

MOVPE growth of GaAs-GaNAs core-shell nanowires for intermediate-band nanowire solar cells

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The use of intermediate band (IB) III-N-V semiconducting alloys (such as GaNAs or GaNP) within a free-standing III-V nanowire hetero-structure may lead to the fabrication of a novel type of highly efficient nanowire-based solar cells [1]. These cells exploit the super-absorptive properties of dense nanowire arrays (e.g. due to nano-antenna and light wave-guiding effects [2]) in combination with the multiple-band light absorption mechanism guaranteed by the IB materials [3]. Furthermore, implementation of a radial p-n junction within a core-(multi)shell nanowire would ensure sufficiently short photo-generated carrier transit lengths, thus overcoming the well-known reduced carrier diffusion lengths limiting the performance of planar III-N-V based solar cells [1].

III-N-V compounds are highly mismatched alloys, and their fabrication is very challenging. Effective N-doping (up to a few atomic percent) of III-V compounds requires growth conditions far from equilibrium: early growth experiments by MOVPE and MBE of planar III-N-V epilayers have shown that N incorporation in these materials is strongly sensitive to temperature, vapour conditions and substrate orientation [4]. Conditions for the growth of III-N-V based nanowires appears even more stringent and reports in the literature are mostly limited to MBE studies [1]. In particular, no attempts have been reported to date on the MOVPE growth of radially-modulated nanowires containing III-N-V alloys.


We report for the first time on the successful MOVPE growth of GaAs-GaNAs core-(multishell) nanowires using *tertiary-butyl-hydrazine*, as its relatively weak tertiarybutyl-N bond makes this molecule less stable with respect to commonly employed N-precursors. Trimethyl-gallium and tertiarybutyl-arsine were used as Ga and As precursors. Dense arrays of core GaAs nanowires were grown at 400°C on (111)B-GaAs substrates by the Au-catalyzed (VLS) method [5], and overgrown at 560°C by a GaNAs shell under different precursors V:III and N:As ratios in the vapor, and varying growth rates. N-incorporation within GaNAs shells was assessed through photoluminescence (PL) measurements and compared with incorporation values obtained by HRXRD measurements in GaNAs epilayers grown under the same growth conditions on (100)-, (111)B- and (110)-oriented GaAs wafers. The latter orientation relate to the sidewall orientation of the core GaAs nanowires over which GaNAs shells are overgrown. In all samples a near-IR (NIR) broad band could be observed, ascribed to the radiative emission from the E_c band gap of the GaNAs alloy. A N-content up to 0.8% was estimated for the GaNAs epilayers. For the nanowire samples the GaNAs emission bands show instead, an appreciable blue-shift, indicating a lower N-content of the GaNAs alloy (in the 0.3-0.16%). Noteworthy, the observed blue-shift of the GaNAs bands correlate well with the nanowire density observed by SEM at the same position where PL spectra were recorded. Present data are interpreted in terms of N-incorporation change with GaNAs shell growth rates, the latter estimated as function of the nanowire density based on a previously published shell growth model [6].

Keywords: MOVPE, nanowires, intermediate-band gap III-V semiconductors, photoluminescence, solar cells.

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