

n and p-doped Germanium grown by MOVPE for solar cell applications



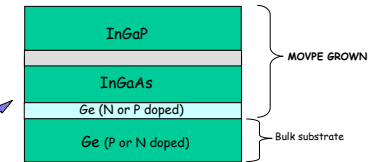
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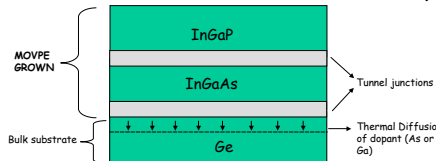
² Rohm and Haas Trading Europe Aps, 185 Rue de Bercy, 75012 Paris, France

Motivation: Extension of MOVPE growth also for the third junction in a InGaP/InGaAs/Ge solar cell

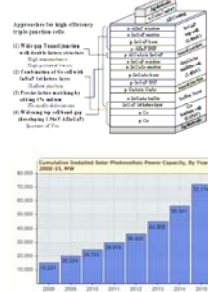
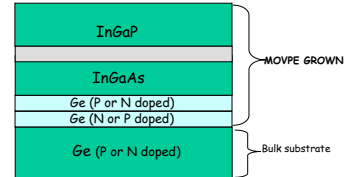
Triple junction realized by MOVPE



Triple junction: third junction obtained by diffusion



Third junction entirely realized by MOVPE



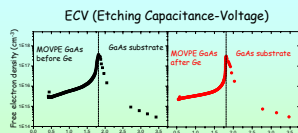
Growth Conditions

- Vertical chamber VEECO D 180; P= 70 Torr, H₂ flow 55000 sccm/min
- IsobutylGermanium source (from Rohm and Haas) around 1.5X10⁻² mBar
- P doping: TMGa, N doping: Arsine
- T growth between 550 and 710 °C
- Substrates: N and P doped Germanium (001) 6° off and SI GaAs 001

No memory effect of Germanium in the MOVPE chamber

The GaAs doping profile is the same before and after the use of Ge

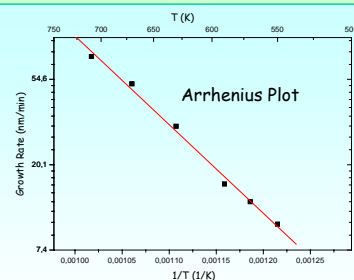
The background n doping is of the same order of magnitude



Vantages

- Well defined doping profiles
- Flexibility: modulation of doping and of the active zone
- Avoiding surface recombinations
- Possibility to form a Quadruple Junction solar cell

Increased V_{oc} and I_{sc} expected!



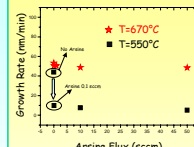
Growth rate vs T for p doped Ge

The growth rate increases at higher T

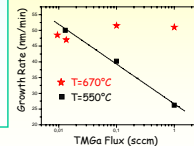
Activation energy of 20.6 kcal/mol

Growth temperature between 550 and 710°C

Role of Arsine and TMGa



At high Temperature:
- Growth Rate almost constant with Arsine and TMGa fluxes



At Low Temperature:
- Growth rate decreases already of 4 times at low AsH₃ fluxes
- Exponential decay of growth rate increasing TMGa flux

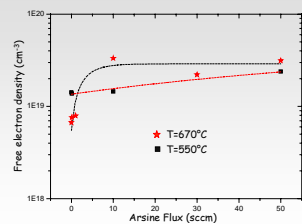
Morphology (AFM)

Arsine flattens the surface!

Intrinsic



From TMGa of 1sccm: pits on the surface!



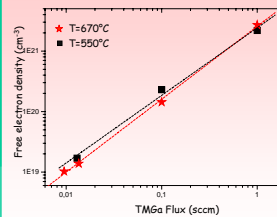
N doping

Study at different Temperatures

T = 670°C Doping Range: 6X10¹⁸-4X10¹⁹cm⁻³

Saturation at 4X10¹⁹cm⁻³

T = 550°C Doping almost constant, around 1X10¹⁹cm⁻³



P doping

Growing Exponential dependence - Free hole density/ TMGa flow for both Growth Temperature of 550°C and 670°C

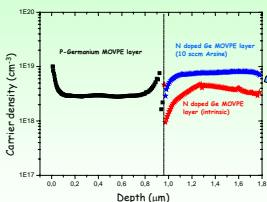
Doping range: 1X10¹⁹-2X10²¹cm⁻³

Doping profile of the entirely MOVPE grown PN junction

Quite Sharp and defined doping profiles

Limited diffusion effects

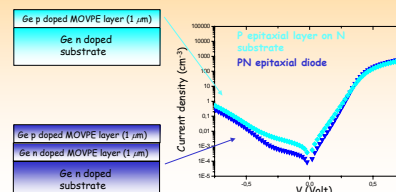
More Control of the doping profile by supplying Arsine



ECV (Etching Capacitance-Voltage) measurement

PN diodes: First results

Lower inverse current in the case of entirely MOVPE grown junctions



	Rectification Ratio (0.5V)	Rectification Ratio (0.25V)
PN entirely MOVPE	4510	670
P MOVPE-N bulk	1480	205

Conclusions

- Realization of P and N doped Germanium layers grown by MOVPE
- Control of the doping, growth rate and morphology at different growth temperatures and conditions
- Study of the role of Arsine and TMGa in controlling the doping profile and the surface quality
- First studies on PN Germanium junctions entirely grown by MOVPE and I-V characteristics

In the future... Optimization of Germanium Diodes and PN junction design for the integration in a complete solar cell structure

Acknowledgments

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- www.crunchgear.com
- Masafumi Yamaguchi, Tatsuya Takamoto, Kenji Araki, Nicholas Ekins-Daukens, Solar Energy 79 (2005) 78-85
- Green Chip Review » <http://www.greenchipstocks.com/>