Towards high-quality GaInAsN(Sb) alloys for space multi-junction solar cells grown by Molecular Beam Epitaxy

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GaInAsN alloys are particularly interesting for lattice-matched multi-junction solar cells (MJSCs) for space applications. Owing to the alloy nature of this compound, one can select independently the bandgap of $GaIn_xAsN_y$ and its lattice constant. In high-efficiency multi-junction solar cells for space applications, it allows to increase the number of junctions from 3 to 4 ($GaInP_2$ - GaAs - GaInAsN - Ge) while choosing the added subcell bandgap to perfectly match Shockley-Quiesser's efficiency optimum and keeping the structure lattice-matched to GaAs, reaching up to 41% efficiency [1, 2].

However, reaching the targetted bandgap for GaInAsN alloys while staying lattice-matched requires to incorporate high amounts of Indium and Nitrogen altogether, which is compromised due to phase separation occuring at high growth temperatures. Fortunately, the growth temperature threshold above which phase seperation is observed can be moved to higher temperatures by using surfactant-mediated growth, as with antimony. On the other hand, if phase seperation is limited while working at low growth temperatures, point defect density is increased, which is very detrimental to solar cell performances: the growth temperature must be kept below a phase seperation threshold, but nevertheless high enough to prevent point defect formation [3].

In this work, we explore how simultaneously tailoring antimony surfactant effect and growth temperature in GaInAsN(Sb) is leading to improved optoelectronic properties. To do so, we perform joint structural (HRXRD, SEM) and electro-optical characterization (photoluminescence) on as-grown thick GaInAsN(Sb) epilayers. We then manufacture 1eV solar cells from these optimum growth conditions. We demonstrate high In and N incorporation in near-1eV GaInAsN lattice-matched to GaAs whithout causing significant phase seperation, and manage to improve the optoelectronic properties of our layers through cautious optimization of growth conditions, thanks to Sb-driven surfactant effect and $in-situ$ growth temperature control.

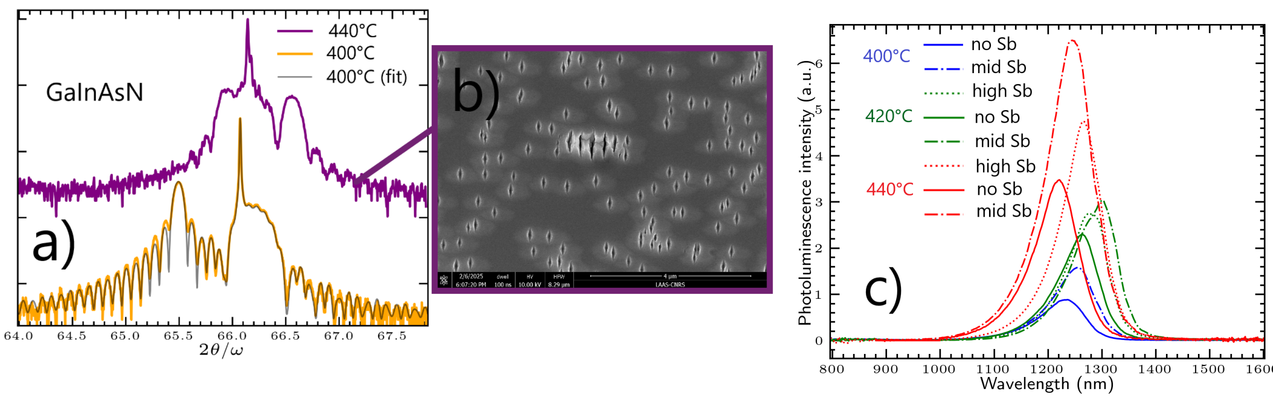

Figure 1: a) High-Resolution X-Ray 004 diffractogram of GaInAsN layers grown at 400°C and 440°C. The 440°C sample exhibits phase separation, as shown by (b), the SEM image of its surface. c) Photoluminescence spectra of as-grown GaInAsN(Sb) layers grown at different temperatures and Sb contents.

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