Towards III-V on silicon solar cells

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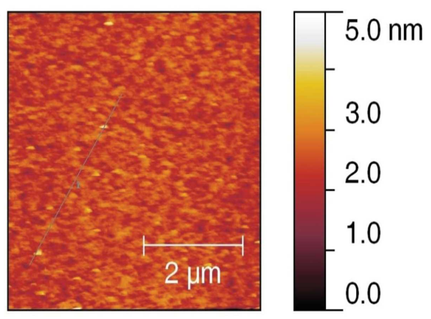
GaP/Si heterojunctions for photovoltaics

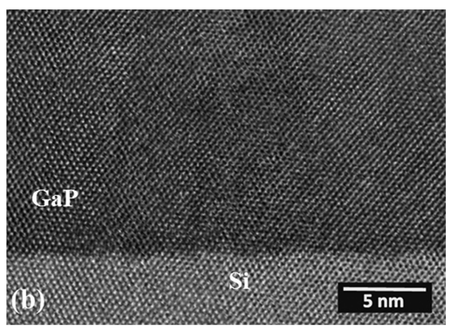
- *Tandem cells on silicon : high performance of multijunction solar cells on a classical photovoltaic substrate : silicon*
- *Epitaxial GaP layer as a transparent conductive layer on a single junction silicon solar cell to limit Si(n) absorption*
- *GaP(n)/Si(p) heterojunction to enhance V_{oc} and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

Optimizing GaP/Si interface

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



AFM : Weak roughness (RMS 0.3 nm)



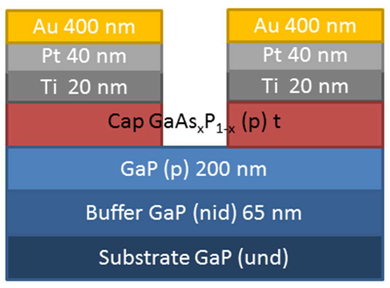
Cross-sectional HRSTEM image of GaP epilayer grown on Si substrate

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

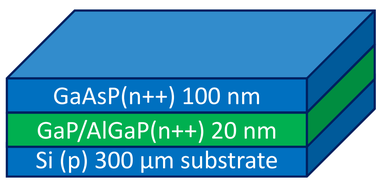


Direct p-type ohmic contact on GaP requires exotic metal : Pd/Zn/Pd

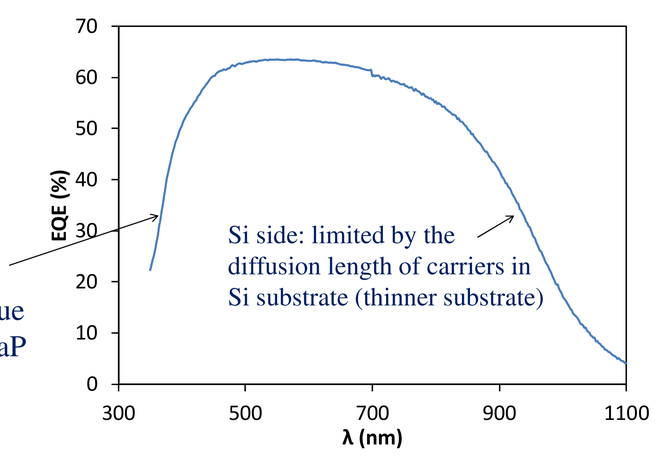
↳ **Supplementary epitaxial GaAsP allows to use Ti/Pt/Au**

20 nm $GaAs_{0,1}P_{0,9}$ heavily doped : N_a=3. 10^{19} cm^{-3}
Ohmic contact on GaP :
ρc = 4.10^{-6} Ω.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

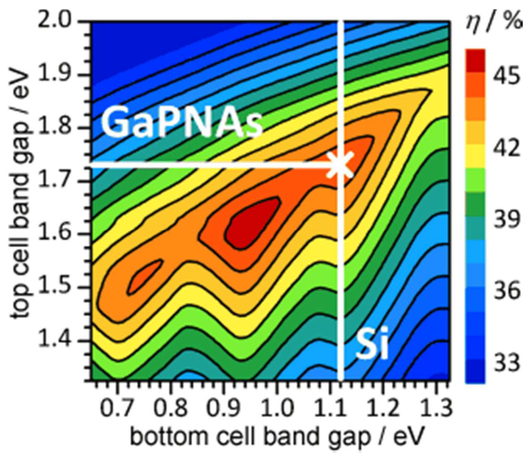


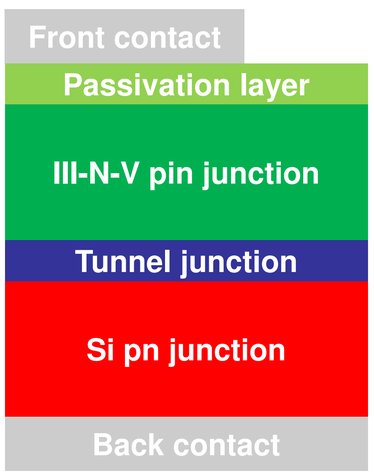
Poor electrical performances due to very bad contact on the Si side and carrier trapping at the doped GaP/Si interface : V_{OC}= 0,244 V, Efficiency : 0.45 %

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.

