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Ohmic contacts by phosphorous ion implantation on (111) N-type CVD Diamond

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Introduction

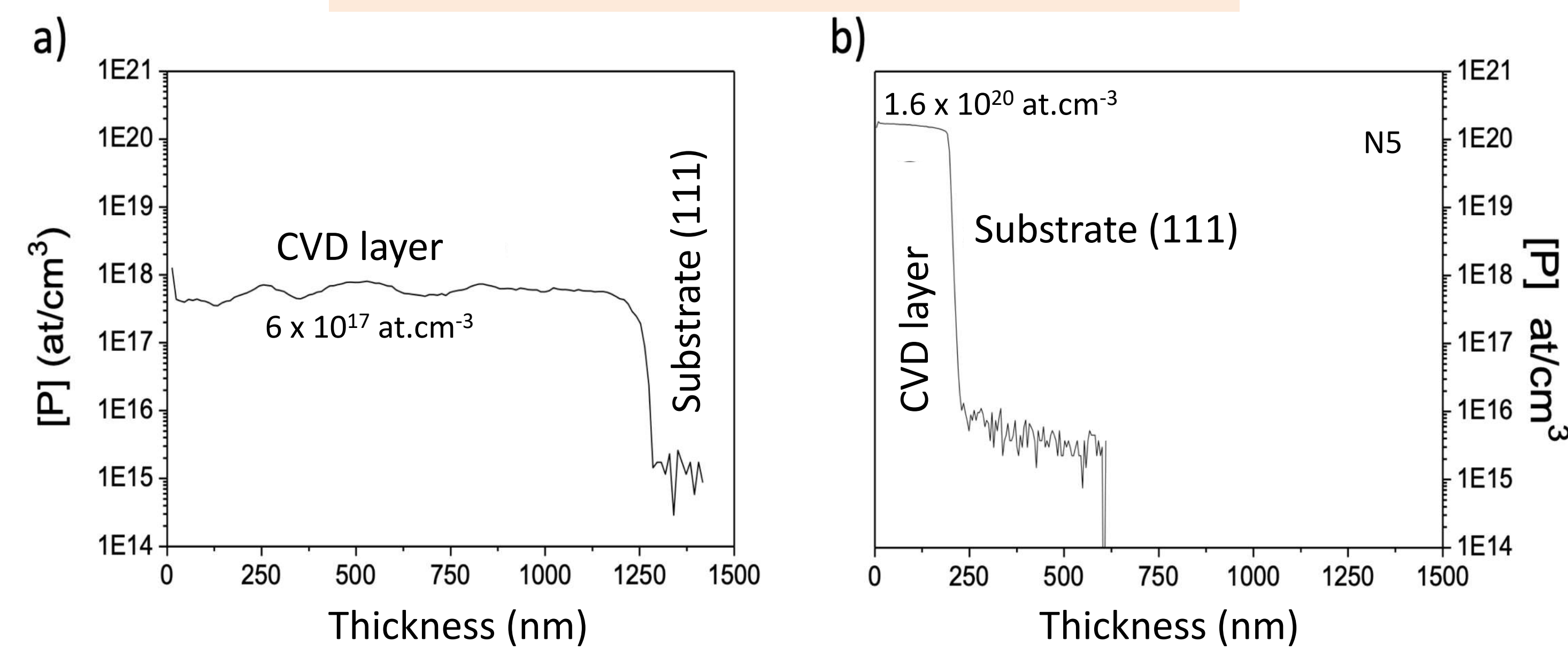
- Development of ohmic contacts on (111) n-type CVD 2x2 mm² diamond
- Study of different n-doping techniques by beam line and plasma immersion ion implantations
- Characterization of contact resistances by linear and circular-type TLM structures

Characteristics of studied samples

- N₂ to N₄**: n⁺-doping by beam line and plasma-immersion ion implantations on 6 x 10¹⁷ at.cm⁻³ phosphorous-doped epitaxial layers
- N₅**: 0.2 μm thick n⁺-layer grown on (111) diamond and heavily doped with [P] = 1.6 x 10²⁰ at.cm⁻³

