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Study of p-type AlGaAs film grown on sapphire substrate using GaAs buffer layer

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ABSTRACT

The characteristics of AlGaAs films grown directly on a lattice-mismatched Al_2O_3 substrate were investigated. Metal organic chemical vapor deposition based AlGaAs films were grown on a transparent Al_2O_3 substrate, using a GaAs film as the buffer layer for the post-growth of the AlGaAs film. It was found that a higher Al composition in AlGaAs film on the Al_2O_3 substrate was observed when GaAs buffer layer was thermally treated. Notably, a resistivity of 0.018 Ω/cm was obtained from the AlGaAs film grown on the Al_2O_3 substrate, almost equivalent to that for GaAs substrate. These results thus support the position that AlGaAs films grown on a transparent Al_2O_3 substrate can be attractive for use in solar cells or light-emitting diodes.

1. Introduction

AlGaAs materials are widely known to be suitable for optical devices such as solar cell, laser diodes, and light emitting diodes because of their higher mobility and direct band-gap structure [1–4]. Over the past several decades, the efficiency of optical devices based on AlGaAs materials has been significantly improved using progressive growth systems and then applying further effective structures [5,6]. However, although numerous works have reported optical devices having a high efficiency, certain intrinsic limitations still exist that considerably decrease their overall efficiency. Specifically, it was shown that the efficiency of optical devices was markedly decreased when using an absorbing GaAs substrate [7], though this type of substrate has been deemed necessary for fabricating optical devices based on an AlGaAs material because the GaAs is typically lattice-matched with AlGaAs.

Some studies have shown that the efficiency of optical devices could be increased by inserting a distribution Bragg reflector (DBR), consisting of AlAs and $Al_{0.5}GaAs$, between the device structure and absorbing substrate [8]. Elsewhere, AlGaAs having a rough 150 μm thickness was used as the transparent substrate in order to fabricate optical devices with higher efficiency [9]. At present, improving this efficiency has been the main focus of many researchers, in attempts to replace the absorbing substrate with a transparent substrate through a post-wafer bonding process [10]. However, current methods remain inefficient because lower yields and additional process cost are incurred.

In this work, we directly grow AlGaAs films on a transparent Al_2O_3 (sapphire) substrate using a metal organic chemical vapor deposition (MOCVD) system. It is found that a higher Al composition could be obtained from the fabricated AlGaAs film by using a GaAs buffer layer annealed at a low temperature. In addition, relatively improved resistivity was observed for the AlGaAs film on the Al_2O_3 substrate, as compared to that for absorbing GaAs substrate.

2. Experimental

The AlGaAs films were grown on an n-type Al_2O_3 C-plane (1 1 1 1) substrate at a 0.2° tilt toward [*M*-Axis] ± 0.1°, [*A*-Axis] ± 0.15° using a MOCVD system. Here, trimethylgallium (TMGa) and trimethylaluminum (TMAl) were used as the group III sources, arsine (AsH_3) was used as the group V sources, and bis(cyclopentadienyl)magnesium (CP2Mg) were used as the p-doping sources. Hydrogen (H_2) was used as the carrier gas for all sources.

First, the ~0.2 μm thick GaAs film used as the buffer layer was grown on an Al_2O_3 substrate at 650 °C for 5 min using MOCVD. The V/III growth ratio for the GaAs layer was 52. For comparative purposes, some buffer layers were thermal-treated in-situ at low a temperature of 550 °C for 10 min under H_2 and AsH_3 ambients. In this work, the GaAs layers were described as having either an

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initial GaAs layer or annealed GaAs layer, respectively, according to when the thermal-treatment was applied.

Then, an AlGaAs film having Al fraction of 0.2 was grown in-situ on both the initial and annealed GaAs films at a temperature of 650 °C for 10 min. The Al composition (x) in the grown $Al_xGa_{1-x}As$ layer was 0.4. The V/III ratio for the AlGaAs films was 30. During growth of GaAs and AlGaAs layers, operating pressure was maintained to 50 mbar.

Generally, the GaAs used as buffer layer was known to be opaque material for wavelengths ranging from 300 nm to 1000 nm. However, it was noticed that transmittance of the GaAs material was increased with decreasing its thickness. Some group

