Transmission Electron Microscopy Study of GaAs/AlGaAs Semiconductor QWIPstructures

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Quantum well infrared photodetectors (QWIPs) have been progressively improved for two decades with their potential applications in advanced optoelectronic devices [1]. QWIP technology based on mature GaAs/AlGaAs material system enables highly uniform, high quality, high impedance, fast response and low cost detector structures such as super lattices or multi-quantum wells in the third atmospheric window [1,2]. This study is aimed to characterize GaAs quantum wells and AlGaAs barriers. The sample used in this study was grown by molecular beam epitaxy (MBE) on (100) GaAs substrate. The asymmetric multi-quantum well structure involved 10 period repeated layers of GaAs three-QW units. Each unit consists of 45A$^{\circ}$, 55A$^{\circ}$ and 65A$^{\circ}$ GaAs quantum wells separated by 400A$^{\circ}$ $Al_xGa_{1-x}As$ barriers with Al concentrations of 0.33, 0.27, 0.24 and 0.20 respectively. Each unit is separated by 500A$^{\circ}$ GaAs layer with the doping concentration of 1×10^{18} cm^{-3} and barriers are undoped. The whole period is sandwiched between 1.5 µm and 1.0 µm GaAs (1×10^{18} cm^{-3} Si doping) contact layers. For transmission electron microscopy (TEM) studies samples were prepared by using focused ion beam (FEI-Nova 600 NanoLab DualBeam) lift out method and examined at 200 kV field emission TEM (Jeol 2100F) attached with an energy filter (Gatan GIF Tridiem), electron energy loss spectrometer (EELS), a high angle annular dark field scanning transmission electron microscope (STEM-HAADF) detector and an energy dispersive x-ray (EDX) spectrometer. The general microstructure of semiconductor epilayers was found to be grown layer-by-layer with different thicknesses (Figure 1). Moreover, the qualitative composition of each layer in GaAs/AlGaAs systems was identified with STEM-EDX point and line scan analysis (Figure 2a-b). Due to the peaks which are closer to each other, quantification results were not observed as expected. For this reason, Ga-$L_{3,2}$ with As-$L_{3,2}$ and As-L_1 with Al-K peaks were separated and the relative concentration of each layer was determined with STEM spectrum imaging-electron energy loss spectroscopy (STEM-SI-EELS) quantitative elemental line scan analysis (Figure 3). As observed from STEM-SI-EELS results, the concentration of Al increases abruptly in the AlGaAs region where Ga decreases. Besides, in the GaAs quantum well region it is observed that Al concentration decreases where Ga concentration increases, as expected. As a conclusion; GaAs quantum wells and AlGaAs barriers were identified separately in terms of relative concentration of Ga and Al by using transmission electron microscopy techniques successfully.

References
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[2] Adachi, Sadao, Properties of Aluminum Gallium Arsenide, Gunma University, JAPAN, 1993
[3] Authors would like to thank The Scientific and Technological Research Council of Turkey for funding the present work under a contract number of 107T012 and National Nanotechnology Research Center (UNAM) for FIB specimen preparation.