Sample	n-epitaxial layer	Phosphorous overdoping by ion implantation
N ₁	1.3 μm / 6 x 10 ¹⁷ at.cm ⁻³	CVD reference (non implanted)
N ₂	"	- Beam line - HT annealing: 1700°C, 30min - Dopant atoms concentration: 5 x 10 ¹⁹ at.cm ⁻³ over 100nm measured by SIMS
N ₃	"	- Plasma-immersion: PH ₃ plasma at 20 keV - HT annealing: 1700°C, 30min
N ₄	"	- Plasma-immersion: PH ₃ plasma at 20 keV - HT annealing: 1700°C, 30min
N ₅	0.2μm / 1.6 x 10 ²⁰ at.cm ⁻³	- Heavily phosphorous-doped in situ, non implanted

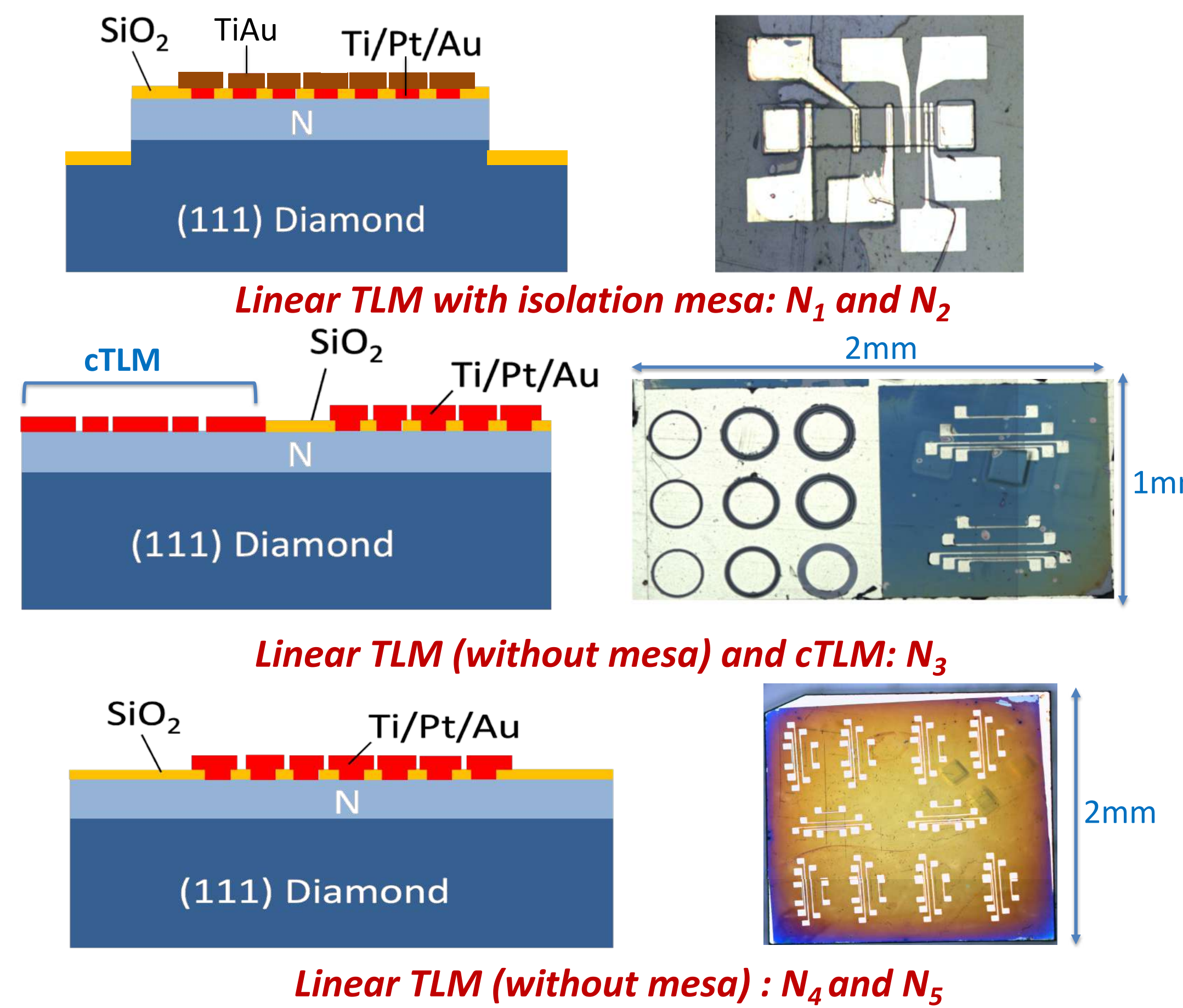
SIMS depth profiles of CVD n-layers



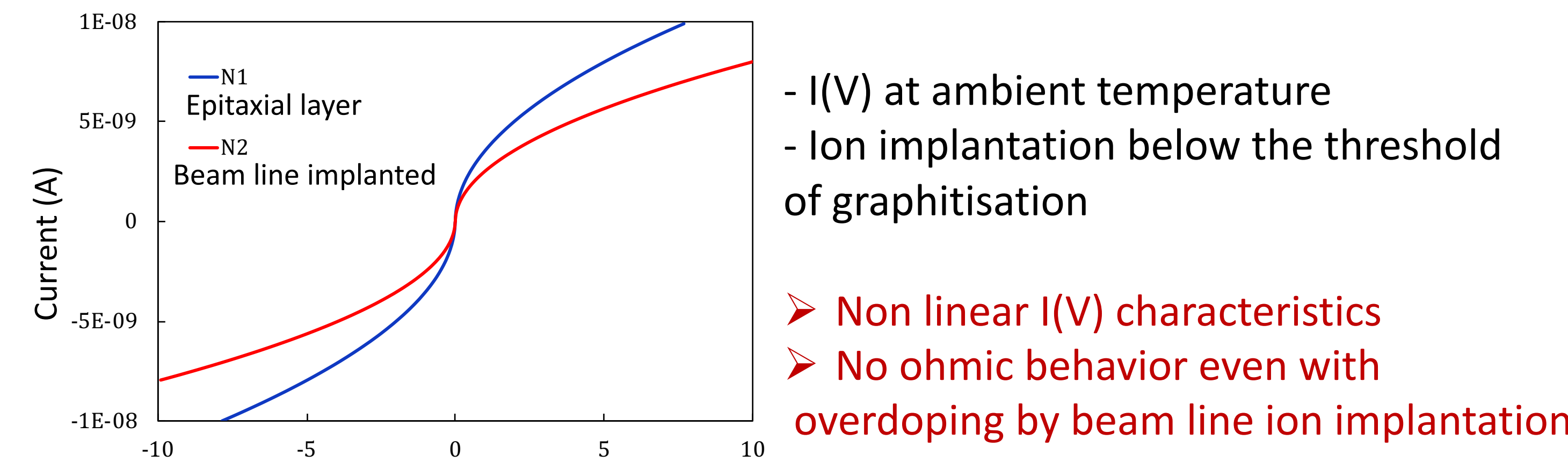
a) phosphorous-doped layer by CVD before ion implantation (N₁-N₄ samples)

b) heavily phosphorous-doped layer by CVD (N₅ sample)

