



## Towards III-V on silicon solar cells

Mickael da Silva, S. Boyer-Richard, C. Cornet, Antoine Létoublon, Christophe Levallois, Alain Rolland, Jacky Even, Laurent Pedesseau, Alain Le Corre, Slimane Loualiche, et al.

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# Towards III-V on silicon solar cells

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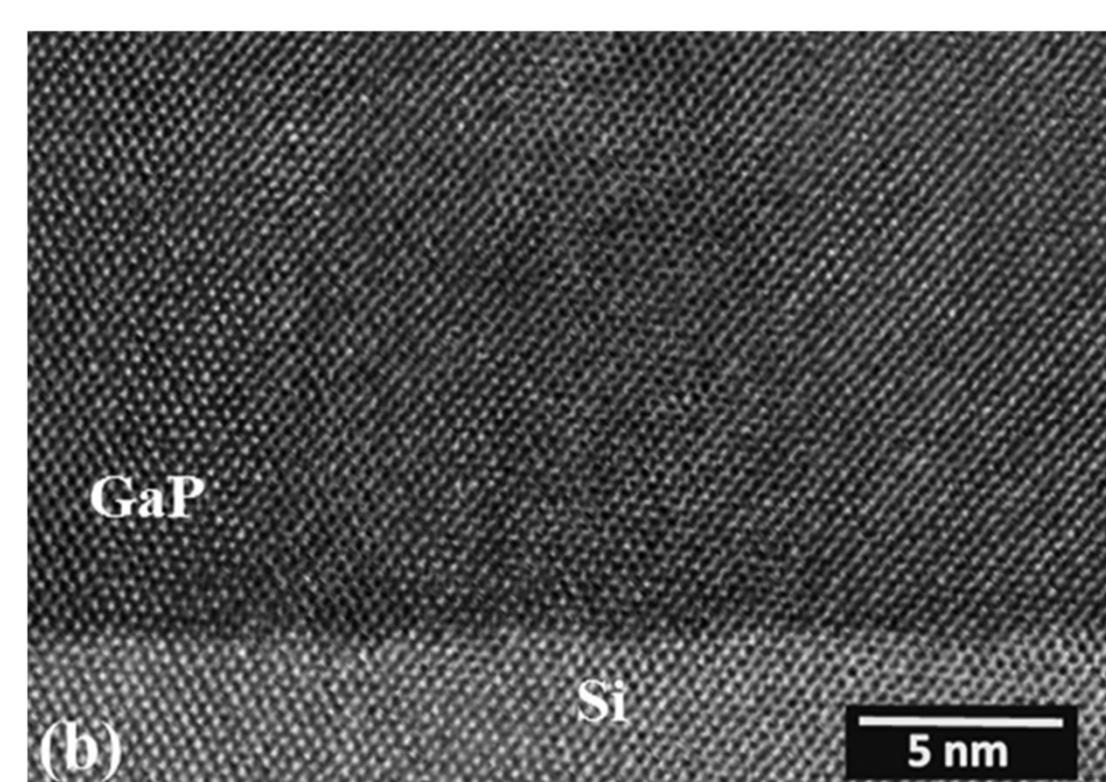
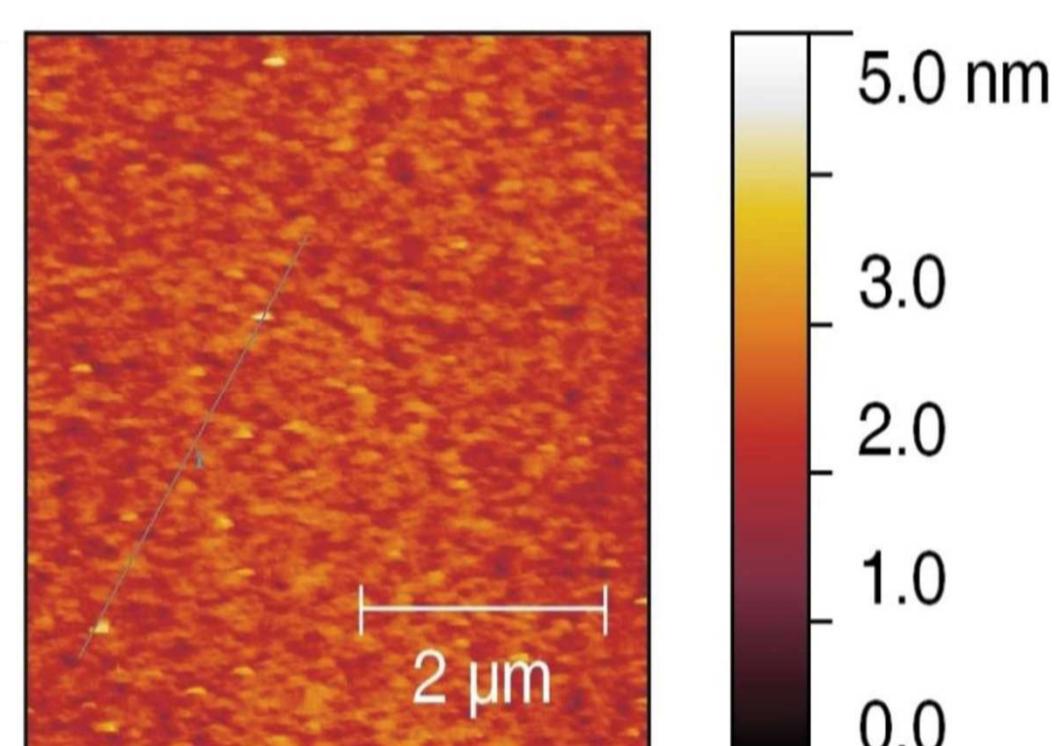
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## GaP/Si heterojunctions for photovoltaics

