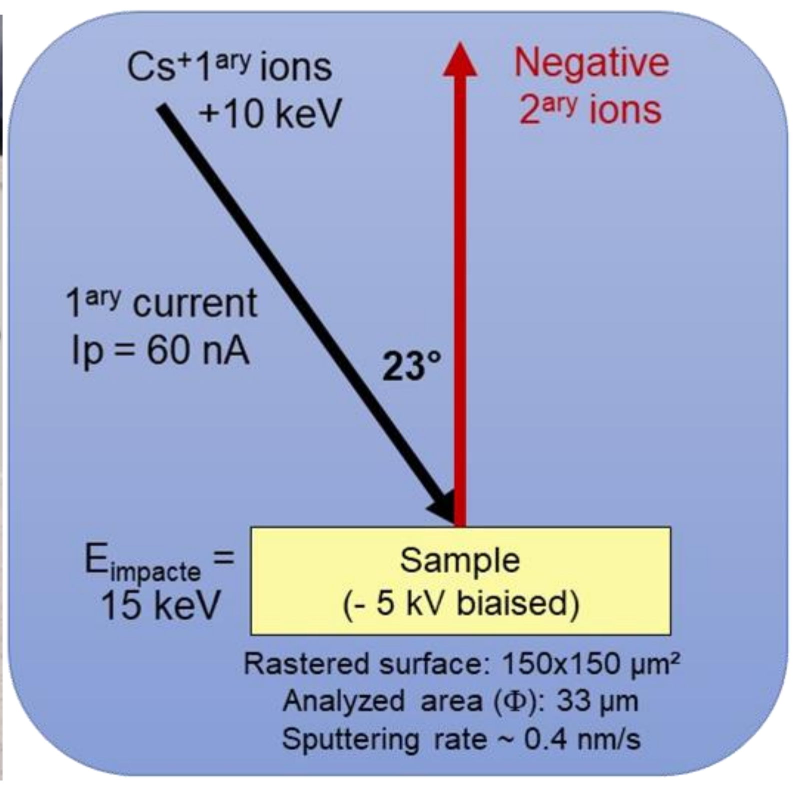
Phosphorus doping (GEMaC): n-type homoepilayers[4] with lower compensation ratio than on (100) with higher electron mobility above 450°C

Precursors and MPCVD reactors

p-type layers	Intrinsic layers	n-type layers
Diborane (B_2H_6)	-	Tertiarybutyl-phosphine (TBP: $C_4H_{11}P$)
Plassys BJS150 reactor	2 reactors Plassys BJS150 : 1 for low phosphorus-doping 1 for undoped layer	Home-made metallic reactor

MPCVD: micro-wave plasma chemical vapor deposition

SIMS analysis under diamond standard Cs^+/M^- conditions & high mass resolution[5]



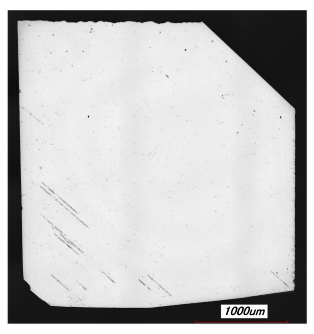
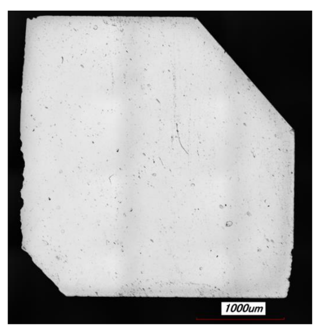
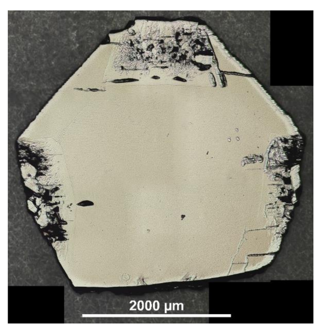
- Analyze simultaneously hydrogen, boron, and phosphorus
- Have low detection limit (DL) for phosphorus
- Identify the phosphorus mass from molecular ions of similar masses
- $^{11}B^{12}C^-$ molecular ion for boron analysis

