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# DEVELOPMENT OF MONOLITHICALLY INTEGRATED (Al)GaAs ON SILICON FOR TANDEM SOLAR CELLS

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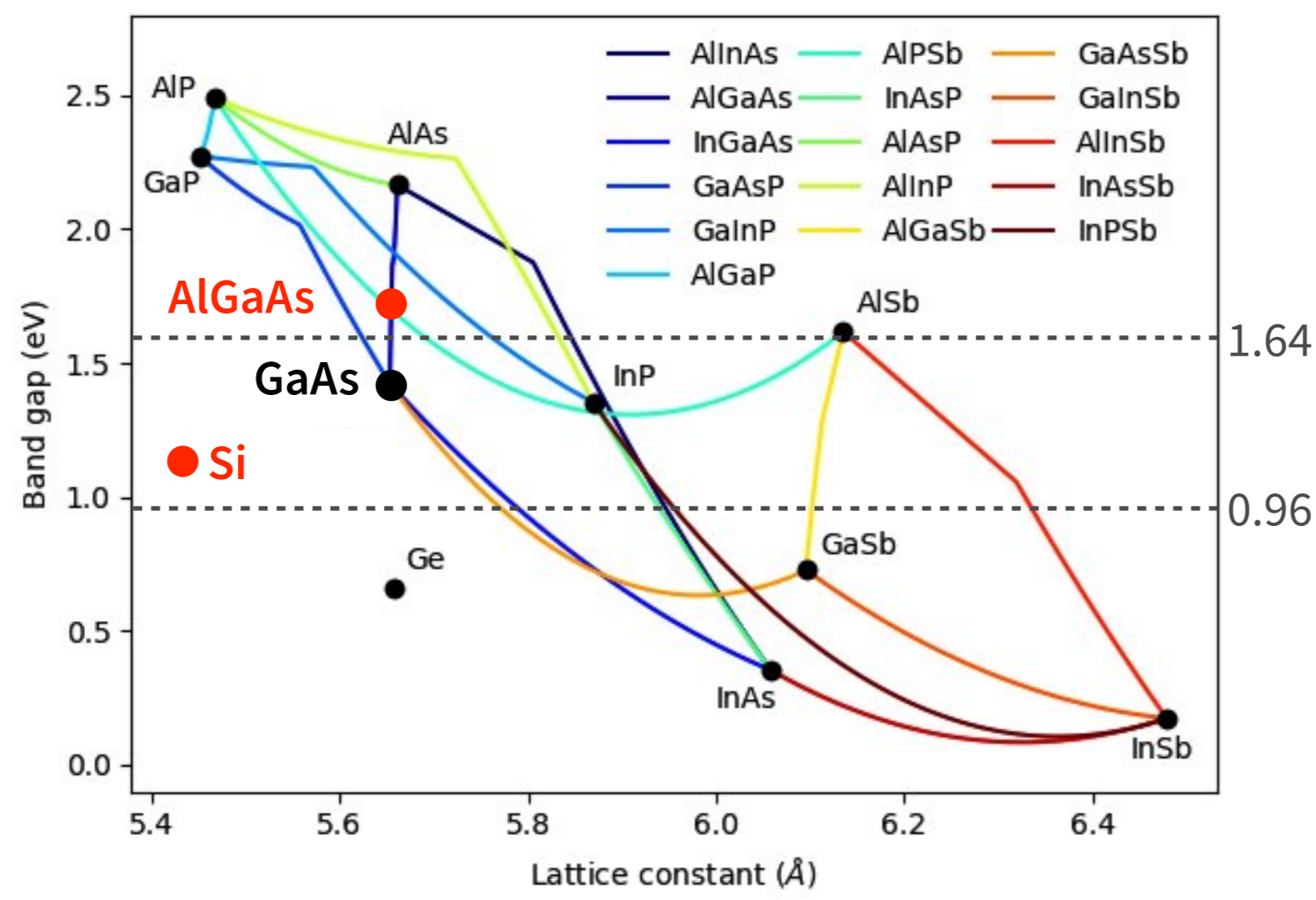
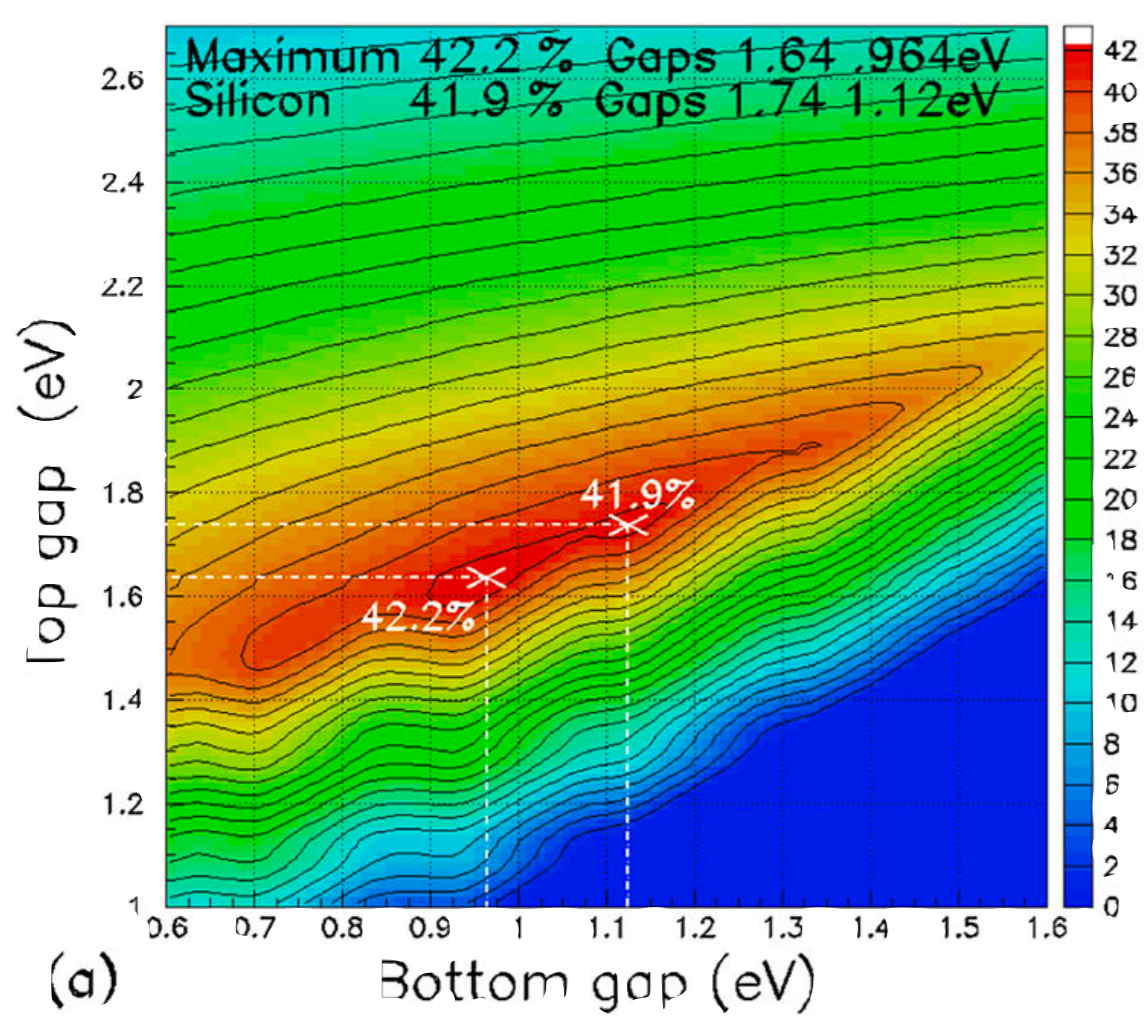
# Development of monolithic integrated AlGaAs on silicon for tandem solar cells