- *Tandem cells on silicon : high performance of multijunction solar cells on a classical photovoltaic substrate : silicon*
- *Epitaxial GaP layer as a transparent conductive layer on a single junction silicon solar cell to limit Si(n) absorption*
- *GaP(n)/Si(p) heterojunction to enhance  $V_{oc}$  and high energy absorption*

## Optimizing GaP/Si interface

GaP MBE 35 nm (500°C)  
GaP MEE 10 nm (350°C)  
Si (001) substrate

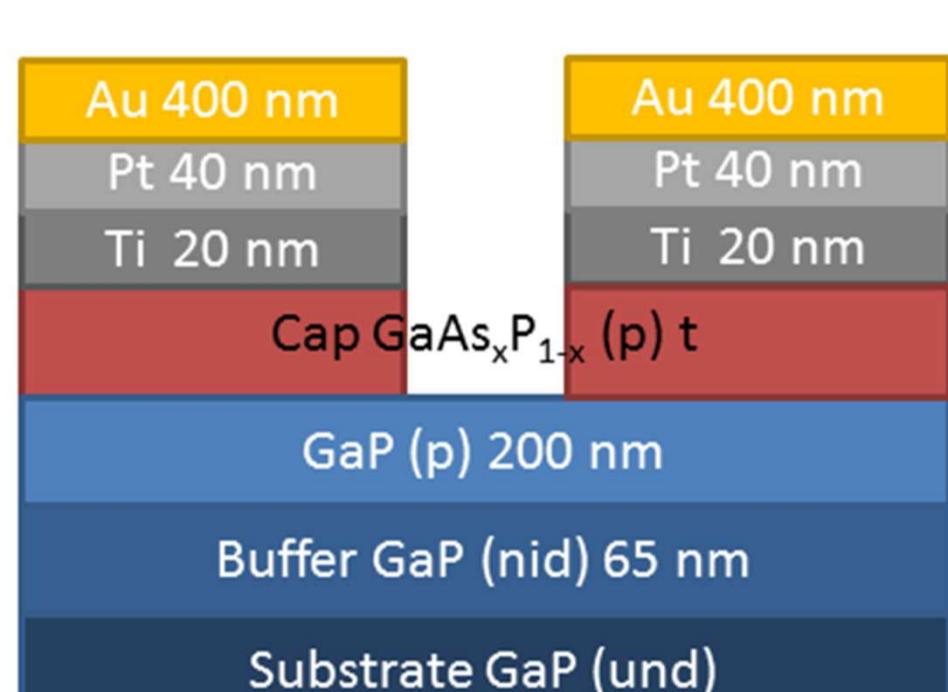


Ping Wang, Y., *Appl. Phys. Lett.* **107**, 191603 (2015)