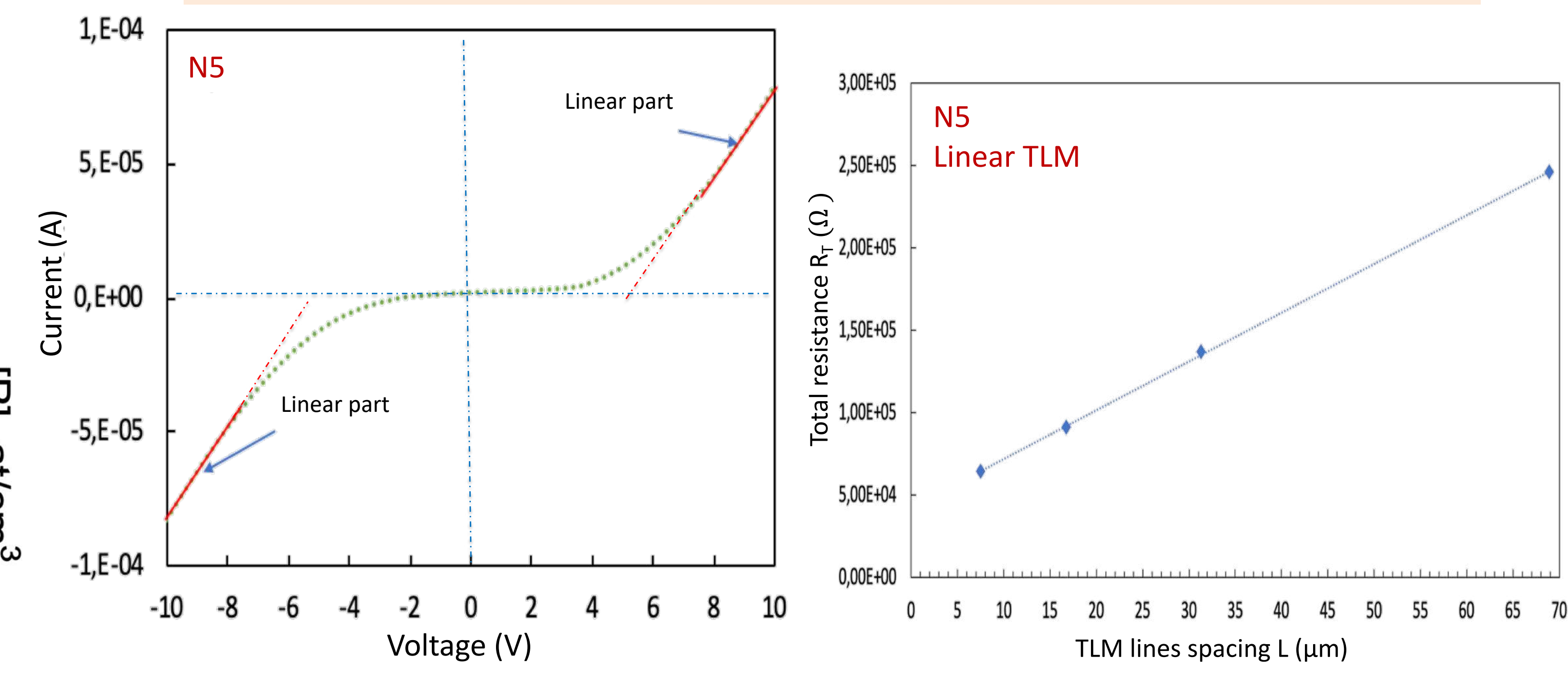
Fabrication and characterization of TLM structures



