InAs/GaAsN superlattice heterostructures for III-V multijunction solar cells

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Lattice matched (LM) GaInP/GaInAs/Ge triple-junction solar cells (SC) with a perfect crystalline quality are currently the main part of the mass production of high efficiency (>40 %) multujunction solar cells [1]. The efficiency of multijunction SC could be increased by inserting a fourth junction with a band gap of 1 eV between GaAs and Ge sub cells [2]. The most attractive material, which meets two main requirements for lattice constant match to GaAs and for band gap value is $Ga_{0.93}In_{0.07}N_{0.02}As_{0.98}$ quaternary alloy with low N and In content [3]. Recently a significant progress in properties of diluted nitrides has been achived using molecular beam epitaxy (MBE) for growth of InGaAsNSb based heterostructures. LM GaInP/GaAs/InGaAsNSb triple-junction SC has demonstrated a efficiency of 44% [4]. However growth of InGaAsNSb layer lead to incorporation of Sb into layers of top junctions. Sb, being an isovalent impurity creates recombination centres, which results in deterioration of the photovoltaic performance of top junctions. To avoid this negative impact of Sb the growth of top junctions should to be carried out in a separate chamber. Here we propose another way to improve the quality of GaInNAs 1 eV layer, being a usage of InAs/GaAsN superlattice (SL).

The p-i-n heterostructures with InAs/GaAsN SL i-layer inserted between p- and n- GaAs layers were grown by MBE on n-type GaAs substrates. The distance between the InAs layers was in the range of 6-11 nm. The thickness of the InAs thin layers was less than 0.5 nm in order to avoid the "quantum dots" formation on the epitaxial surface (Fig 1). A high structural quality of the grown GaInNAs layers was confirmed by X-ray diffraction measurements. The InAs/GaAsN heterostructures exhibit a strong peak of photoluminescence at 1200 nm at room temperature meaning the value of band gap to be equal to 1.03 eV.

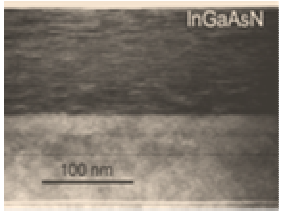

Fig. 1. TEM image of InAs/GaAsN SL cross section

The developed heterostructure exhibits external QE being more than 75% at zero reflection, which corresponds to the internal QE of 90%. A high value of the open circuit voltage over 0.4 V was also archived. These promising results for photovoltaic application were obtained because of minority carriers lifetime increase due to reduced defects density by eliminating the use of alloys containing indium and nitrogen at the same time, such as InGaAsN. Thus a new technological approach to fabrication of 1 eV III-V alloys lattice matched to GaAs demonstrating a high potential for use in multi-junction solar cells was developed.

References

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