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## Objective & Concept



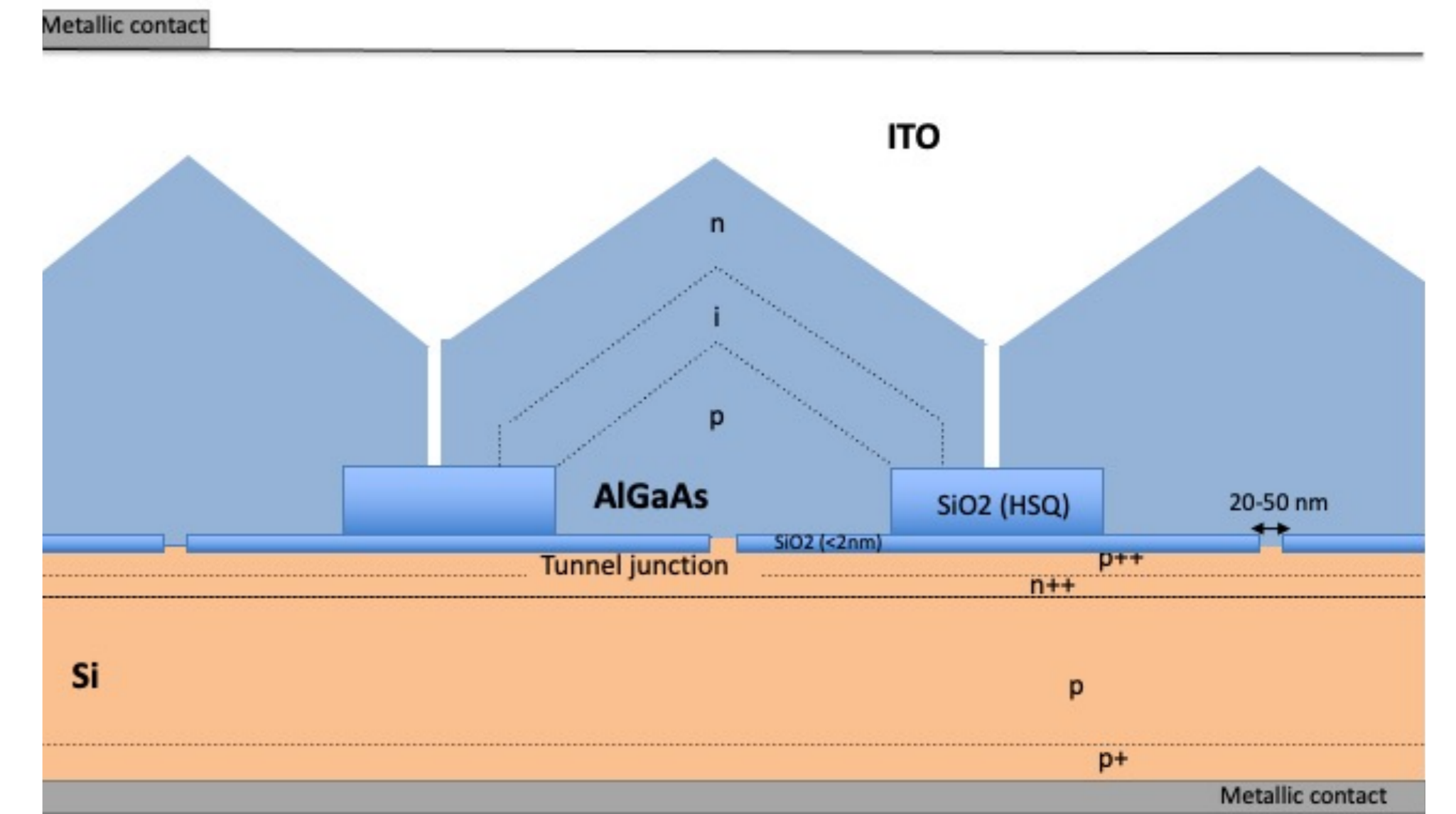
## Multifunctions solar cells

### GaAs on Si integration challenges

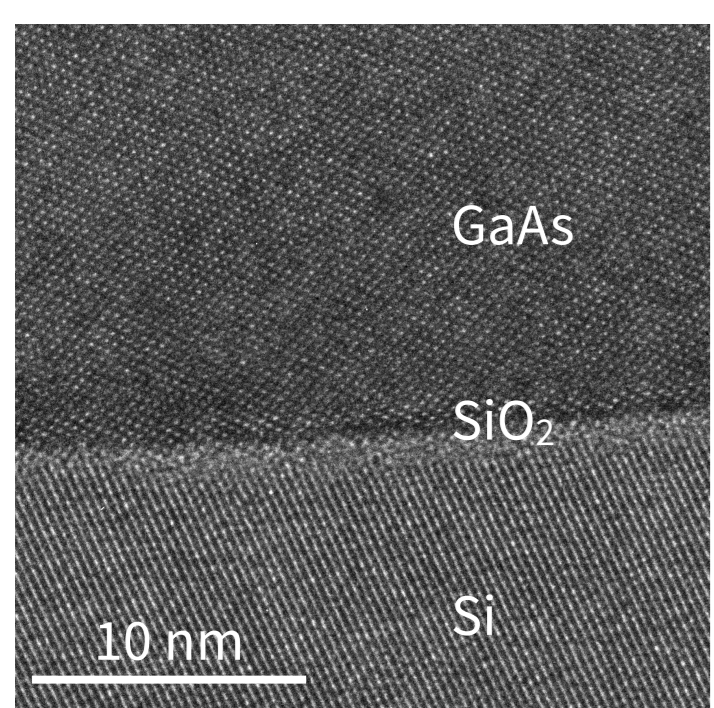
- High lattice mismatch 4.2%
- Different thermal coefficient
- Anti-phase domains

