Patterned growth of GaAs on Si using alternative lithography methods

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The integration of III-V semiconductors such as (Al)GaAs compound on silicon is of great interest for photovoltaic (PV) devices, notably for high-efficiency tandem solar cells. AlGaAs, with its direct bandgap is an ideal top cell candidate in a tandem junction AlGaAs/Si architecture. However, heteroepitaxy of (Al)GaAs on Si remains a major challenge due to the 4.1% lattice mismatch and the formation of anti-phase domains and dislocations, which degrade the electronic and optical quality of the material.

To overcome these limitations, we have developed the ELTOn method (Epitaxial Lateral overgrowth on Tunnel Oxide from nano-seed), which enables the defect-free integration of GaAs on Si through selective epitaxial growth from nanometric openings (< 90 nm) in an ultra-thin tunnel oxide layer (< 2 nm). This method yields strain-free, epitaxial GaAs microcrystals on Si, with excellent electrical connectivity via tunnelling through the oxide layer, offering promising perspectives for monolithic integration of III-V materials on Si in PV applications [1].

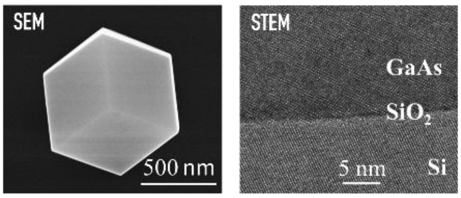

Figure 1: SEM image: GaAs /Si(111) grown via the ELTOn method; STEM image: Defect-free GaAs on ultrathin SiO_2/Si(111). [1]

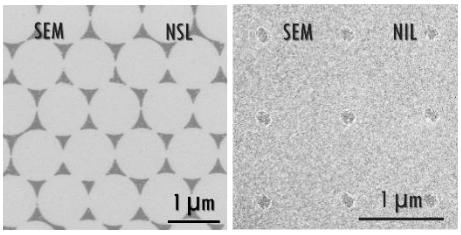

Figure 2: Ge pattern transfer via nanosphere lithography: NSL SEM image; via soft UV nanoimprint lithography: NIL SEM image.

To maximize photovoltaic efficiency, we aim to increase the active surface area by achieving the highest possible GaAs coverage on the silicon substrate. This requires moving toward a quasi-continuous GaAs layer, formed by ordered arrays of microcrystals grown over large areas, while preserving an ultra-thin interfacial silica layer. To this end, we are developing fast, low-cost, and scalable surface texturing methods using nanosphere lithography (NSL) [2] and soft UV nanoimprint lithography (NIL). These techniques enable precise pattern transfer onto the ultra-thin SiO_2 surface, preserving its integrity and allowing for localised, electrically connected crystal growth.

This work is a key step toward the demonstration of a monolithically integrated AlGaAs/Si tandem solar cell with a potential efficiency exceeding 30% [3], while maintaining compatibility with industrial, low-cost silicon substrates.

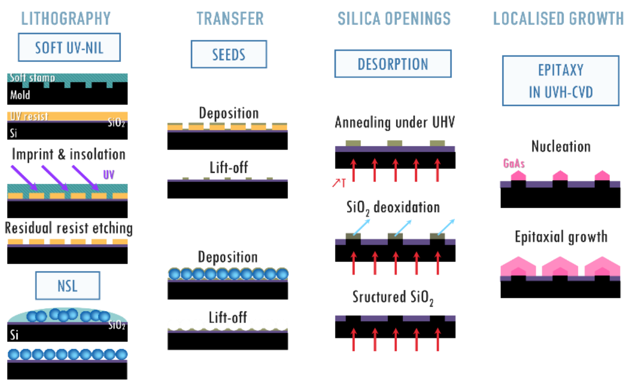

Figure 3: Illustration from lithography to growth

[1] C. Renard et al, Sci. Rep, 2016, 6, 25328. doi:10.1038/srep25328.
[2] D. Gogel et al, Journal of optoelec. and adv. materials, 2010, 12, 3
[3] J. P. Connolly et al, Progress in Photovoltaics, 2014, 22, 810