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Building blocks development for defect-free growth of GaAs on silicon for tandem solar cells

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The monolithic integration on silicon of GaAs, and more generally of III-V semiconductors, is a very attractive and promising route for the production of high efficiencies multijunctions devices in the manner of those developed for space applications on germanium, but at a much lower cost suitable for terrestrial PV applications. The lattice parameter mismatch leading to threading dislocations is however the major problem that many approaches have tried to circumvent. But until now no one has succeeded in achieving defect-free and cost-effective direct integration of the simplest GaAs binary compound on silicon. In previous work, we have demonstrated the perfect integration on silicon of micrometric size GaAs crystals without any structural defects nor stress, using Epitaxal Lateral Overgrowth on Tunnel Oxide from nanoseeds (ELTOn) [1]. The GaAs array of micro-crystals, free of structural defects, is therefore a promising route to III-V on Si mulltijunction solar cells. However, in order to produce a PV device demonstrator of significant area around 1 cm^2, an important aim is now to extend this epitaxial method to surface patterning in order to integrate the crystals in a regular way to have a quasi-complete covering of the Si substrate, without coalescence of the GaAs microcrystals to maintain their very good electronic properties by avoiding detrimental grain boundaries. We achieved good initial results (Figs. 1 and 2) with a conventional technique based on E-beam lithography. However, as can be seen in Fig. 1, not all GaAs crystals are monocrystalline (e.g. the defective crystallite in the first column on the left). The reason has been identified and the route to improve this process or the use of an alternative more up-scalable technique will be presented. The purpose of this paper is then to present the building blocks we have developed for defect-free growth of GaAs on silicon for tandem solar cell applications. This will be addressed from the technological point of view as well as from design, modelling and characterization perspectives. Preliminary work has allowed the identification of critical technological bottlenecks, following which solution routes have been developed as will be presented and discussed. The resulting design for a GaAs/Si tandem solar cell, which can be further extended to triple junctions, will then be described.

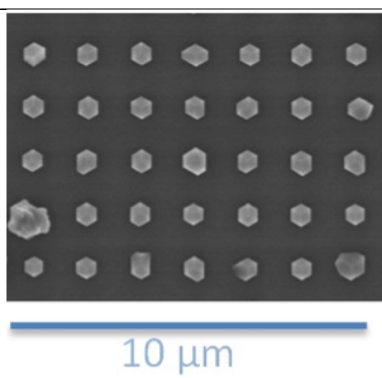

Fig. 1: Plan-view of a scanning electron microscopy (SEM) image of regularly patterned microscale GaAs crystallites on (111)Si.

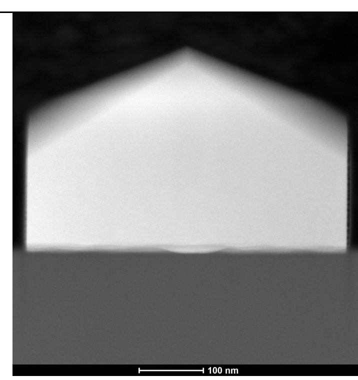

Fig. 2: Dark-field cross-sectional TEM images of the localised GaAs/(111)Si µ-crystal showing the perfect integration without any antiphase domains nor dislocations nor twins.

[1] Renard C., Molière T., Cherkashin N., Alvarez J., Vincent L., Jaffré A., Hallais G., Connolly J.P., Mencaraglia D. , Bouchier D., ***High current density GaAs/Si rectifying heterojunction by defect free Epitaxial Lateral overgrowth on Tunnel Oxide from nano-seed,*** Scientific Reports, vol. 6, p. 25328, 2016 (doi: 10.1038/srep25328), www.nature.com/articles/srep25328