### Epitaxial Lateral Overgrowth (ELO)

- Nano-apertures in ultra-thin SiO<sub>2</sub>
- GaAs growth, relaxed and defect free
- Conductive interface via tunnel junction



## GaAs/Si junction

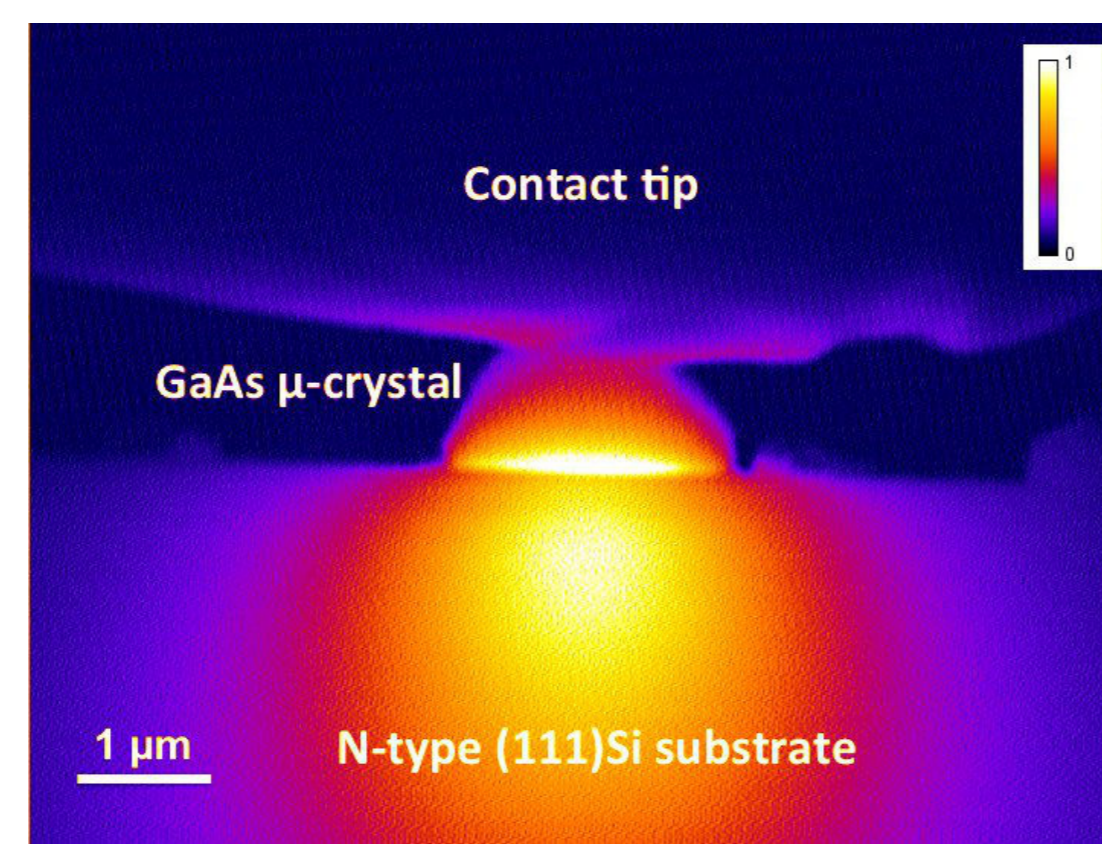


### Random thermal opening

SiO<sub>2</sub> ultra-thin ~ 1.2 nm  
Direct Bias 4 V: 4.2 x 10<sup>-5</sup> A  
Current passing across the entire surface  
10 kA.cm<sup>-2</sup>

### CP-AFM

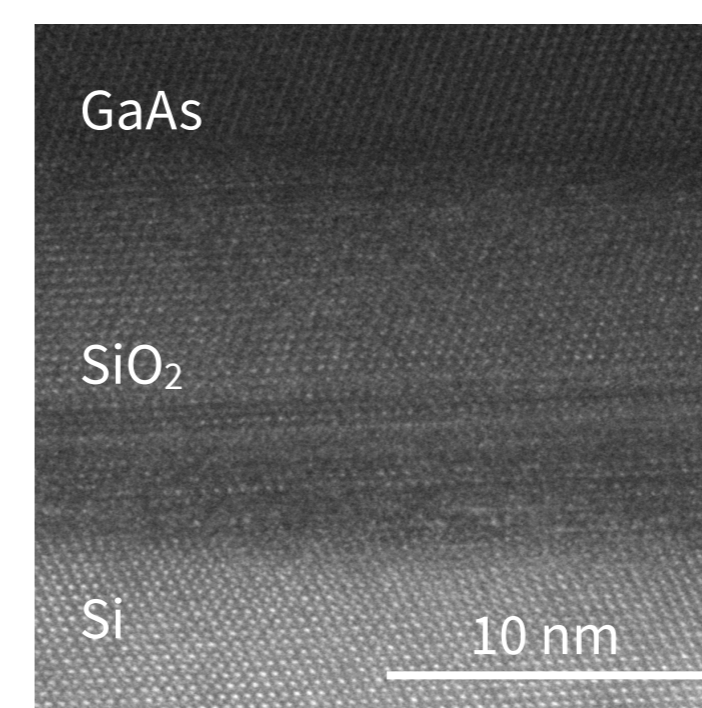
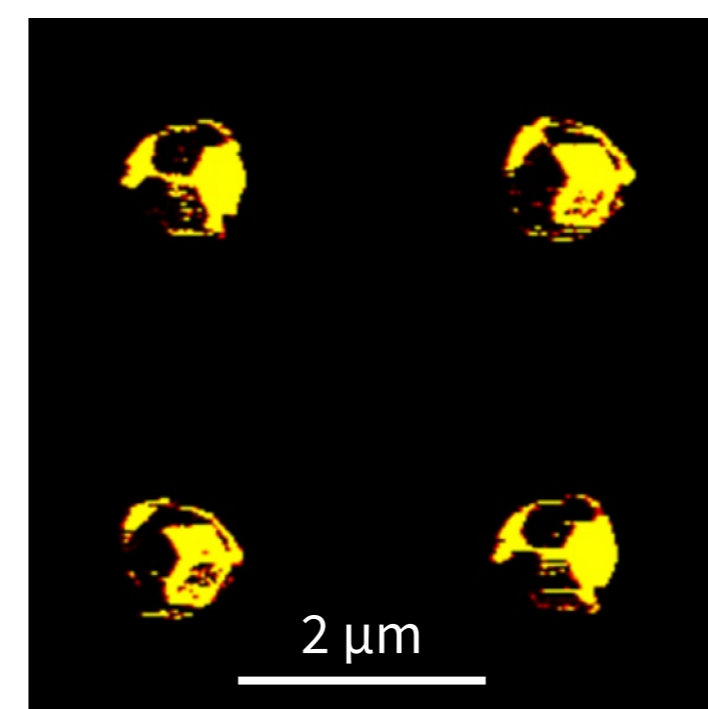
Direct bias  
200x lower