Influence of overdoping by beam line ion implantation : N₁ and N₂

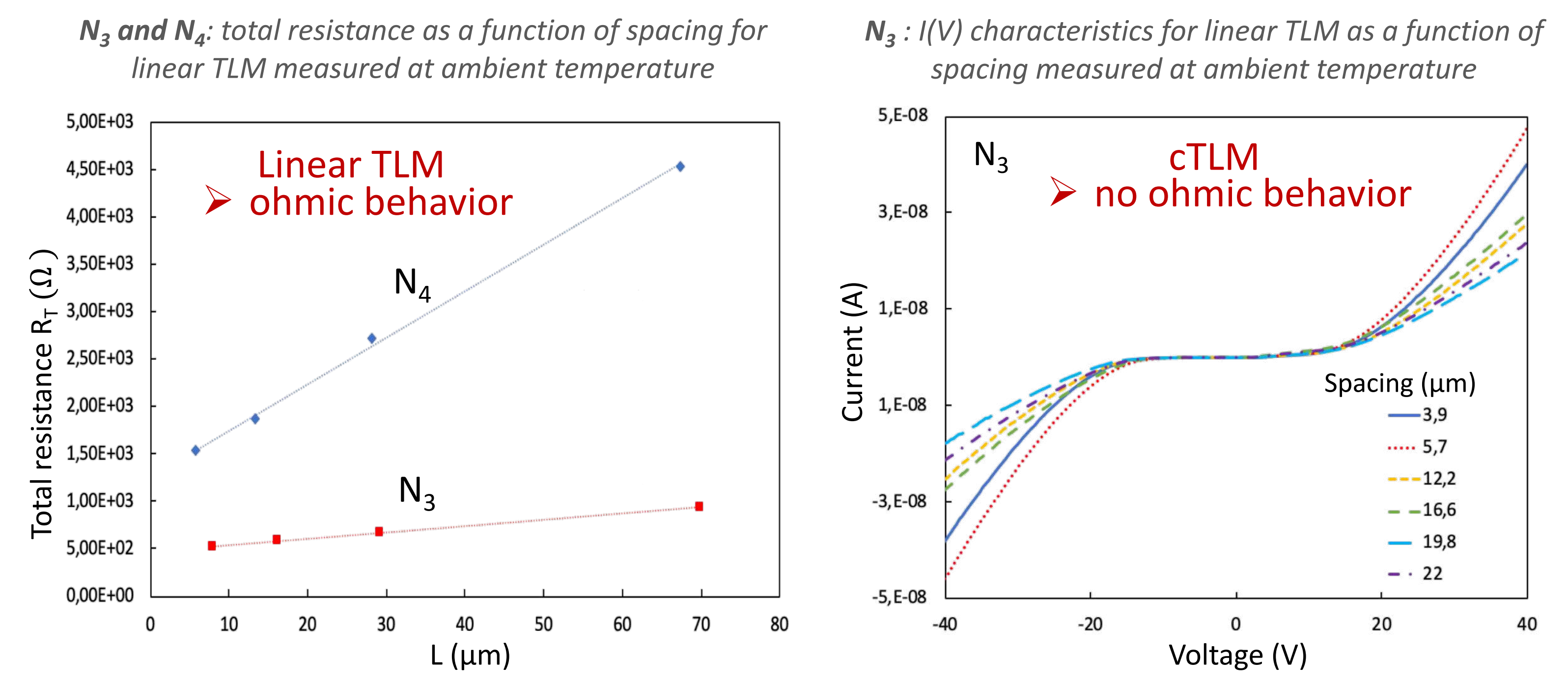


Heavily phosphorous doping by epitaxy [P]=1.6 x 10²⁰ at.cm⁻³ : N₅



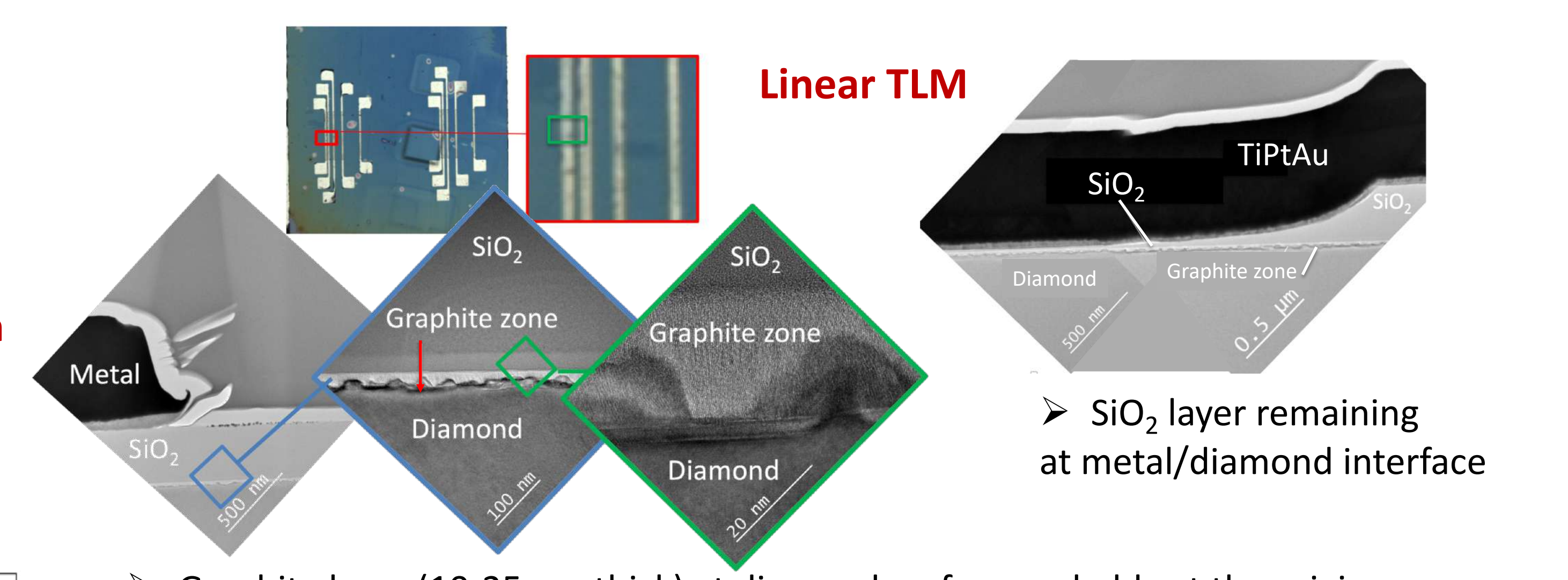
Difficulty to achieve ohmic contacts on heavily phosphorous-doped epitaxial layers

