Germanium-based virtual substrates for low cost III-V on Si tandem solar cell

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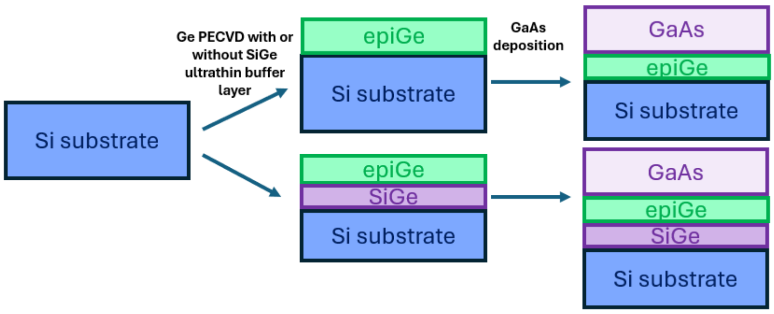
Efficiency records for single and multijunction solar cells rely on III-V materials such as GaAs. Nevertheless, single junction GaAs based solar cells are 200 times more expensive to produce than Si based solar cells.[1] This is mostly due to the cost of substrates used for GaAs deposition: GaAs and Ge. Therefore, replacing the usual substrates with a cheaper one could be a way to reduce the cost of those solar cells. Moreover, to have a tandem solar cell, it would be interesting for the substrate to act as a bottom cell. Silicon is a cheap material which can also act as a bottom cell for tandem devices. So, an attractive option is to use silicon as both a substrate for GaAs deposition and bottom cell for tandem device.

Nevertheless, the lattice mismatch between GaAs and Si ($\Delta a_{Si/Ge} = 4{,}0\%$) induces important strains and dislocations in the deposited GaAs. Dislocations are preferential areas for hole-electron pairs to recombine, resulting in a decrease of the solar cell efficiency. Therefore, direct growth of good quality, dislocation-free GaAs layer on Si is complicated. Some direct growths are made using gradient buffer layer, like GaInP/GaAs/Si with AlGaAsP gradient buffer layer. Nevertheless, the buffer layers is more than 2 µm thick, which leads to important material consumption and cost, interferences with optical properties such as absorption. Moreover, efficiency of this device is 25.9% under AM1.5g conditions, 14% less than III-V multijunction efficiency record under same conditions.[2]

For many years, PECVD deposition of Ge layers on Si has been studied at LPICM.[3] Latest results show Ge layers with low dislocation density: 5.10^{6} cm^{-2}.[4] In the light of these results, this project aims to develop direct growth of GaAs on a virtual substrate made of an ultrathin Ge layer deposited on Si.

To determine the deposition parameters of Ge on Si in a PECVD reactor leading to the best Ge quality, an analysis of impact of thickness, deposition temperature and substrate properties has been conducted. Moreover, the deposition of SiGe on Si has been studied for further implementation of a gradient SiGe layer in the virtual substrate. Finally, a technique to measure the TDD in Ge layer must be studied as it is a critical criterion to evaluate the layers quality.



1 M.A. Fazal & al, (2023), Progress of PV cell technology: Feasibility of building materials, cost, performance, and stability, *Solar Energy,* 258, https://doi.org/10.1016/j.solener.2023.04.066.

2 Feifel, M., Lackner, D., Schön, J., Ohlmann, J., Benick, J., Siefer, G., Predan, F., Hermle, M. and Dimroth, F. (2021), Epitaxial GaInP/GaAs/Si Triple-Junction Solar Cell with 25.9% AM1.5g Efficiency Enabled by Transparent Metamorphic $Al_xGa_{1-x}As_yP_{1-y}$ Step-Graded Buffer Structures. Sol. RRL, 5: 2000763. https://doi.org/10.1002/solr.202000763

3 Ghosh & al, (2022), Ultrathin Ge epilayers on Si produced by low-temperature PECVD acting as virtual substrates for III-V / c-Si tandem solar cells, *Solar Energy Materials and Solar Cells*, 236, https://doi.org/10.1016/j.solmat.2021.111535.

4 Romain Cariou, P. R. (2014). *Croissance épitaxiale de Si(Ge) sur Si et GaAs à basse température par PECVD, pour cellules solaires tandem*. Thèse de doctorat, Ecole polytechnique, Palaiseau. Retrieved from https://theses.fr/2014EPXX0065