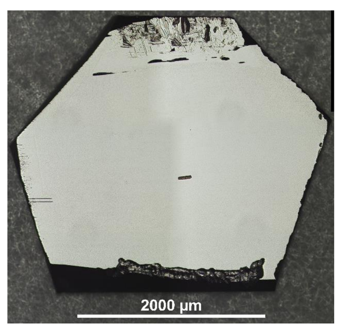
Mass (a.m.u.)	1 (^1H)	23 ($^{11}B^{12}C$)	31 (^{31}P)
DL (at/cm³)	1.0-1.4 x10^{19}	1.3-3.5 x10^{15}	4.5-5.7 x10^{14}

Pseudo-vertical structures

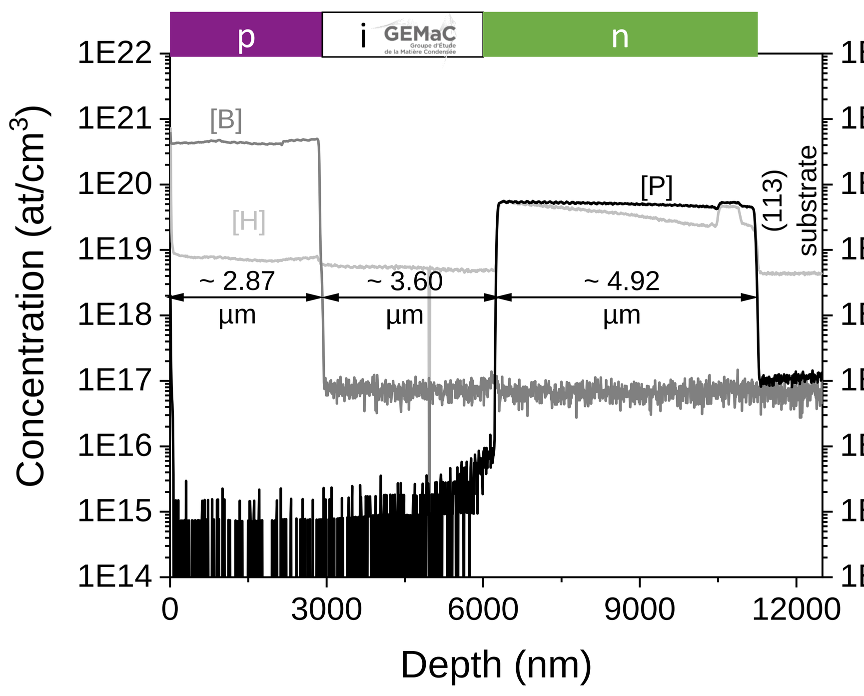
Vertical structures

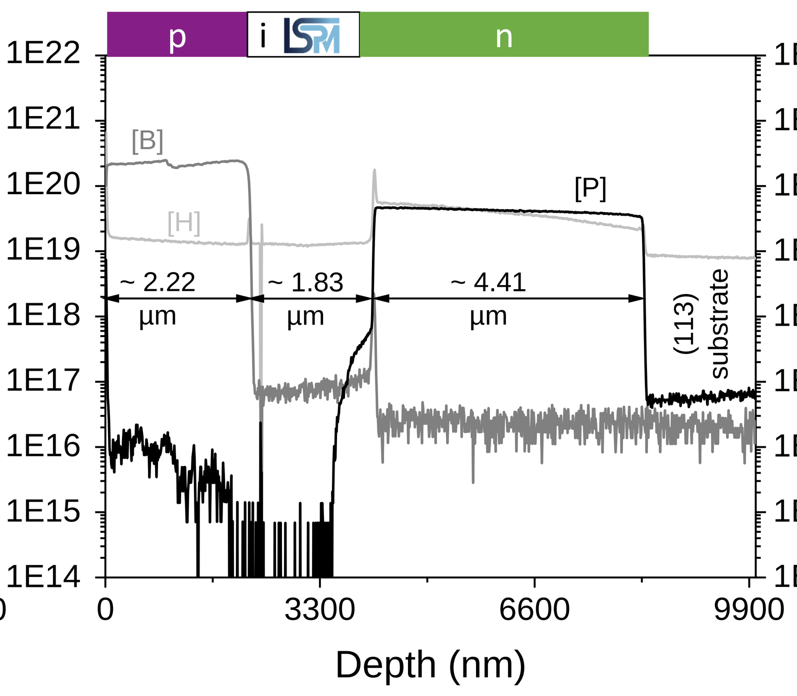
Optical images

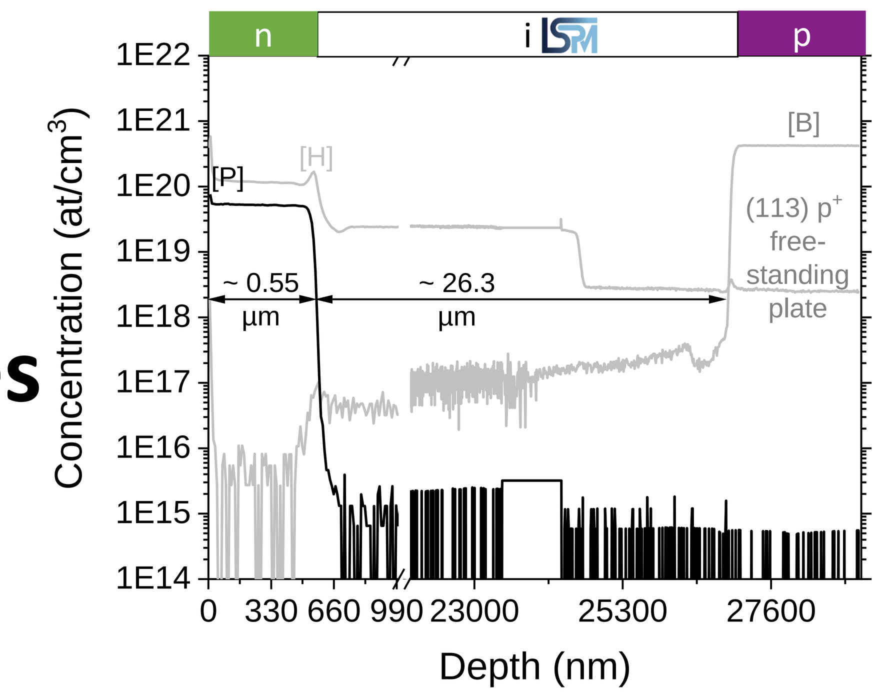