**State-of-the art GaP/Si(001) platform :**  
Very low density of micro-twins  
annihilation of the antiphase domains after only 10 nm GaP growth

But doping GaP at the Si interface remains challenging

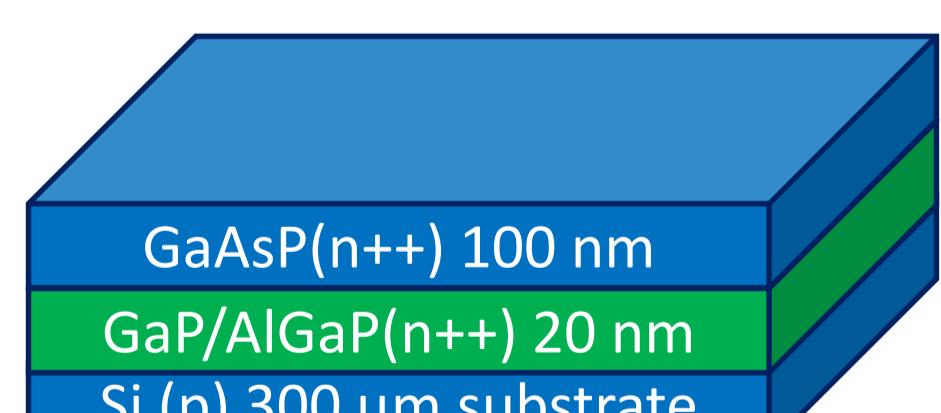
## Ohmic contacts on GaP



Direct p-type ohmic contact on GaP requires exotic metal : Pd/Zn/Pd  
Supplementary epitaxial GaAsP allows to use Ti/Pt/Au

20 nm GaAs<sub>0,1</sub>P<sub>0,9</sub> heavily doped :  $N_a = 3 \cdot 10^{19} \text{ cm}^{-3}$   
Ohmic contact on GaP :  
 $\rho_c = 4.10^{-6} \Omega \cdot \text{cm}^2$  after 35s annealing @ 375°C

## Attempt of GaP/Si heterojunction solar cell



External quantum efficiency max : 63.5%

Drop of EQE at short wavelength due to surface recombination at the n-GaP surface and diffusion length on the GaP side