Phosphorous overdoping by plasma-immersion implantation: N₃ and N₄



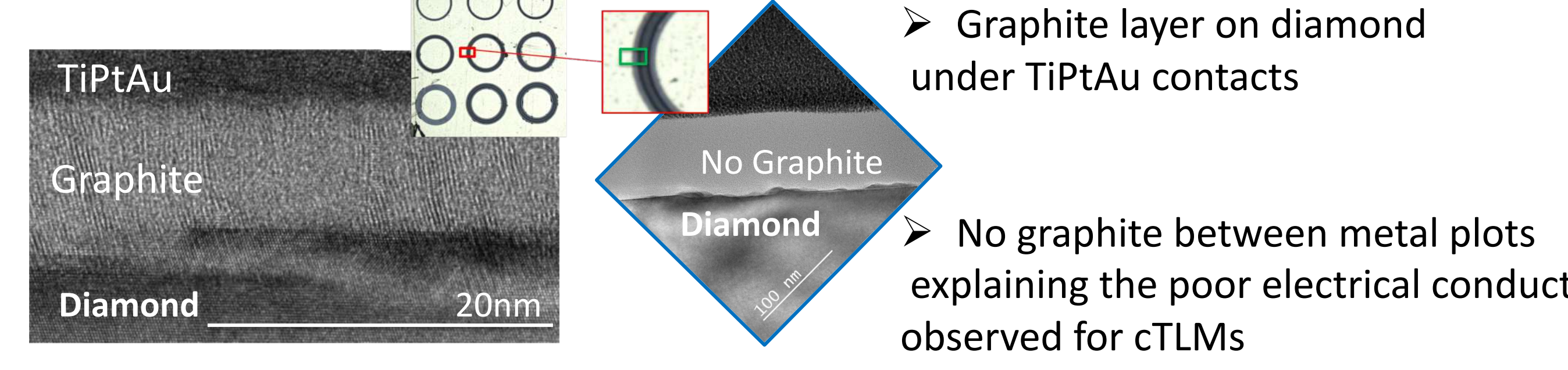
Linear TLM	Sheet resistance	Specific contact resistance
N ₃	R _{SH} = 1.5 kΩ/□	ρ _C = 1.7 x 10 ⁻³ Ω.cm ²
N ₄	R _{SH} = 9.7 kΩ/□	ρ _C = 6.7 x 10 ⁻² Ω.cm ²

TEM characterizations performed on N₃



Graphite layer (10-25 nm thick) at diamond surface probably at the origin of the electrical conduction observed

Circular TLM



Conclusion

- No ohmic contact obtained with highly phosphorous-doped epitaxial layer or by beam line implantation overdoping
- Ohmic behavior with plasma-immersion ion implantation with PH₃ plasma at 20keV and 10¹⁴ at/cm³ with the formation of a conducting graphite layer
- Studies are on going to explain the graphite layer formation and for testing new PIII implantation conditions