Journal of Alloys and Compounds 859 (2021) 157783

Contents lists available at ScienceDirect

Journal of Alloys and Compounds

journal homepage: http://www.elsevier.com/locate/jalcom

Optical properties of coherent InAs/InGaAs quantum dash-in-a-well for strong 2 μm emission enabled by ripening process

Rafael Jumar Chu [a, b], Dae-Hwan Ahn [a], Geunhwan Ryu [a], Won Jun Choi [a], Daehwan Jung [a, b, *]

[a] Center for Opto-electronic Materials and Devices, Korea Institute of Science and Technology, Seoul, 02792, South Korea
[b] Division of Nano and Information Technology, KIST School at University of Science and Technology, Seoul, 02792, South Korea

ARTICLE INFO

Article history:
Received 28 August 2020
Received in revised form
28 October 2020
Accepted 31 October 2020
Available online 4 November 2020

Keywords:
InAs quantum dot
Dash-in-a-well
Molecular beam epitaxy
Photoluminescence
Annealing
Infrared emission

ABSTRACT

We report molecular beam epitaxy of InAs quantum dash-in-a-well (DWELL) on InP for 2 μm wavelength emission using intentional ripening. By inserting the quantum dashes into a 10 nm InGaAs quantum well and employing 60 s of ripening, a ground state emission wavelength of 2 μm with an improved photoluminescence (PL) intensity and small linewidth of 67 meV was achieved. Morphological transformation towards taller and shorter nanostructures was observed for the optimized InAs/InGaAs DWELLs. Buried quantum dashes imaged by transmission electron microscopy were 26.7 nm wide in the [110] direction and 4.5 nm tall without misfit dislocations. Temperature-dependent PL measurement revealed no evidence of charge carrier trapping at low temperatures and yielded low thermal activation energies of 19 meV and 161 meV. InAs DWELL with enhanced optical properties enabled by ripening is promising for next-generation short-wavelength infrared lasers on InP.

1. Introduction

InAs quantum dots (QDs) grown via the strain-driven Stranski-Krastanov growth mode have been studied for decades to understand their novel optoelectronic properties and for their use as active materials for datacom and telecommunication light sources [1]. Due to the zero-dimensional structure and delta function-like density of states that these nanostructures possess, lasers employing QDs as gain materials were proposed and demonstrated to exhibit very low threshold current densities [2]. After years of research, InAs/GaAs QD-based lasers have eventually shown performance superior to their quantum well counterparts in terms of lower threshold current densities and lower reflection sensitivities, putting them at the forefront of materials engineering research for 1310 nm datacom applications [3–5]. InP-based QD or quantum dash (Qdash) lasers have also been investigated in the last two decades in an attempt to outperform the conventional InAlGaAs-based strained quantum well (QW) technology for 1550 nm telecommunication band applications [6,7]. Although InP-based Qdash lasers have yet to show lower threshold current densities than QW lasers, their application in other areas, such as for broadband gain lasers, continue to be investigated [8–10].

Recently, the use of the wavelength regime around 2 μm was proposed as a supplement to the existing architecture of low-loss optical communication bands [11], and novel materials that can cover this spectral regime have been studied. Coherently grown and strained InAs multi-QW lasers on InP were recently demonstrated to cover up to 2.4 μm [12]. Metamorphic buffers such as InAlAs or InGaAs on InP enabled an even longer lasing wavelength of 3 μm, reaching the shorter wavelength side where quantum cascade lasers can work very efficiently [13,14]. While these QW-based lasers have shown progress in performance beyond 2 μm, Qdash lasers still hold promise for novel applications that are made possible by its quasi zero-dimensional structure [15,16]. Some groups have demonstrated Qdash lasers with wavelengths towards 2 μm by adopting dash-in-a-well (DWELL) structures [17,18]. Growth of elongated InAs DWELLs by metal organic chemical vapor deposition has also been reported showing photoluminescence (PL) emission wavelengths up to 2.46 μm at 6 K and 2.35 μm at 77 K [19,20].

Ripening, through annealing or growth interruption, is a useful method for tuning the emission of InAs/InP Qdash materials to

* Corresponding author. Center for Opto-electronic Materials and Devices, Korea Institute of Science and Technology, Seoul, 02792, South Korea.
E-mail address: daehwan.jung@kist.re.kr (D. Jung).

https://doi.org/10.1016/j.jallcom.2020.157783
0925-8388/