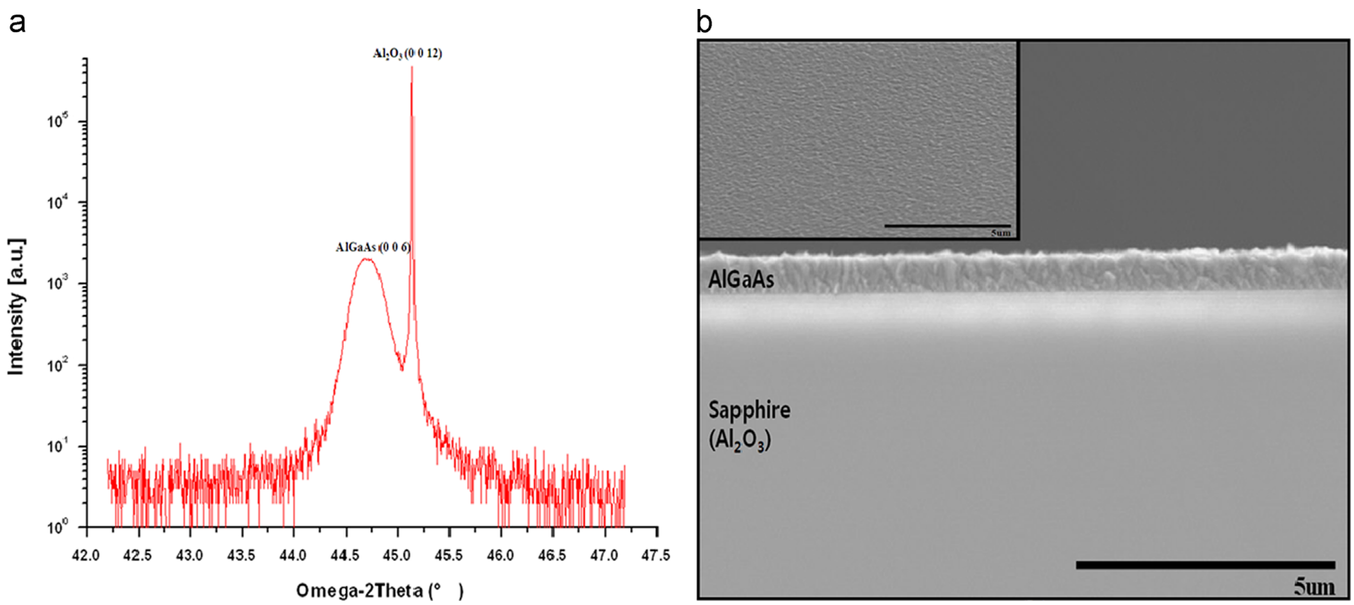

Fig. 1. (a) XRD analysis and (b) SEM image for AlGaAs film grown on transparent Al_2O_3 substrate. Inset (b) shows SEM image of its surface.

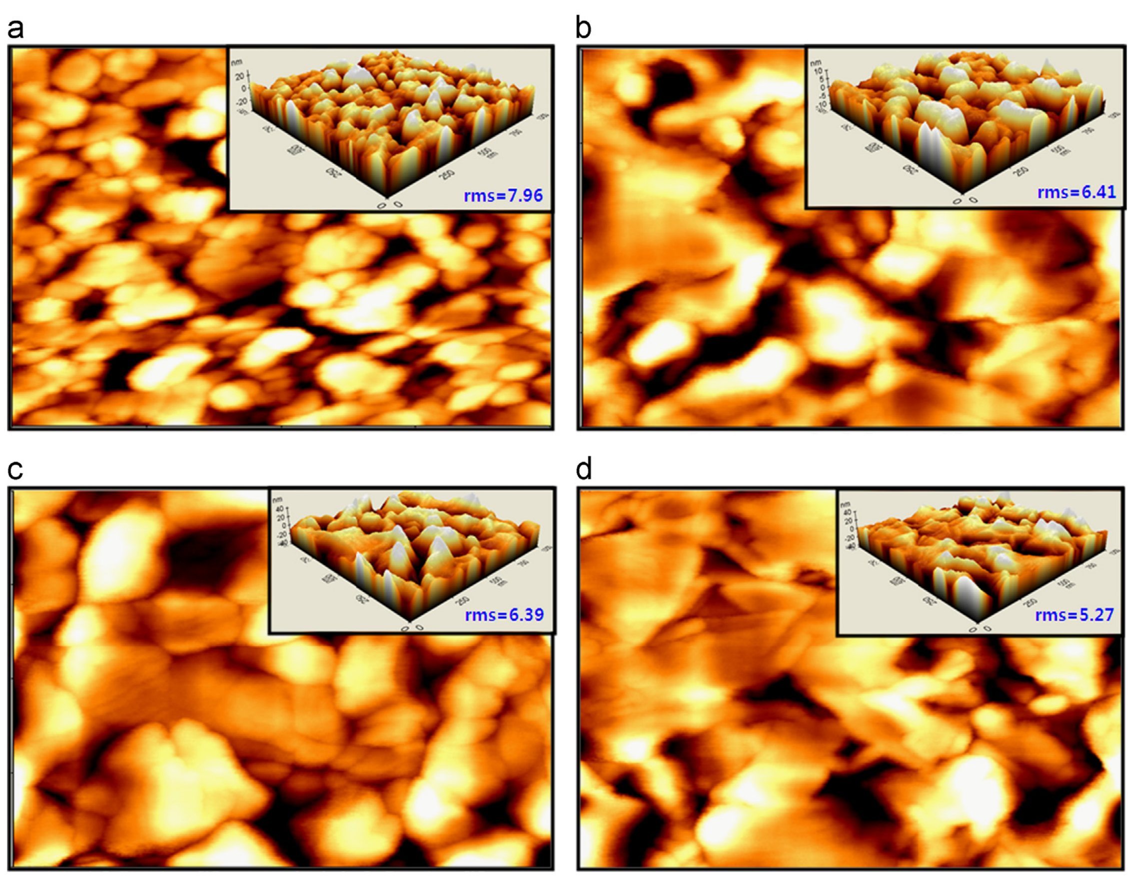

Fig. 2. AFM images for (a) initial GaAs film, (b) annealed GaAs film, (c) AlGaAs film on initial GaAs film, and (d) AlGaAs film on annealed GaAs film; grown on transparent Al_2O_3 substrate.