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Bismuth Particle Formation in Annealed Dilute $GaAs_{1-x-y}P_yBi_x$ Alloys

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$GaAs_{1-x}Bi_x$ is an attractive material for optoelectronic devices such as multi-junction solar cells because its bandgap varies strongly with Bi content by about 88 meV per atomic percent Bi [1]. Furthermore, with the addition of P to counterbalance the increase in lattice parameter due to the large Bi atoms, quaternary of $GaAs_{1-x-y}P_yBi_x$ with a wide range of bandgaps can be grown lattice-matched to GaAs substrate. Growth of high quality $GaAs_{1-x-y}P_yBi_x$ is difficult because Bi tends to segregate onto the surface of GaAs lattice at temperatures above 400 ºC [1]. Therefore, growth temperatures must be relatively low compared to standard GaAs growth by MBE or MOVPE and post-growth processes such as annealing must be employed to reduce the density of defects that are inherent to low temperature growth.

In this work, we study the effects of annealing on the optical and structural properties of MOVPE grown $GaAs_{1-x-y}P_yBi_x$ by steady-state photoluminescence (PL) and transmission electron microscopy (TEM). Low temperature growth between 380 ºC and 400 ºC was used to grow the following layers: GaAs, $GaAs_{1-y}P_y$, $GaAs_{1-x-y}P_yBi_x$, $GaAs_{1-y}P_y$, and GaAs. The $GaAs_{1-y}P_y$ layers serve as barrier layers and the compositions and layer thicknesses varied depending on the growth. Part of each as-grown sample was annealed at 800 ºC for 45 min.

TEM and elemental analysis by energy dispersive x-ray spectroscopy (EDXS) show that the as-grown sample contains ~3.5% of uniformly distributed Bi. However, after annealing 15$\pm$7 nm Bi-rich particles are observed in a GaAsP matrix that is devoid of measurable Bismuth. The Bi-rich particles are crystalline but not coherent with the surrounding lattice.

Steady-state PL measurements at 10K show five distinct peaks in the as-grown sample. After annealing, the PL intensity increases ~20 fold. Furthermore, the PL of the annealed sample contains one unique peak.

Additional information will be presented at the conference poster session [2].

References:

[1] T. Tiedje, E.C. Young, and A. Mascarenhas. Inter. J. of Nanotechnology. **5** (2008) p 963.
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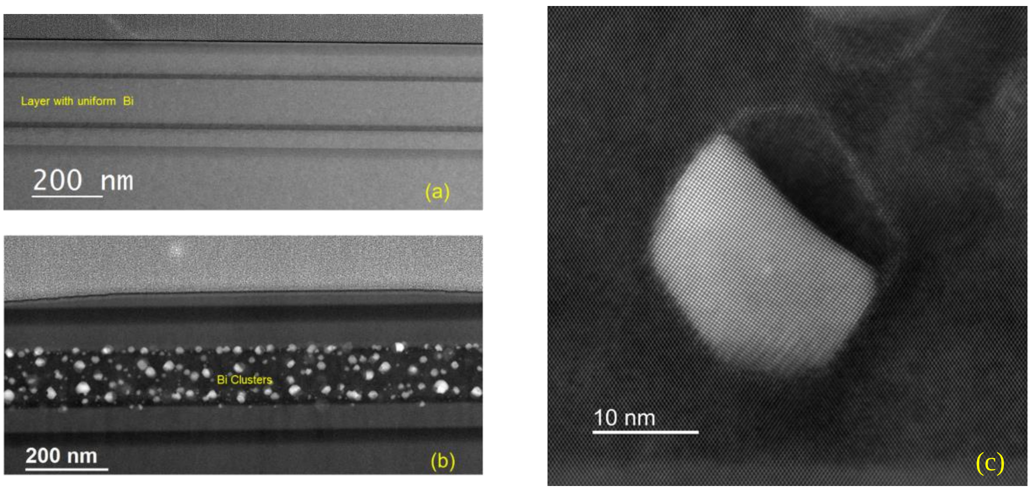

Figure 1. Z- contrast scanning transmission electron microscopy (STEM) image of the as-grown sample (a) and the annealed sample in (b). EDXS analysis (not shown) indicated that the as-grown sample contained uniform Bi in the layer marked in (a). Upon annealing there is a dramatic change in structure. Many Bi-rich clusters (as identified by EDXS of the sample in (b)) are present. (c) High resolution STEM image of one of the Bi-rich particles in (b) showing its crystalline nature.

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