### Localized opening by EBL

SiO<sub>2</sub> ~ 10 nm

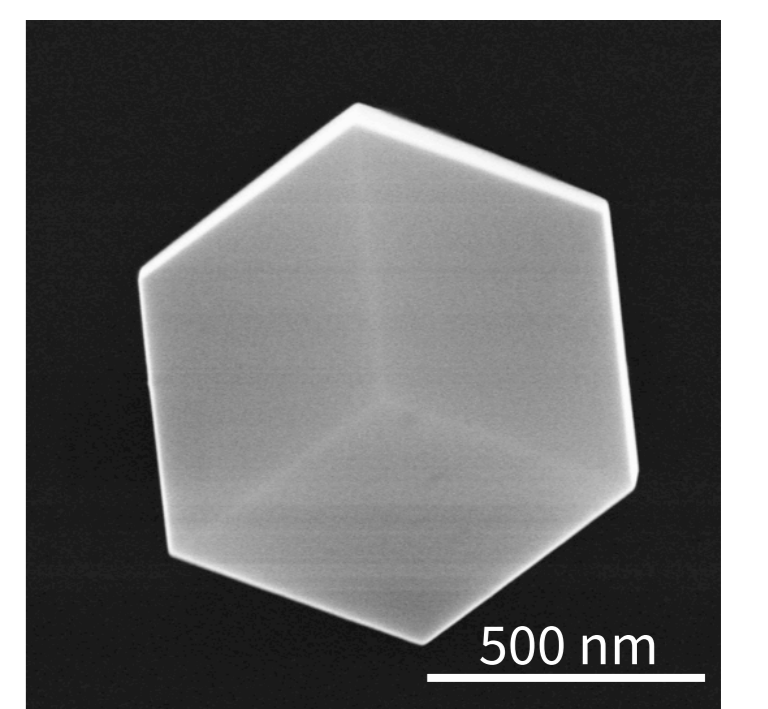
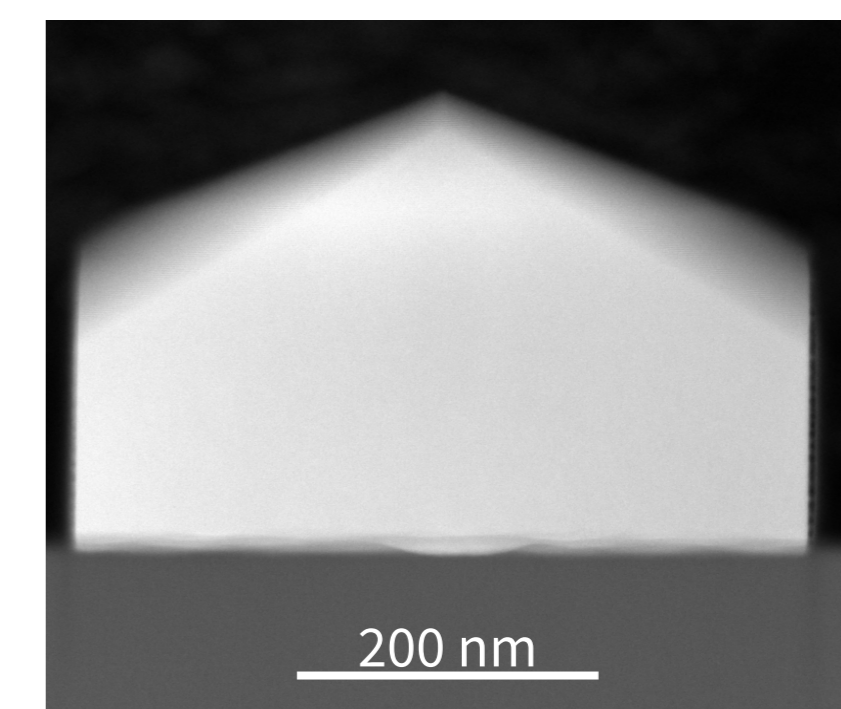
Direct Bias 4 V: 7 x 10<sup>-7</sup> A  
Current passing only through the opening  
7 kA.cm<sup>-2</sup>



## ELO GaAs μ-crystal requirement

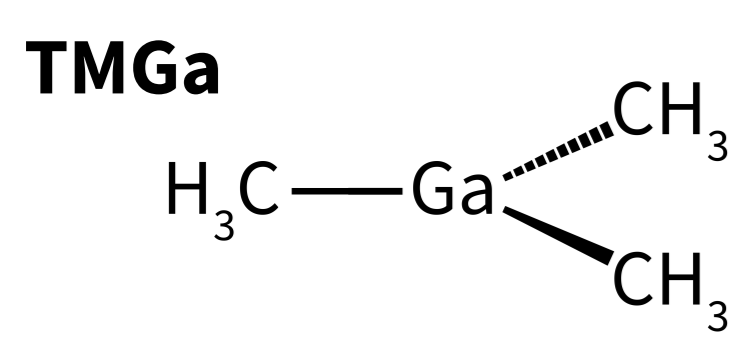
No defect at the GaAs/Si interface  
Aperture diameter < 80 nm  
Electrical integration via tunnel effect  
SiO<sub>2</sub> thickness < 2 nm