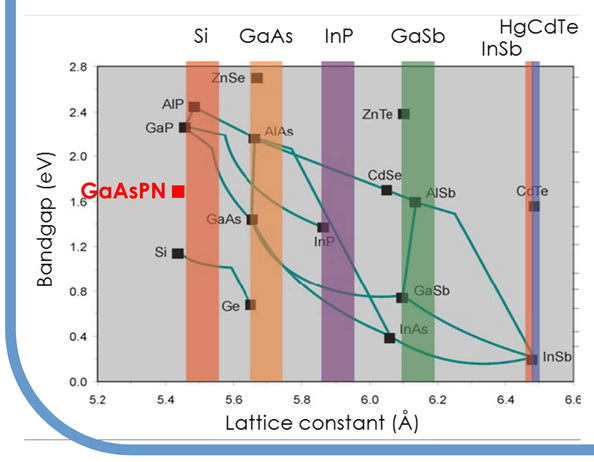
Further work :
- **optimizing Si contact and GaP/Si interface with dopants**
- **Using the GaP layer as transparent conductive layer on a Si homojunction**

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



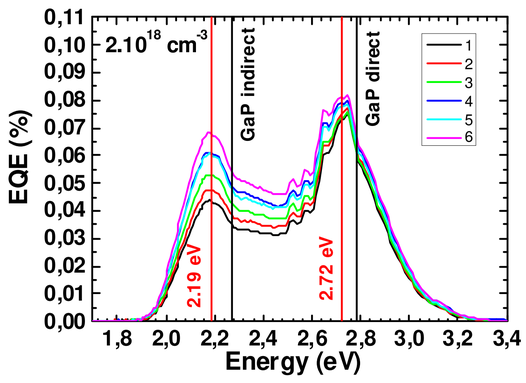
Main challenges:

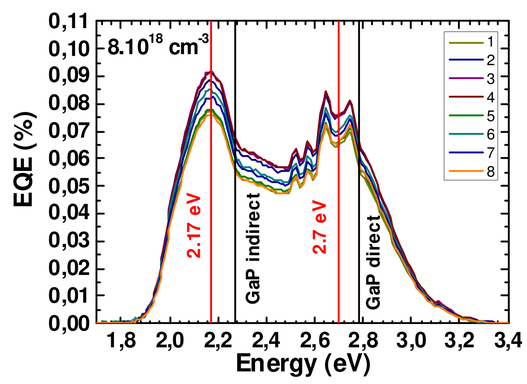
- **Ohmic contacts on GaP (n:Ni/Au/Ge and p:Ti/Pt/Au on GaAsP p++)**
- **Reducing the surface recombination velocity**
- **Improving optoelectronic properties of the III-V absorber**
- **III-V/Si interface (Si/GaP pseudo-substrate)**
- **Efficient tunnel junction between III-V and Si based materials**

GaP top cell optimization

Several studies already performed :
- **Absorber layer optimization : Tg = 480°C, V/III = 10-11, Gr = 0,5ML/s**
- **Low carrier mobility in GaAsPN: 300 nm-thick absorber**
- **Optimized composition : $GaAs_{0,1}P_{0.88}N_{0.02}$: pseudo-direct gap @ 1.7 eV, lattice matched to silicon**

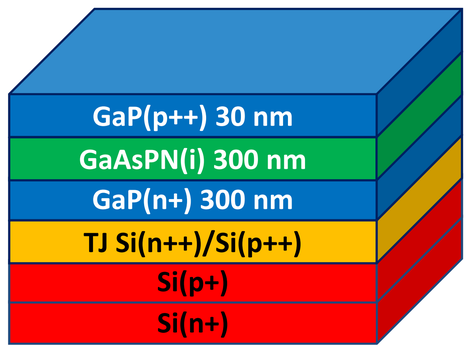
New study : optimization of the n-doped layer

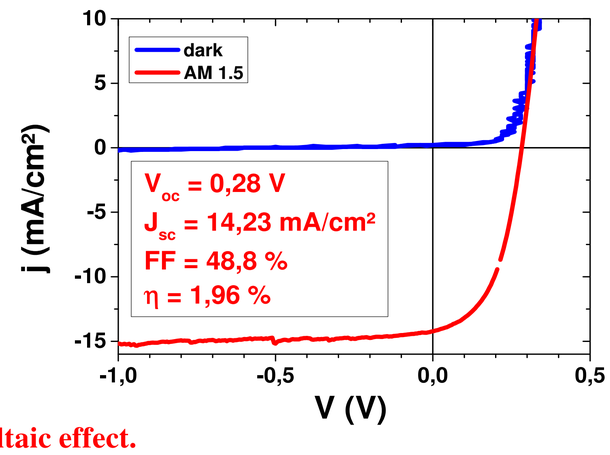




Low energy peak increases with n doping level: better current collection near the GaAsPN/GaP:n interface

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} ?