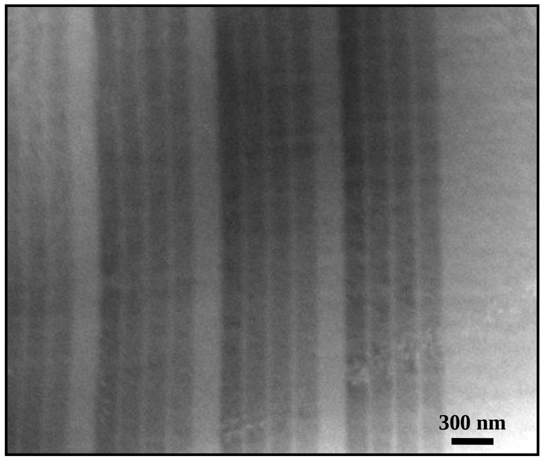
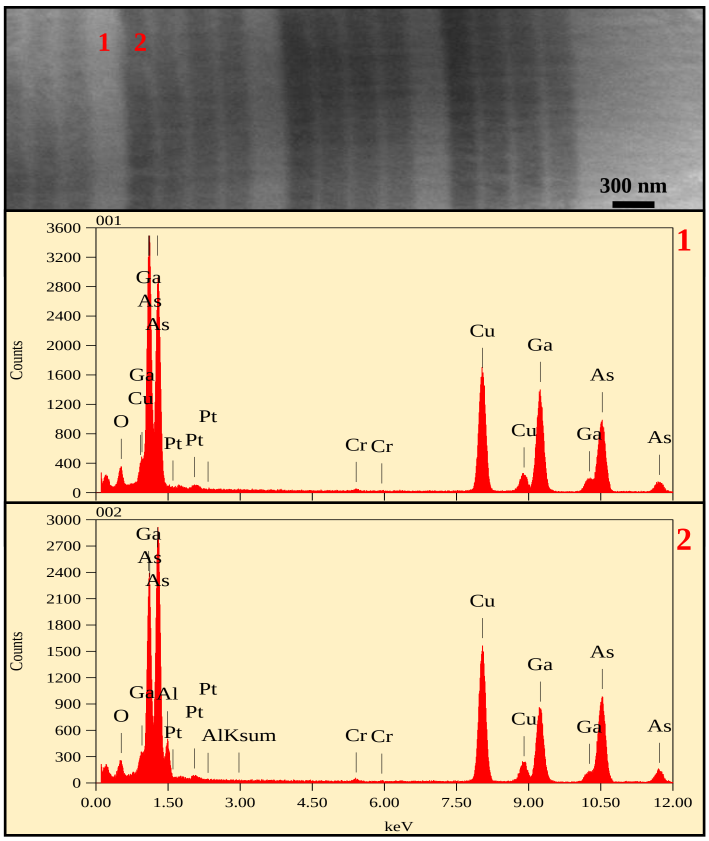
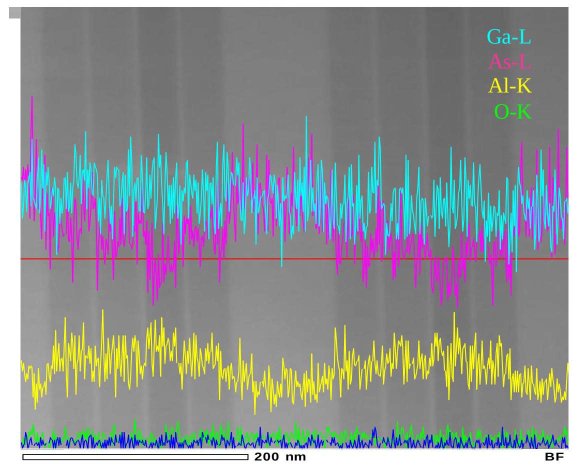


Figure 1 STEM-HAADF image showing the microstructure of AlGaAs/GaAs QWIPstructures.



(a)



(b)

Figure 2 (a)STEM-EDX point analysis of GaAs/AlGaAs QWIP structures **(b)** STEM-EDX Line Scan Analysis of GaAs/AlGaAs QWIP structures.The line scan analysis was taken at 10 msec. dwell time.

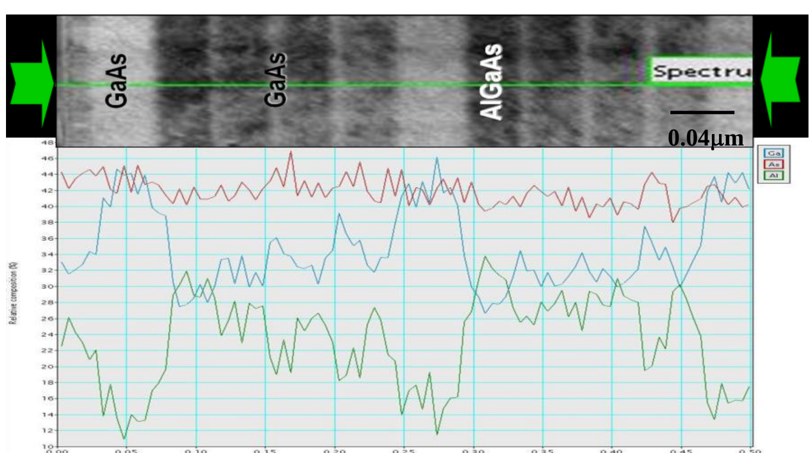


Figure 3 The EELS line scan quantification profiles of Ga-L3,2, As-L3,2 and Al-K edges obtained from the STEM-SI data. Please note that green arrows show where spectrum imaging was recorded from.