InAlAs metamorphic buffer with digital alloy intermediate layers for InP-based 2-3 μm devices

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BIOGRAPHY
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TECHNICAL ABSTRACT

InP-based InGaAs photodetectors and lasers in near-infrared wavelength have been widely developed for fiber communication applications. By increasing the indium content in the InGaAs absorption layer of photodetectors or quantum well layer of lasers, the wavelength can be shifted to mid-infrared 2-3 μm range, which offers some advantages comparing with GaSb-based structures [1, 2]. However, a large lattice mismatch with respect to InP substrate is introduced. This problem can be partly overcome by constructing a virtual substrate on InP substrate, which is so-called “metamorphic buffer”. The main challenges of metamorphic buffer are the rough interface and high density of threading dislocations (TDs), while various dislocation restriction techniques have been implemented to reduce the TD density of metamorphic buffer [3]. In the past, digital alloy (DA) has been applied as an option for the growth of ternary or quaternary materials of various compositions by molecular beam epitaxy (MBE) without additional source cells or laborious growth interruption for cell temperature changes, and has been proved effective to decrease the strain energy and suppress the three-dimensional growth mode [4]. In this work, we incorporate InAs/In0.52Al0.48As DA layers with InP-based InxAl1-xAs graded metamorphic buffer, and the TD suppression effects of DA intermediate layers are reported.

Two samples with different InxAl1-xAs metamorphic buffer structures were grown on (100) oriented InP substrates in a V80H gas source MBE system. As shown in Fig. 1(a), the indium composition was continuously graded in the buffer of sample A, while two 100 nm InAs/In0.52Al0.48As DA intermediate layers were inserted in the graded buffer of sample B. Fig. 1(b) shows the cross-sectional transmission electron microscope (XTEM) bright-field images. The top-most portion of the buffer for sample B is free from dislocations, whereas several MDs can be observed in the identical portions for sample A. For sample B, the dislocation density in the graded buffer layer between DA intermediate layer I and II is also decreased, while some MDs still exist in the regions of DA layers. The decreased strain energy of DA layers in graded buffer can reduce the MD density as well as the MD interaction, and hence suppress the TDs in the metamorphic buffer. The 20×20 μm² root mean square roughness measured by atomic force microscope is 13.6 nm and 6.1 nm for sample A and B, respectively. Photoluminescence (PL) measurements were carried out to assess the optical properties of the In0.8Ga0.2As/In0.8Al0.2As quantum wells grown on those metamorphic buffers as shown in Fig. 2. The PL intensity of sample B is about twofold of sample A at both 300 K and 77 K. It means DA intermediate layers can dramatically improve the optical quality of metamorphic buffer and indicates a strong TD suppression effects. It shows great potential to apply DA intermediate layers in InP-based metamorphic buffers for the demonstration of 2-3 μm photodetectors and quantum well lasers.

References:

Keywords: metamorphic, digital alloy, InP-based, 2-3 μm

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Fig. 1. (a) Schematic design structure and; (b) XTEM images of the samples.

Fig. 2. PL spectra at 300 K and 77 K.