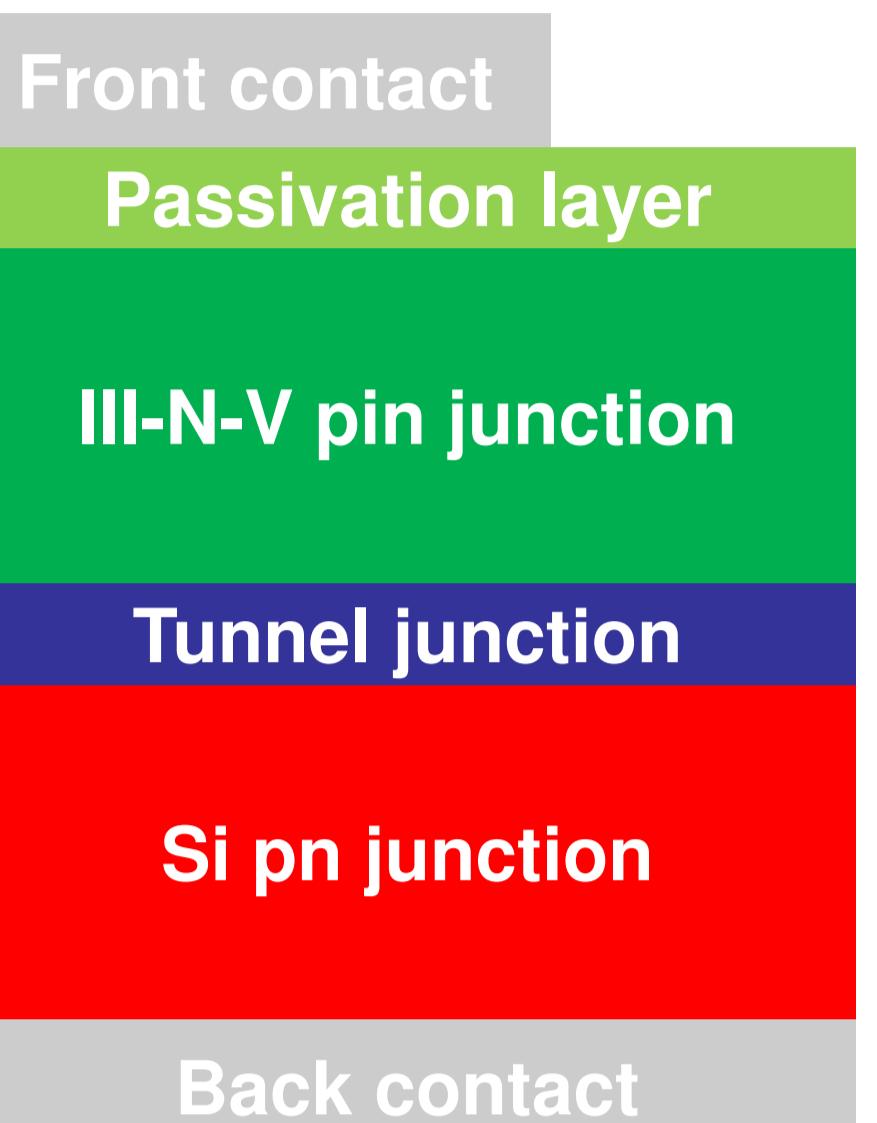
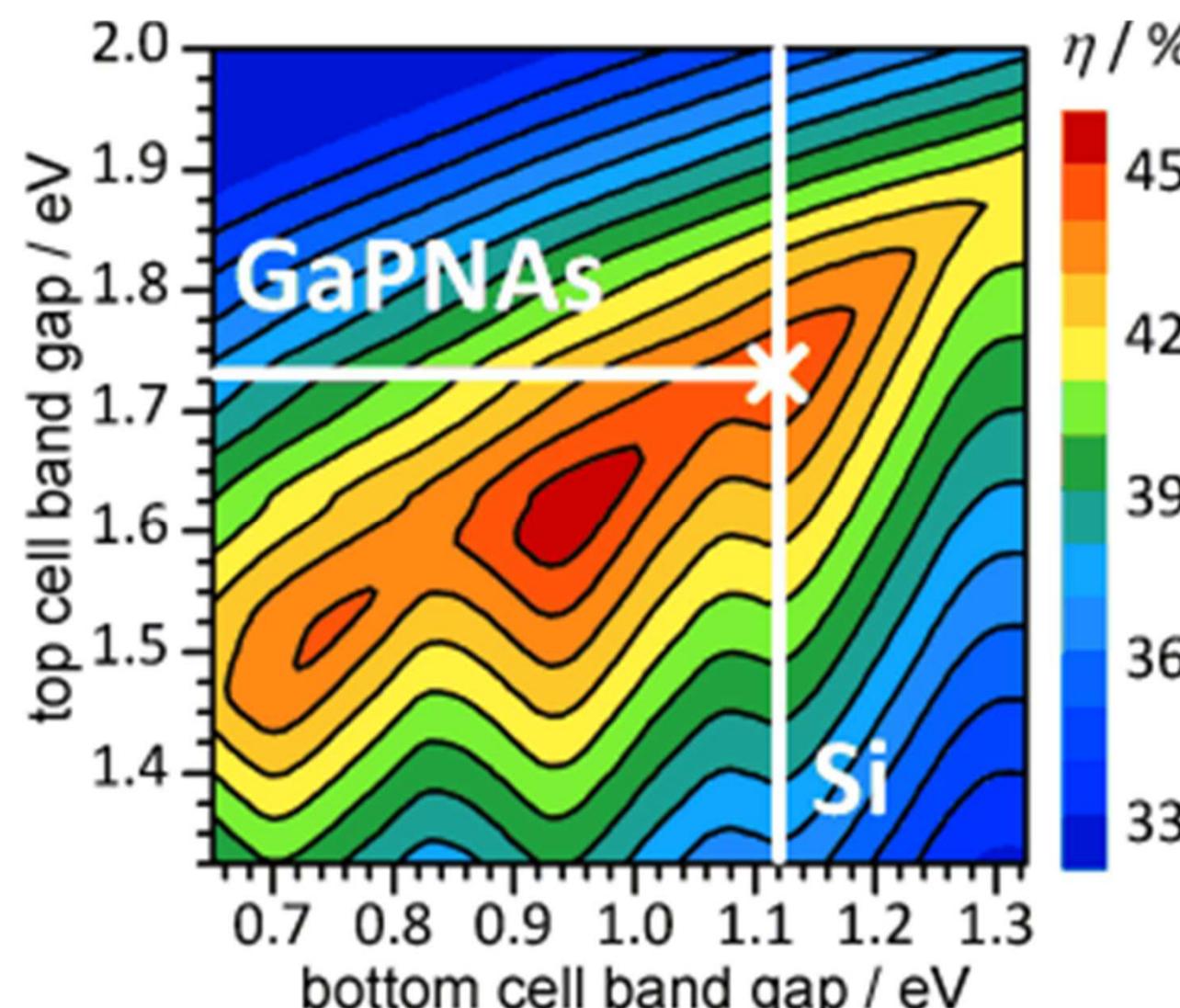
Poor electrical performances due to very bad contact on the Si side and carrier trapping at the doped GaP/Si interface :  $V_{OC} = 0.244 \text{ V}$ , Efficiency : 0.45 %

