GaAsPN Single and Tandem Solar Cells on Silicon

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***Abstract* — The development of a III-V on silicon tandem cell is reported. GaAsPN material is considered for top cell absorber because of its quasi-lattice matching with silicon and its pseudo-direct bandgap at 1.7 eV. First, GaAsPN single cells are grown on both GaP and Si substrates, and their electrical performances are compared. It is found that the performances of the cell are limited by the low carrier mobility induced by the use of dilute nitrides. Then the first-stage development of a tandem photovoltaic solar cell is reported, including a tunnel junction (TJ) made of Si. This work was presented during the MBE 2016 poster session in Montpellier.**

Keywords—dilute nitride; tandem solar cell; III-V; silicon integration

Photovoltaic conversion records have been obtained with III-V multijunctions. However such cells suffer from the cost of III-V substrates. Therefore, our strategy is to develop a tandem cell on Si, in order to benefit from both the low cost and technological maturity of Si cells. Indeed, a tandem cell gathering a 1.7 eV bandgap material on a 1.1 eV Si cell would theoretically reach efficiencies up to 37%[1] . GaP is the material with the lowest lattice mismatch with silicon. Moreover N and As incorporation decreases the bandgap from 2.3 eV to the required 1.7 eV and satisfies the perfect lattice matching with Si, resulting in a GaAsPN quaternary pseudo-direct absorber[2].

First, we have studied the top cell grown on GaP. A first step growth conditions optimization has been investigated along with post-growth annealing parameters, which play a decisive role in the improvement of the optical properties of the GaAsPN absorber by reducing the point defect density induced by the large N incorporation in the alloy. This resulted in a PIN solar cell GaP(p)/GaAsPN(i)300 nm/GaP(n) displaying a 2.3% conversion efficiency, and with room for further optimization about growth, annealing and solar cell design.

Moreover, a PIN single cell has been grown on GaP/Si(001) platform with the same growth and annealing parameters. The current-voltage curve is shown in Fig.1 and compared to the one grown on GaP. One can notice the similarity between the short-circuit current of these cells (≈ 4 $mA.cm^{-2}$). Assuming that the divergences between the other parameters, especially the fill factor FF, are induced by parasitic resistive effects due to technological process and design discrepancies, the weak efficiencies seem to be more related to short diffusion lengths in the absorber than to structural defects originating from the III-V/Si hetero-epitaxy.

A GaAsPN/Si tandem cell is then grown. The GaAsPN is deposited by MBE on the top of a 13% efficiency Si solar cell grown by VPE. A TJ Si(n++)/Si(p++) with suitable doping levels and low resistivity is shown (Fig.2) and will be implemented in future III-V/Si tandem cells. This tandem cell allows the photovoltaic conversion, but with limited performances. This is attributed to the presence of anti-phase boundaries, which are threading in this case, and to the degradation of the carrier lifetimes in the silicon substrate due to the thermal treatments[3]. Optimization of the structure is in progress to enhance the structural interface quality on top of the Si/Si TJ.

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