French-Russian Workshop "Beyond silicon : heterojunction and multijunction solar cells"
Paris, France, December 2016

Quantum dots for III-V solar cells

R A Salii[1,2], S A Mintairov[1], M A Mintairov[1], and N A Kalyuzhnyy[1]
[1] Ioffe Institute, Russia, Polytechnicheskaya str. 26, 194021 St.-Petersburg
[2] E-mail: r.saliy@mail.ioffe.ru

Abstract. In this work the topical problem of development of quantum dot (QD) array growth technology by MOCVD has been investigated. GaAs solar cell nanoheterostructures with arrays of QDs were designed and obtained. Ones have been demonstrated a significant increase of photogenerated current due to photoeffect in array of InAs QDs (0.07 mA/cm^2 per a QD layer).

Introduction

Last twenty five years, solar cells (SC) based on cascade pseudomorphic GaInP/Ga(In)As/Ge heterostructures grown by metalorganic vapor-phase epitaxy (MOVPE) demonstrates high conversion efficiency of solar energy into electricity and are the most promising photovoltaic devices for industrial production [1]. However, there is a fundamental problem that restricts the possibility to achieve the efficiency of such SC to the theoretical limit. This is the current mismatch that appears between currents generated by sub-elements of the triple-junction SC structure, which is a consequence of non-optimal values of the forbidden gap of materials of which the structure consists. To preserve the advantages of pseudomorphic growth while solving the current mismatch issue of photogenerated currents, one can use GaInAs subcell with quantum-size objects - quantum dots (QDs). QDs do not affect the lattice parameter of the subcell matrix but expand its spectral sensitivity, improving total cell efficiency this way. In addition, using QDs in the SC structures can opens up the prospect of developing an intermidiate band SC (IBSC).

1. Modern trends in the development of multi-junction solar cells (MJSC)

The most popular fields in the development of multijunction solar cells were considered. Two approaches have been compared: lattice-matched and metamorphic SC. It was shown that the most promising approach, from the epitaxial growth and post-processing point of view is the introduction of QDs into the pseudomorphic structure of the MJSC.

2. Recent progress of the development of QD technology by MOVPE for SC in Ioffe institute

In this work the topical problem of development of QD array growth technology by MOVPE has been investigated. The technology is oriented to pseudomorphic GaInP/GaInAs/Ge multijunction solar cells. All epitaxial structures were obtained by MOCVD technique in Ioffe Physical-Technical Institute. The growth peculiarities in InAs-GaAs lattice-mismatched system were studied. The multimodal distribution of QDs by sizes was found using AFM, TEM and PL methods. GaAs solar cell nanoheterostructures with arrays of QDs were designed and obtained. Ones have been demonstrated a significant increase of photogenerated current due to photoeffect in array of InAs QDs (0.07 mA/cm^2 per one QDs array).

3. Perspective of QDs using for intermediate-band (IB) SCs and MJ SCs

It was shown that the InAs/GaAs QDs can noticable contribute to the spectral sensitivity, but are poor for the realization of MJSC curren balance. However, it was also demonstrated that InGaAs QDs allows to achieve reference value of SC efficiency at 20 QDs layers embedded in GaAs subcell of GaInP/GaAs/Ge MJSC which make such kind of QDs wery interesting for further investigations. In addition, it has been established that InAs/GaAs QDs are not effective for the realization of IBSC since this require for matrix material bandgap close to 1.91 eV [2].

The work has been supported by the Presidium of the Russian Academy of Sciences.

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