Doping the GaP layer at the vicinity of the GaP/Si interface is a very strong issue because dopants seem to accumulate at APBs locally overpassing the solubility limit.

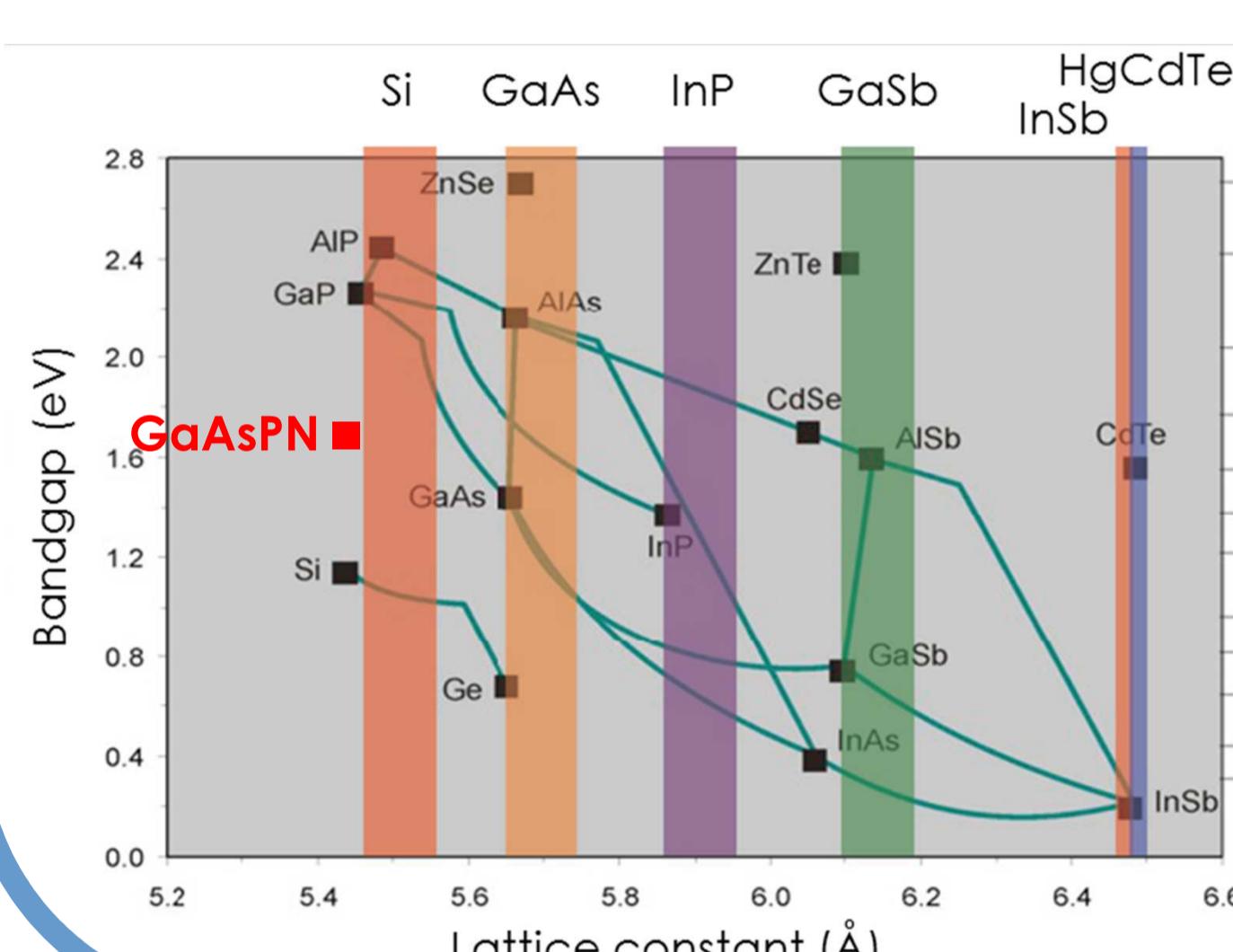
Further work :