→ To localized in a ultra thin SiO<sub>2</sub> layer



## Doping control

### Gaz precursors



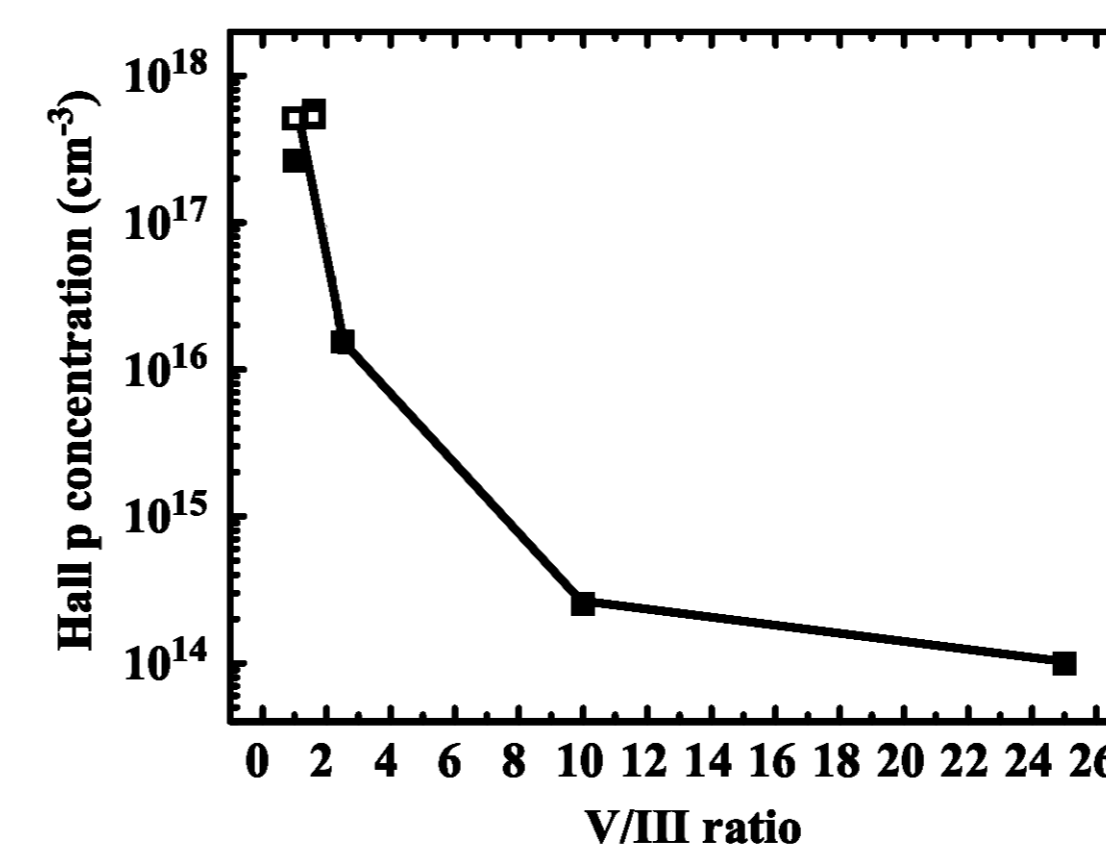
Carbon incorporation  
Incomplete decomposition of TMGa

| TMGa Radical bond | Dislocation energy kJ.mol <sup>-1</sup> |
|-------------------|---|
| 1st               | 149                                     |
| 2nd               | 249                                     |
| 3rd               | 325                                     |

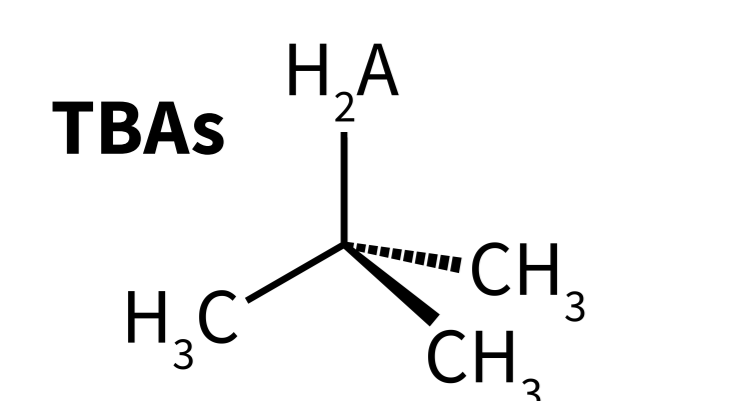
Jacko and al, *J. Chem. Phys.*, 1560-1567, 1963

To avoid p-type doping by Carbon  
Increase V/III ratio

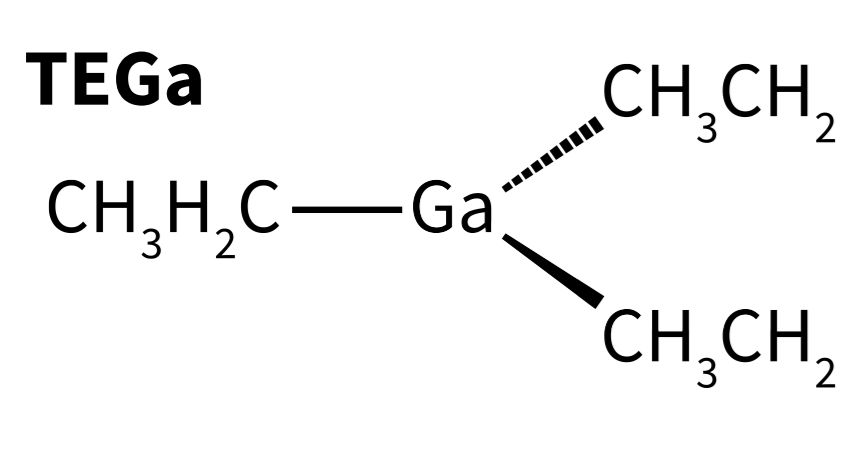
Enhancing TMGa decomposition  
Increasing TBAs → H release  
Volatile CH<sub>4</sub> formation



