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N-IBCELL

ENGINEERED GROUP III-N-(AS) ALLOYS AND LOW-DIMENSIONAL HETEROSTRUCTURES FOR HIGH EFFICIENCY INTERMEDIATE BAND SOLAR CELLS

RO14-0010, 2014-2017

The issues that this project attempts to address are long-range fundamental research issues that, if solved, will make it possible to leap-frog solar cells efficiencies from current peak values of 44.4 % to values above 50 %.

The project has several clearly defined but interconnected objectives such as:

Objective 1. The growth, treatment, and characterization of lattice-matched bandgap-engineered (x»3y) dilute-nitride (x≤1%) Ga1-xInxN-yAs1-y/GaAs alloys with significantly improved electrical and optical properties suitable for achieving high conversion efficiencies (ideally close to the theoretical values) when integrating in an intermediate band solar cell.

Objective 2. The design, growth, processing and characterization of IBSCs containing engineered GaInNAs/GaAs alloys showing significantly improved photocurrents with minimal drop in photovoltage.

Objective 3. The growth and characterization of device-quality BzInxGa1-x-zN/GaN alloys with dilute boron and low indium contents (z≤5%,x<20%) and strained engineered In(Ga)N/BInGaN/InGaN QDs array for IBSCs applications.

Objective 4. The design, growth, fabrication and characterization of intermediate band solar cells on GaN substrates containing bandgap and strained-engineered multiple-layers In(Ga)N/BInGaN/InGaN QDs with enhanced photocurrents and minimal photovoltage drop.

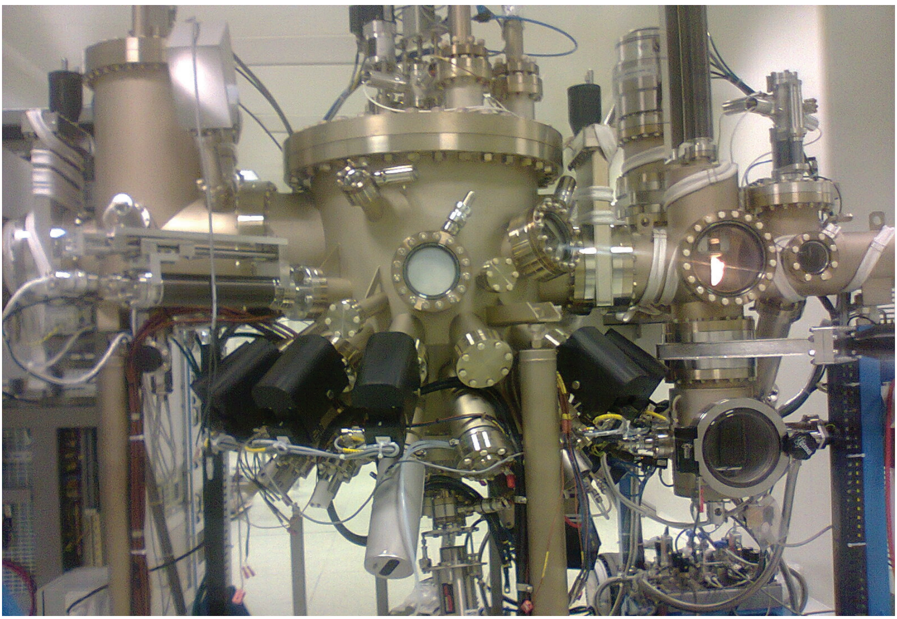
ENGINEERED GROUP III-N-(AS) ALLOYS AND LOW-DIMENSIONAL HETEROSTRUCTURES FOR HIGH EFFICIENCY INTERMEDIATE BAND SOLAR CELLS

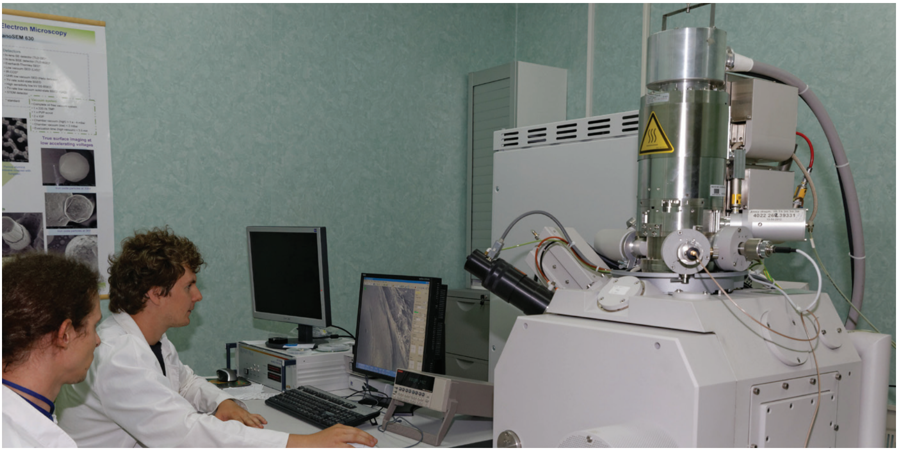
The project, N-IBCell, aims to fabricate high efficiency intermediate band solar cells (IBSCs). These are solar cells design to absorb also below bandgap energy photons by means of an electronic energy band that is located within the host semiconductor bandgap, producing thus enhanced photocurrent while ideally maintaining the photovoltage given by the host photovoltaic material bandgap.

GENERAL PRESENTATION

IBSCs have a theoretical efficiency limit of 63.2%, 50% higher than the limit for standard solar cells. Another advantage of such IBSCs is their simplicity, and hence their reduced production costs, as they require a single p-n junction only. The first IBSCs were fabricated only 10 years ago, and a few different approaches have so far been suggested and attempted. The most successful one relies on quantum dots (QDs) based on III-As semiconductors.

Promising results have been achieved, although the optimum materials have not been identified and realized yet. The realization of an ideal QD-IBSC requires a periodical three-dimensional (3D) superlattice of relatively small QDs with a narrow size distribution. A confined energy level of electrons in the QDs form the desired IB, and ideally only a single confined level exists. The most popular fabrication method is to take advantage of the spontaneous self-assembly of coherent 3D islands in lattice mismatched epitaxy known as Stranski-Krastanov (SK) growth.





An array of closely spaced QD layers will complete the 3D QD superlattice. The QD approach is the only so far demonstrating both the absorption of below bandgap photons and the photo-voltage preservation in IBSCs. However, the photo-generated current in QD-IBSC has been too small to lead to the expected high conversion efficiencies. This is mainly due accumulation of QD lattice-mismatch strain, which tends to degrade the QDs, increase their size inhomogeneity, reduce their surface density and limits the number of absorbing QD layers in the superlattice (to avoid misfit dislocations).

ESTIMATED RESULTS:

- Innovative technology for improving the transport and optical properties of lattice-matched dilute nitride quaternary GaInNAs/GaAs alloys (N≤1%) by electron irradiation and subsequent thermal annealing.
- Innovative technology for growth by MBE of high quality BInGaN/GaN epitaxial layers with dilute boron content up to 5% and indium content < 20%.
- Experimental and functional models of GaInNAs-based IBSCs with improved conversion efficiencies.
- Experimental and functional models of strain engineered In(Ga)N/BInGaN/GaN QDs intermediate band solar cells with improved conversion efficiencies.

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