- optimizing Si contact and GaP/Si interface with dopants
- Using the GaP layer as transparent conductive layer on a Si homojunction

## GaAsPN on Si tandem cells: high efficiency and low cost



N and As decrease the GaP bandgap from 2.3 eV to 1.7 eV and ensure the lattice matching with Si



## Main challenges:

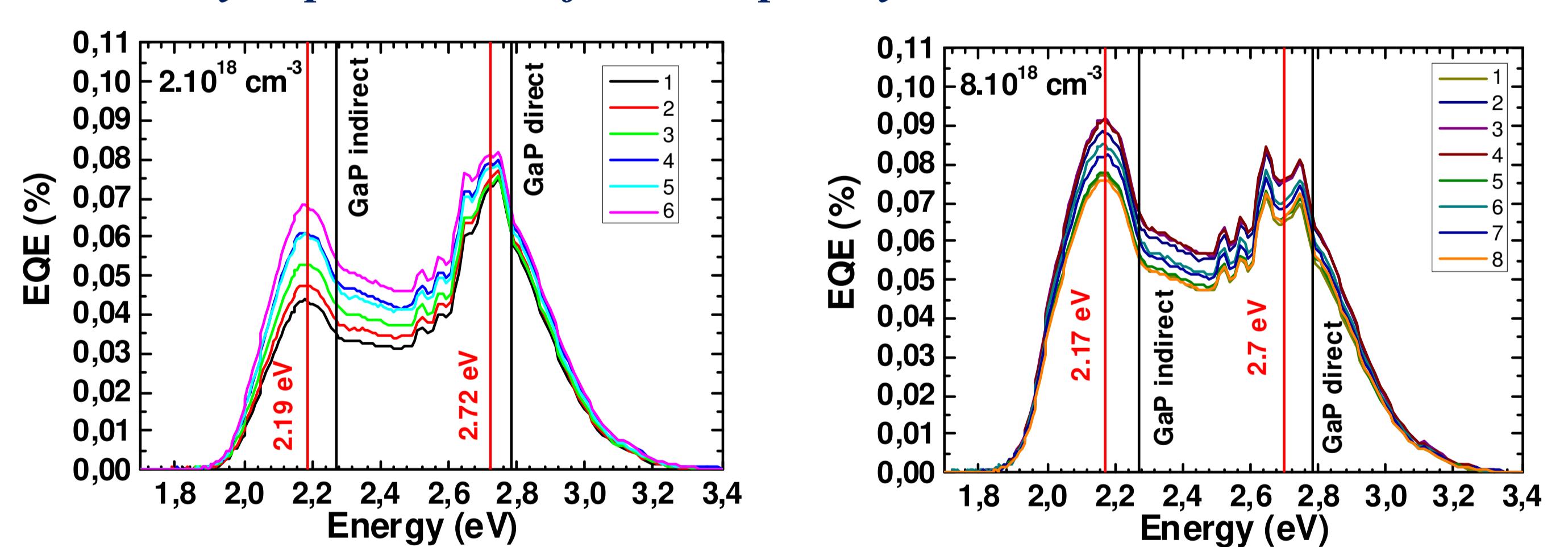
- Ohmic contacts on GaP (n:Ni/Au/Ge and p:Ti/Pt/Au on GaAsP p++)
- Reducing the surface recombination velocity
- Improving optoelectronic properties of the III-V absorber
- III-V/Si interface (Si/GaP pseudo-substrate)
- Efficient tunnel junction between III-V and Si based materials