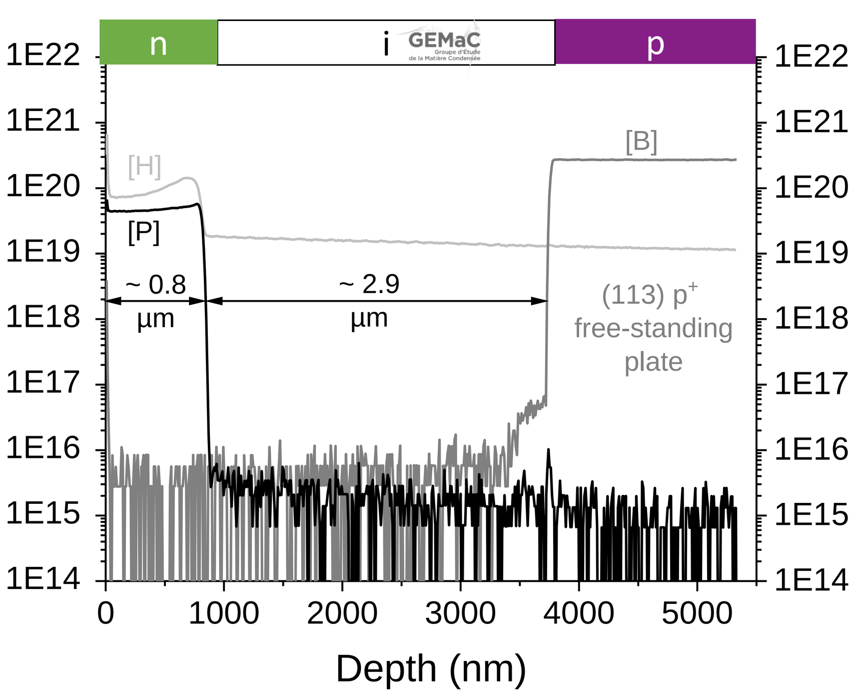


SIMS profiles





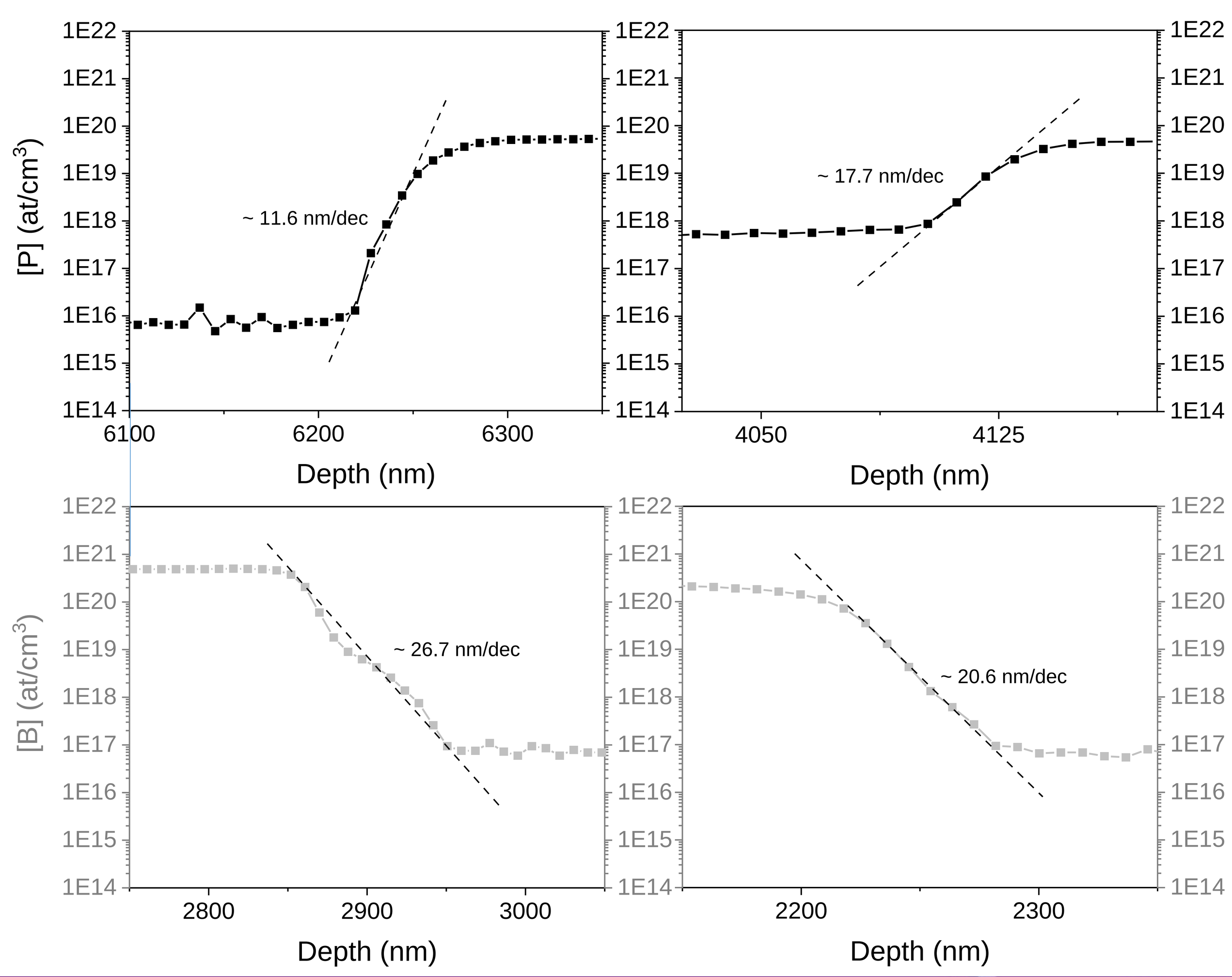


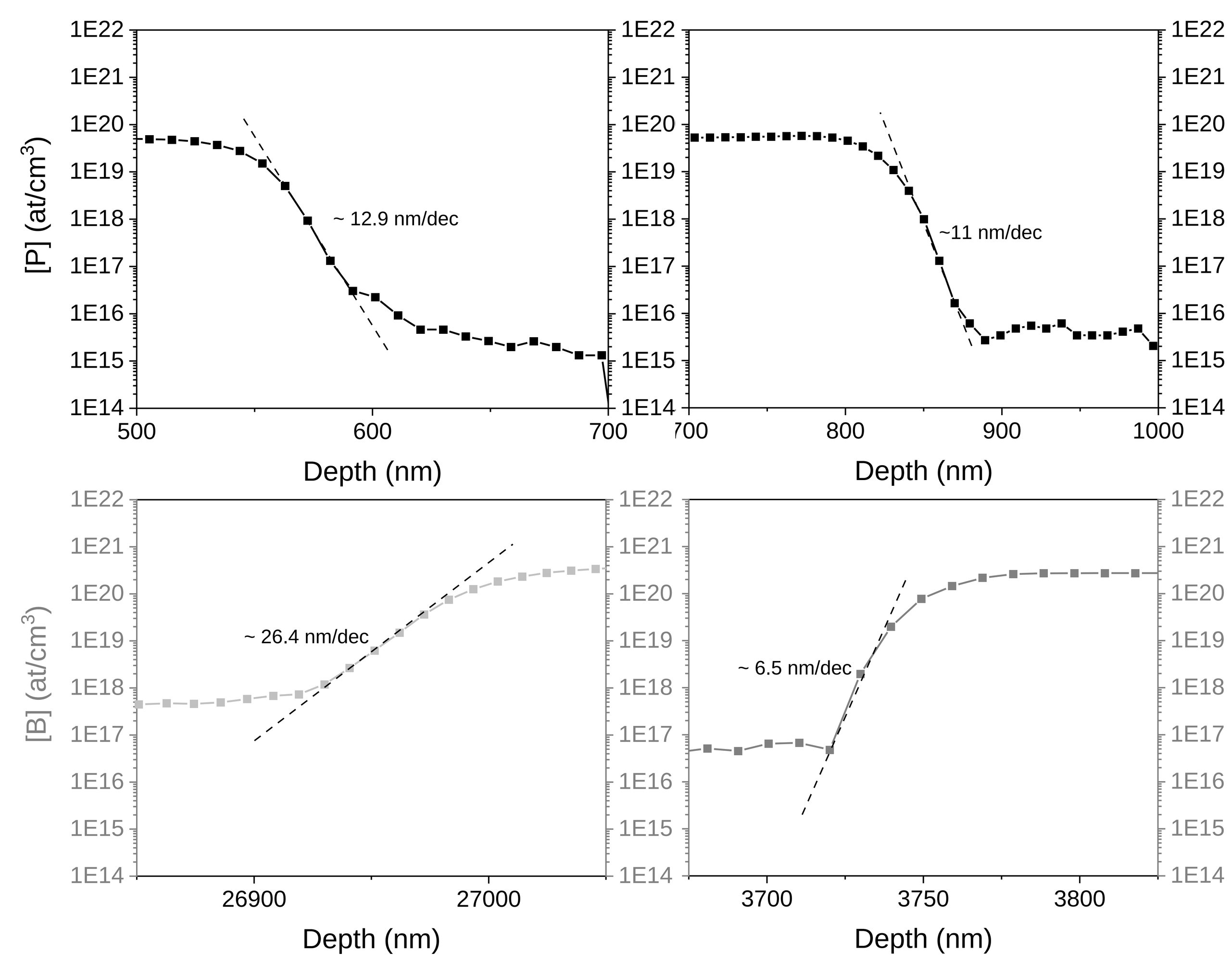


Zoom on the interface

Phosphorus ⇔ intrinsic layers

Boron ⇔ intrinsic layers





The consortium masters the homoepitaxy of (113) phosphorus- and boron-doped diamond over a large range of content (10^{15} - 10^{20} at/cm³) with sharp interfaces and precise thicknesses.

In future work, the SIMS dopant profiles will be used to simulated the electrical response of the structures. The PIN and NIP structures will be also processed to realize and study diodes.

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[1] F. Silva et al. Diamond Relat. Mater. **17** (2008) 1067
[2] R. Mesples-Carrère et al. Diamond Relat. Mater. **149** (2024) 111659
[3] A. Tallaire et al. Diamond Relat. Mater. **66** (2016) 61
[4] M.-A. Pinault-Thaury et al. Carbon **175** (2021) 254
[5] M.-A. Pinault-Thaury et al. Stat. Sol. A **220** (2023) 2200324

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