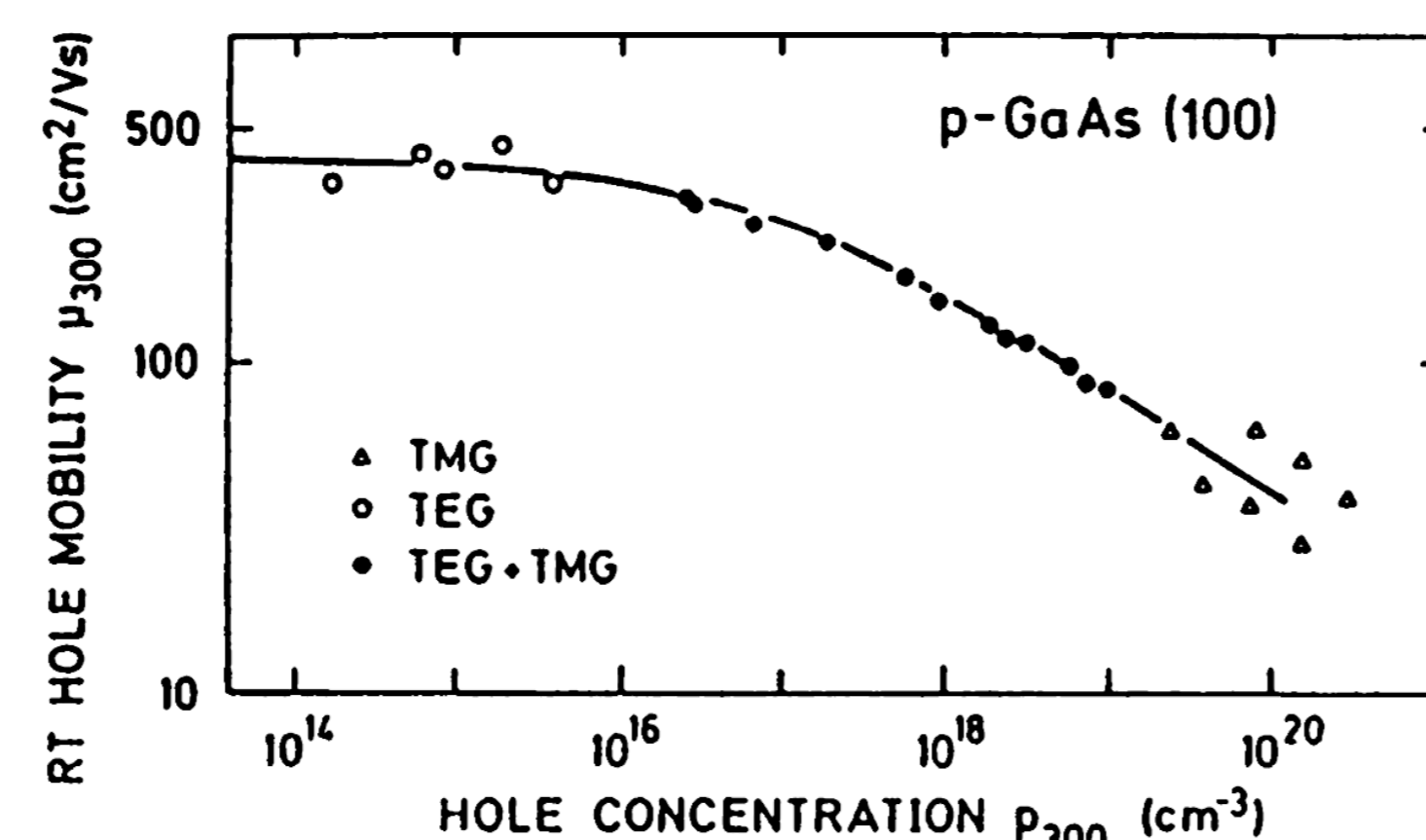
Longo and al, *J. Crystal Growth* 248, 119-123, 2003



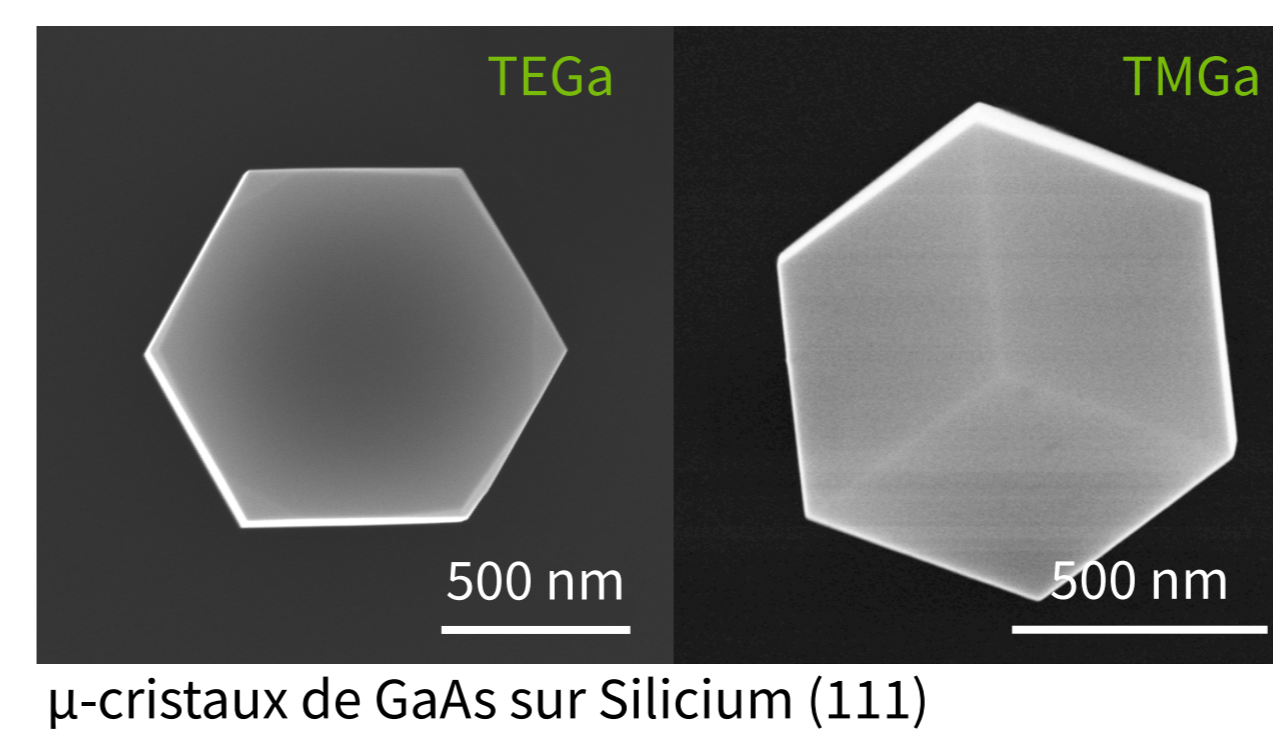
TMGa: Tri-M thylGallium  
TBAs: TertiaryButylArsine  
TEGa: Tri- thylGallium



