A Report on the Initial Growth of GaAs and AlGaAs via Molecular Beam Epitaxy

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INTRODUCTION

Molecular beam epitaxy (MBE) is a deposition process that uses the evaporation method. It provides precise control of growth rates, doping, and mole-fraction profiles. In principle, the growth rates and doping levels are controlled by adjusting the molecular fluxes relative to the Gallium flux. In this paper, we would like to present the initial results of the growth runs carried out. We have successfully grown GaAs and AlGaAs of various thicknesses and doping concentrations. Doped and undoped layers of AlGaAs were also deposited using different mole-fractions of Al.

The deposited samples were characterized via X-Ray Diffraction (XRD) in order to determine the mole-fraction of AlGaAs and the layer thicknesses were measured using Scanning Electron Microscopy (SEM). The doping concentrations were measured using a Hall Effect Setup. A Photo-Luminescence (PL) experiment was also carried out to confirm the XRD peaks used to calculate the mole fraction of AlGaAs.

The growth rate of GaAs for the Ga flux of 2.99×10^{-7} and As flux of 7.50×10^{-6} was found to be about 1.0 micron per hour from the thickness measurements on SEM as shown in Fig. 1. An overpressure of As of about 20-25 times the Ga flux is needed to grow a good GaAs layer. The lower limit for the As flux was found to be 2.2×10^{-6} via observation of RHEED patterns taken in-situ. The fluxes of Al and growth rates of the AlGaAs for different mole-fraction (x) were computed using equation (1) and (2), respectively.

$$\text{Flux Al} = \text{Flux Ga} \times \left(\frac{x}{1-x}\right) \times \left(\frac{0.92}{1.68}\right) \times \text{geometric factor} \quad (1)$$

$$\text{Growth Rate AlGaAs} = \text{Growth rate GaAs} \times \left(\frac{1}{1-x}\right) \quad (2)$$

Doping levels of Si (n-type) 1.17×10^{18} cm^{-3} and $3.6 \times 10^{16} cm^{-3}$ of (p-type) Be doped GaAs was also achieved on separate samples.

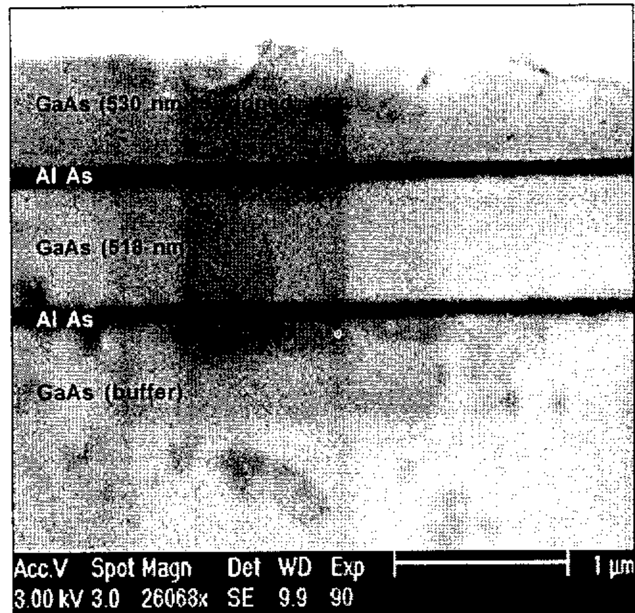

Fig. 1. SEM image of the interfaces of Sample L001. The topmost layer is Si-doped and grown for 32 minutes and layers of AlAs were grown to provide contrast. The GaAs middle layer was grown for 31 minutes

As a representative of the layers grown, we are presenting the SEM image (Fig. 2), XRD peaks (Fig. 3) and Photoluminescence spectrum (Fig. 4) of sample L011. Sample L011 has a doping concentration of 1.2×10^{17} cm^{-3}. The thickness of the grown layers were used to compute for the growth rates of Si-doped $Al_xGa_{1-x}As$ at the mole fraction of x=0.30 and 0.15. A thin layer of Si-doped GaAs cap layer was deposited to prevent possible oxidation of the Al. Further to distinguish the two layers of AlGaAs;Si an intermediate layer of Si doped AlAs was deposited to provide a demarcation line in the SEM image. The layer after the AlAs;Si is AlGaAs with mole fraction of x=0.15.

