Optical and structural properties of GaAs highly doped with carbon

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Abstract: - This work presents the characterization of p-type GaAs layers highly doped with carbon grown in a metallic-arsenic-based-MOCVD system. The gallium precursor was the compound trimethylgallium (TMG) and elemental arsenic as precursor of arsenic, respectively. The influence of the doping in the optical and structural properties of the GaAs layers has been studied by photoluminescence (PL) and Raman dispersion measurements, Hall effect and High resolution X-ray diffraction (HRXRD). In order to dope with carbon in the range of 10^{16} to 10^{20} cm^{-3}, it was necessary to modify the activity of hydrogen in the growth atmosphere with the control of a mixture H_2+N_2, which was used like carrying gas. The PL and Raman scattering responses of the samples are strongly dependence of the growth temperature, which were investigated based on the hole concentration. Device quality GaAs layers have been grown in a broad range of growth temperatures.

Key-Words: - Semiconductor compounds III-V, MOCVD, Gallium arsenide, photoluminescence, Raman scattering.

1 Introduction

Recently, the investigation of AlGaAs/GaAs heterojunctions bipolar transistors (HBTs) has accelerated from the viewpoint of high speed digital and analog circuits applications. However, unstable behavior of conventional base dopants such as Be and Zn in operating devices, has introduced serious problems for practical devices applications [1]. For further improvements of in the HBTs reliability, it is necessary to develop a growth technique of GaAs epilayers in the high doping range with stable dopants. Carbon (C) is a successful alternative base dopant because of its very low diffusion coefficient in GaAs. We have investigated the carbon-doping technique in GaAs and AlGaAs by metal organic chemical vapor deposition (MOCVD) using trimethylgallium (TMG) and elemental arsenic hole concentrations is high as 2×10^{20} and 10^{21} cm^{-3} have been achieved in the case of GaAs and AlGaAs, respectively. These concentrations are necessary for the high frequency performance in the devices as HBTs, in order to decrease the base resistance, i. e., to reduce the resistivity in the base layer.

2 Experimental details

The GaAs epilayers were grown in an MOCVD system at atmospheric pressure, its characteristics has been reported in the literature [2]. The growth temperature is obtained by a system consist of 4 halogen lights of 500 Watts and a temperature controller of the type PID. The hydrogen, which is the carrier gas, is purified in situ by diffusion through of a Palladium-Silver (Ag-Pd) cell. The substrates were (100) GaAs semi-insulating doped with chromium, or of n-type conductivity doped with silicon. Previous to growth process, the GaAs substrates were prepared using a normal process of cleanliness. The precursor of gallium was trimethylgallium (TMG), as the arsenic source used metallic arsenic of 7N was used. It was explored the range of growth temperatures (T_G) from 620 to 780°C. For the electrical characterization the Hall-van der Pauw method at 77 and 300 K was used. For the photoluminescence measurements (PL) a double grating monochromator, SPEX model 1406, and a PAR 124 lock-in amplifier, were used. As exciting source used a He-Ar laser (λ = 488 nm) with 20 mW nominal power. The PL measurements at 10 K were made with a closed cycle of He cryostat.

Raman scattering experiments were performed at room temperature using the 5145 Å line of an Ar-ion laser at normal incidence for excitation. The laser light was introduced into a microscope having a 50x (numerical aperture 0.9) microscope objective. The measurements were done with a laser power of 20 mW. Care was exercised not to heat the sample inadvertently to the point of changing its Raman spectrum. Scattered light was analyzed using a Jobin-