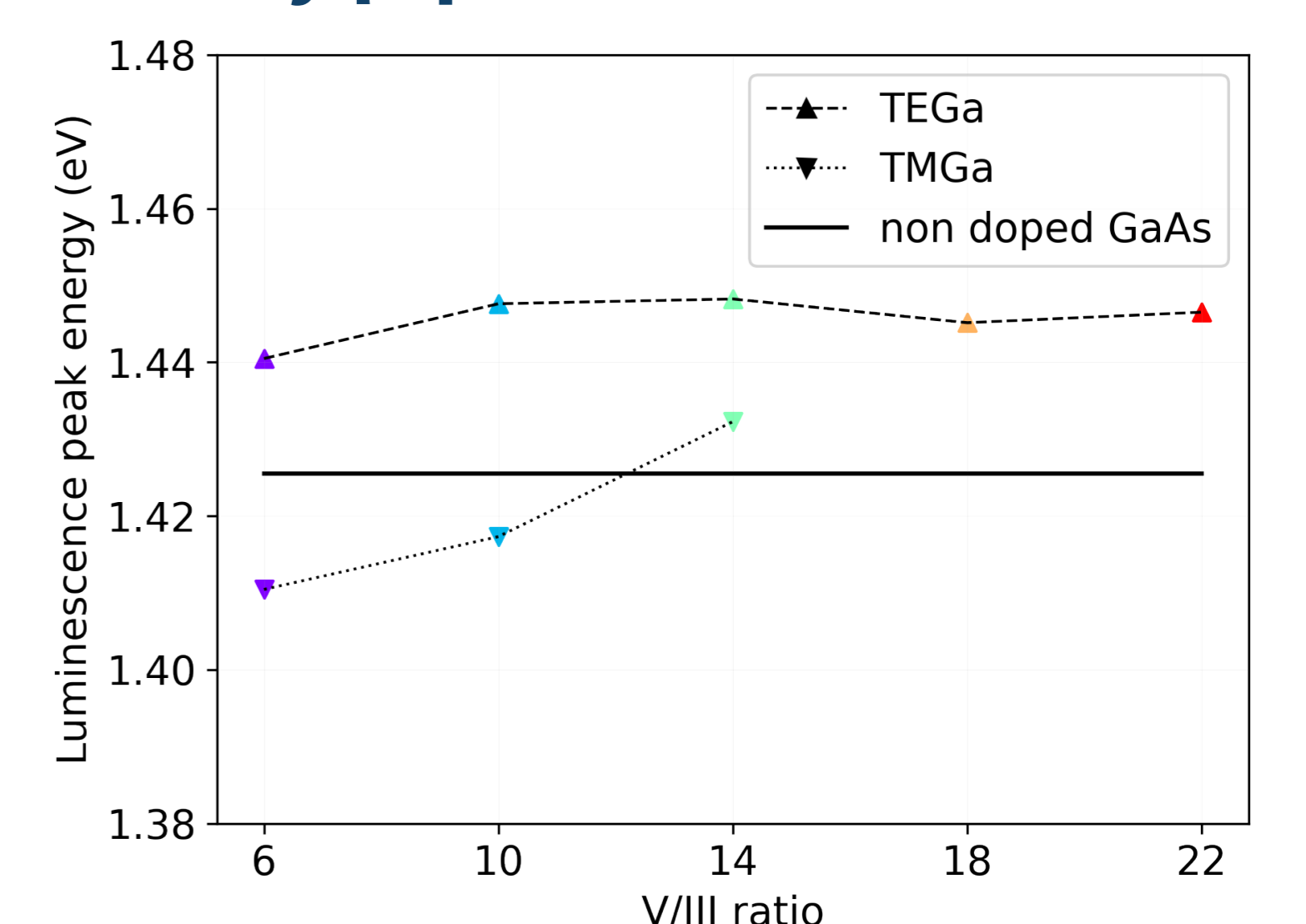
To avoid p-type doping by Carbon  
TEGa as Gallium gaz precursors



L th and al, *Solid Surfaces, Interfaces and Thin Films*, 166, 2010



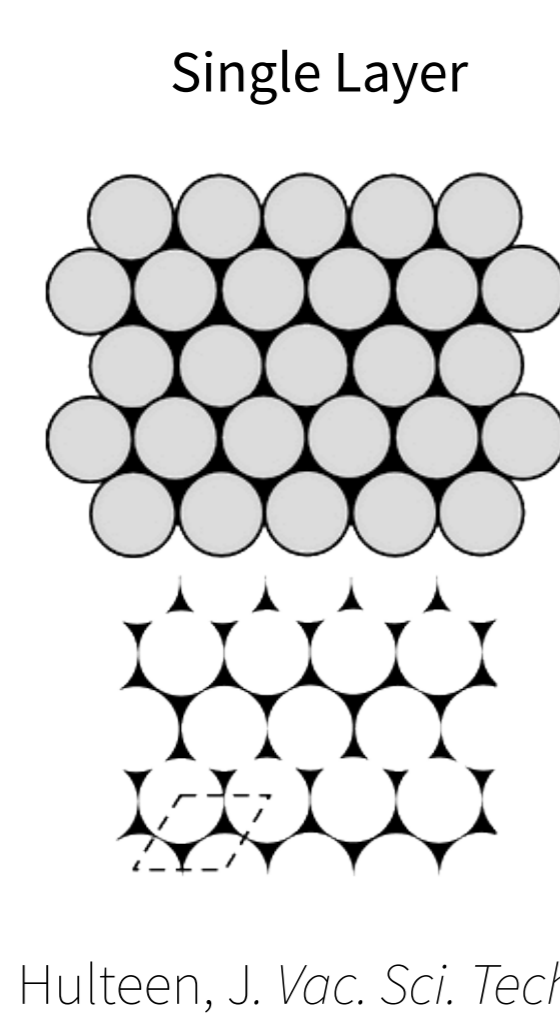
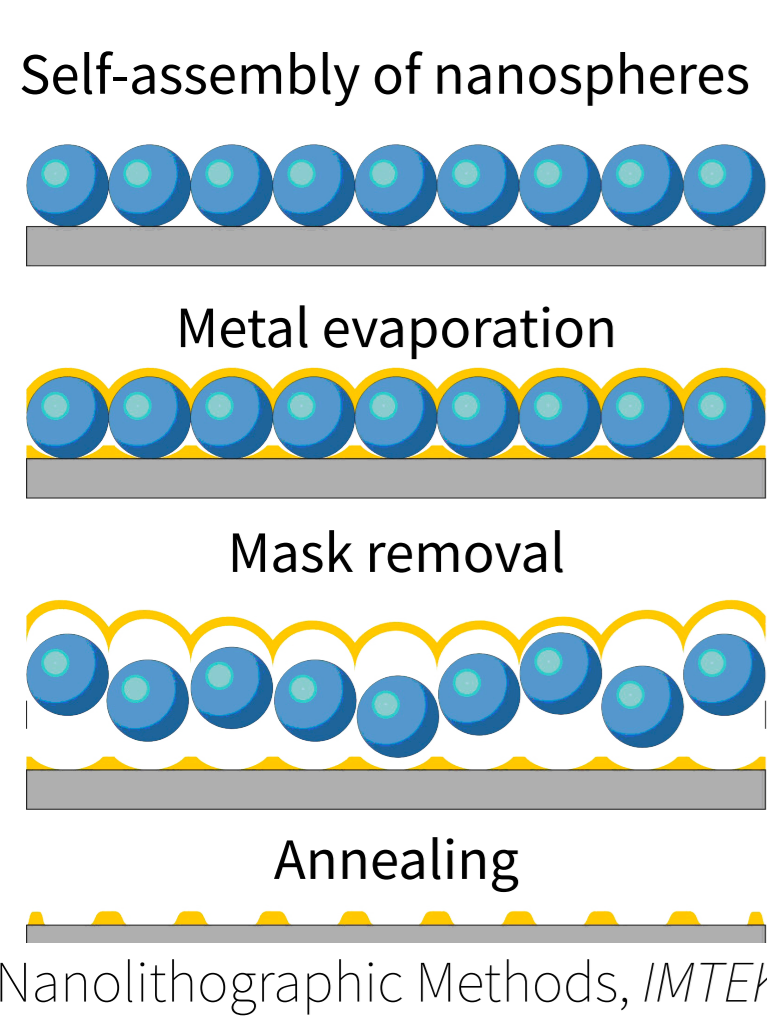
## Doping level determination by μ-photoluminescence