The XRD peak can only resolve the AlGaAs; x=0.30 peak since the (x=0.15) peak could practically be embedded in the GaAs (substrate) peak. But the PL spectra was able to confirm the presence of the x=0.18 and the x=0.367 mole fraction of AlGaAs layers.

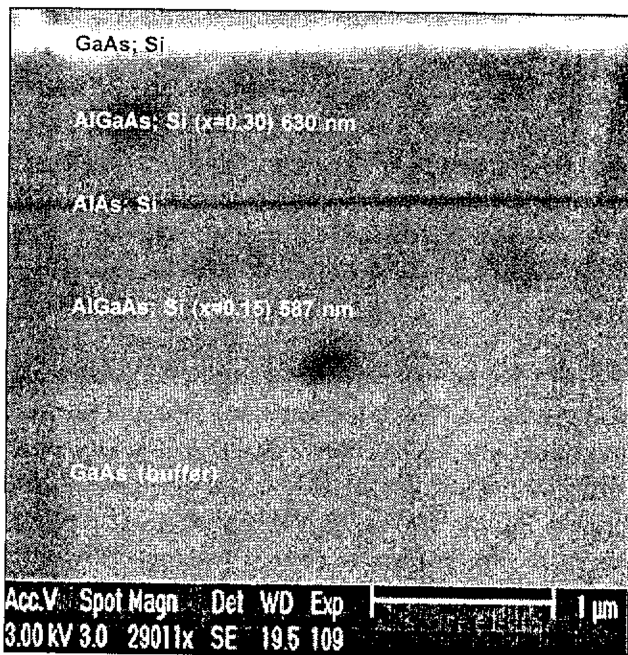

Fig. 2. SEM image of the interfaces of Sample L011. Thw white top layer is a Si doped GaAs cap layer to prevent oxidation. The second layer is AlGaAs;Si of x=0.30. The dark stripe is AlAs;Si. The last layer is AlGaAs;Si of x=0.15

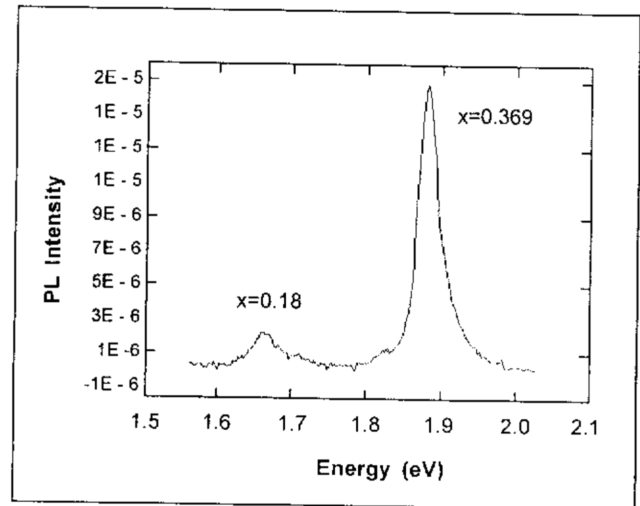

Fig. 3 Photoluminescence spectrum of $Al_xGa_{1-x}As$ showing the energies of the x=0.18 and x=0.36 layers

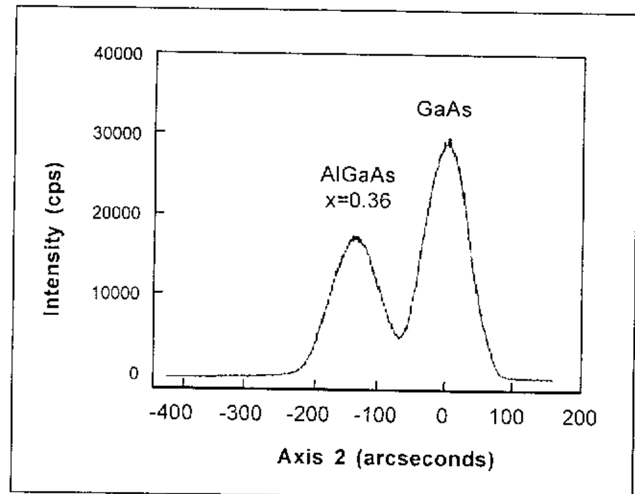

Fig. 4 XRD plot of $Al_xGa_{1-x}As$ layers grown by MBE showing the x=0.36 peak and the x=0.15 peak probably embedded in the GaAs 004 peak

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