## GaP top cell optimization

Several studies already performed :

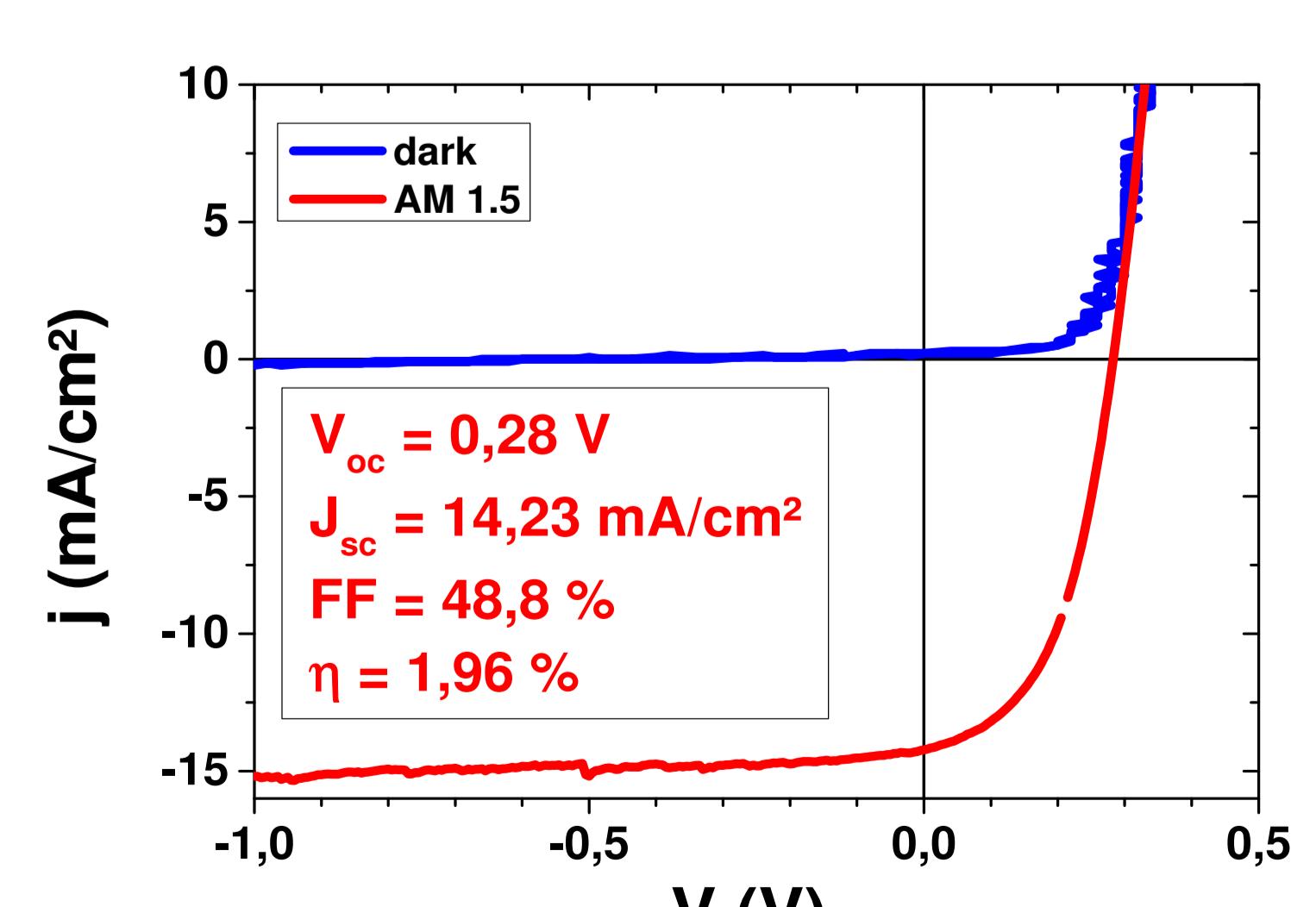
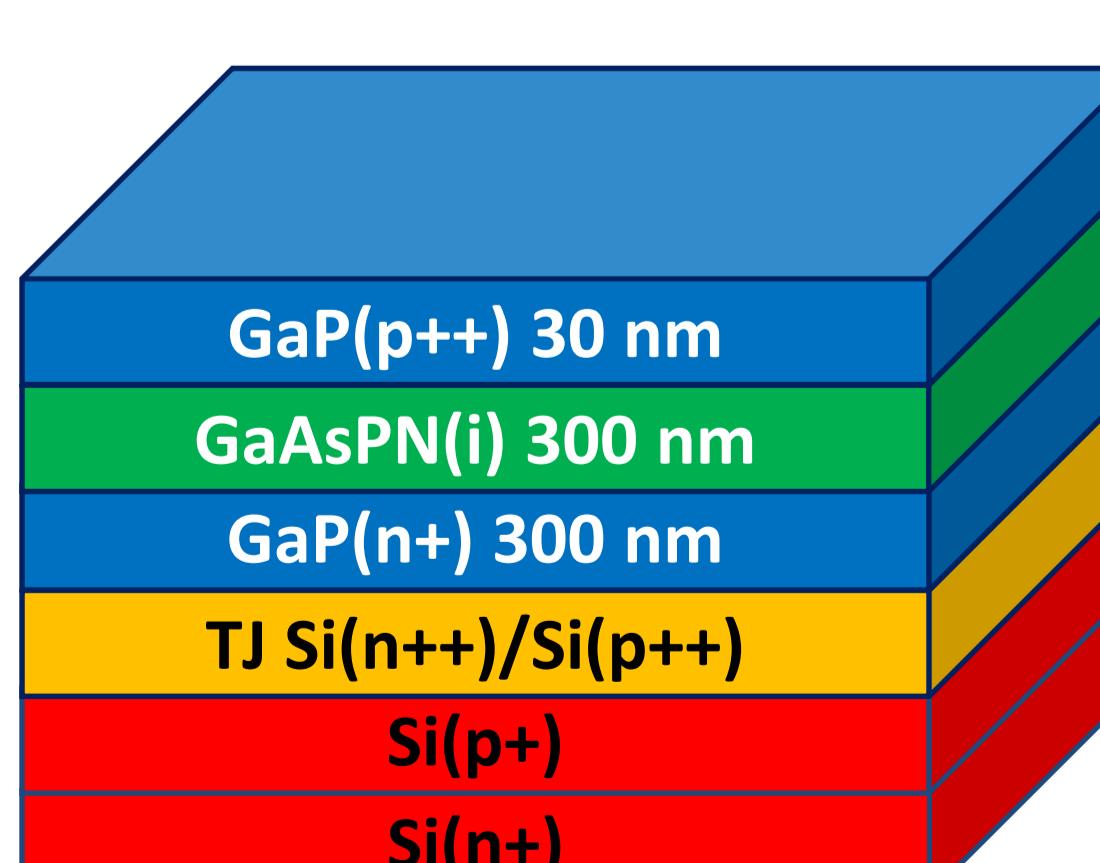
- Absorber layer optimization :  $T_g = 480^\circ\text{C}$ ,  $V/\text{III} = 10-11$ ,  $\text{Gr} = 0.5\text{ML/s}$
- Low carrier mobility in GaAsPN: 300 nm-thick absorber
- Optimized composition : GaAs<sub>0,1</sub>P<sub>0,88</sub>N<sub>0,02</sub> : pseudo-direct gap @ 1.7 eV, lattice matched to silicon

New study : optimization of the n-doped layer



Low energy peak increases with n doping level: better current collection near the GaAsPN/GaP:n interface

## First tandem cell on VPE Si pn junction



Encouraging photovoltaic effect.

Non optimal regrowth due to new TJ process  
→ low surface quality → interfacial recombinations = low  $V_{oc}$  ?