TMGa  
→ influenced by V/III ratio  
→ p-doped for low V/III ratio  
TEGa  
→ non-influenced by V/III ratio  
→ seems to be undoped

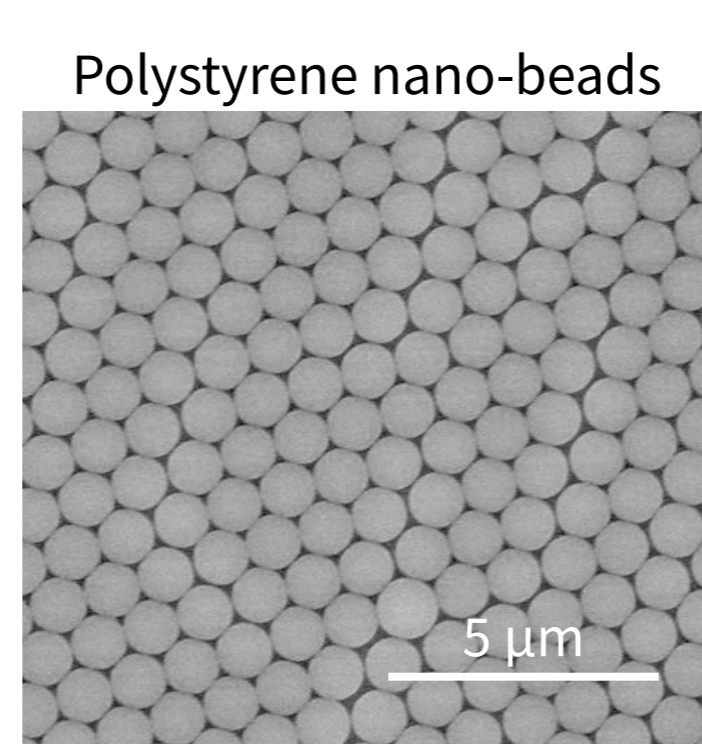
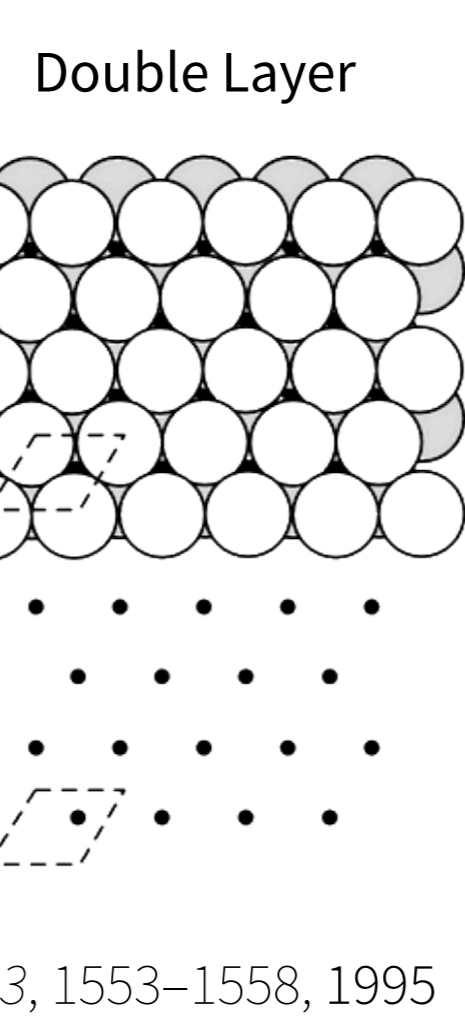
## Localisation process

### NanoSphere Lithography (NSL)



### On ultra-thin SiO<sub>2</sub>

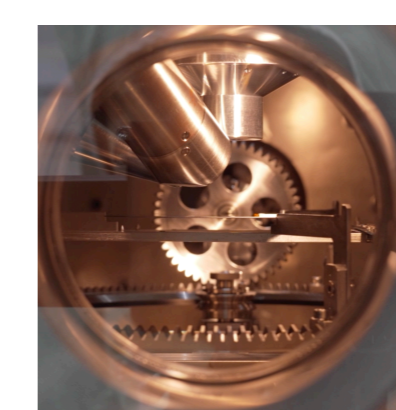
Low cost localization process  
Self-assembly by Van der Waals force



Hulteen, *J. Vac. Sci. Technol. A* 13, 1553-1558, 1995

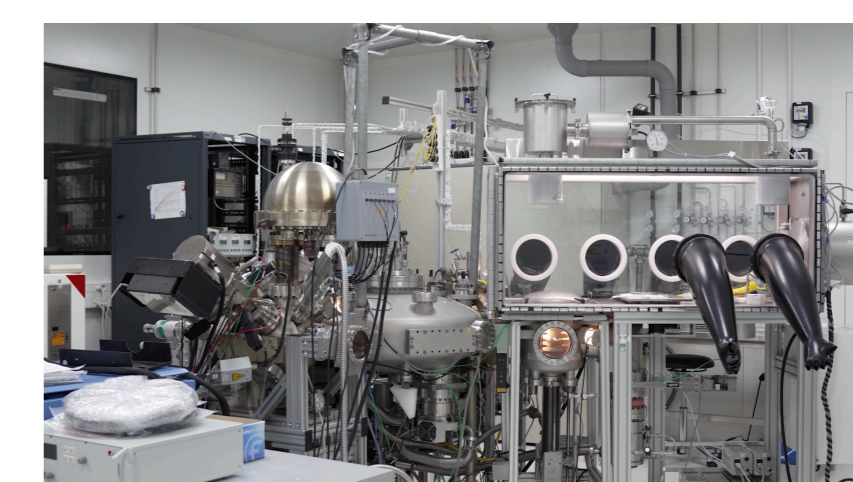
## Epitaxial Cluster Tool

1 UHV-CVD chamber  
IV-IV materials  
(with RHEED in situ)



1 CBE chamber  
dedicated to IV-IV and III-V materials  
(with RHEED in situ)

→ 8" compatible, 4" in standard  
→ Growth chambers base pressure: 10<sup>-10</sup> mbar  
→ Working Pressure: 10<sup>-4</sup> - 10<sup>-1</sup> mbar



1 Characterization chamber  
XPS, AES, SEM

