

Investigation of DX Centers in Modulation-Doped Field-Effect Transistor-Type $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}/\text{GaAs}$ Heterostructures Using a Fourier-Transform Deep Level Transient Spectroscopy System

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$\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}/\text{Si}/\text{GaAs}$ modulation-doped field-effect transistor-type heterostructures were grown using two different growth temperatures (500 and 620°C) and three doping modes (δ -doping, pulse-doping, and uniform-doping). Deep level transient spectroscopy (DLTS) measurements were performed on these structures using a new Fourier-analysis method. Up to four DLTS peaks, related to the different possible configurations of the nearest Al and Ga neighbors around each DX site, were observed. Both the growth temperature and the doping-mode are found to affect the DLTS spectra, in particular the number of observed peaks and their width. These results are interpreted in terms of the different mobilities of the Si doping atoms on the surface during growth.

Key words: $\text{AlGaAs}/\text{GaAs}$, deep level transient spectroscopy (DLTS), DX center, molecular beam epitaxy, modulation-doped field-effect transistor (MODFET), planar doping

INTRODUCTION

The performances of modulation-doped field-effect transistor (MODFET) devices grown in the $\text{Al}_x\text{Ga}_{1-x}\text{As}/\text{Si}/\text{GaAs}$ system with Al concentration above 22% are limited by the presence of the DX centers in the AlGaAs doped layer. This center was shown to be a metastable state of the shallow dopant.^{1,2} One of its peculiar features is the nonexponentiality of its emission transient, which was particularly noticed in the deep level transient spectroscopy (DLTS) measurements. The generally accepted model for this defect is the one proposed by Chadi and Chang,^{1,2} the so-called negative U-center model. According to recent developments by Morgan^{3,4} and Mooney et al.,^{5,6} it appears that the DX center is a state of the substitutional donor which has moved in an intermediate position between the substitutional and the interstitial one, or which has exchanged sites with an As atom. In both models, the Si atom is therefore sur-

rounded by three nearest group III atoms to which it is particularly related. In GaAs there is only one possible configuration around the DX site, and only one peak should be resolved in the DLTS signal, as confirmed by experiment.⁶ In $\text{Al}_x\text{Ga}_{1-x}\text{As}$ material, the three group III atoms around the DX site can be any combination of gallium and aluminum. The peaks into which the DLTS signal can be resolved would correspond, according to the previously mentioned models, to the four possible configurations of the three nearest aluminum and/or gallium neighbors around each DX site.

The differences in the spectrum of the DLTS signal of samples grown at two growth temperatures will be examined here. The discrepancies between the calculated distribution of DX sites and the one observed by DLTS will also be studied. Our experiments are based on a recently developed high-resolution Fourier-transform DLTS system.⁷ It can provide a very high emission rate resolution and produces spectra which are easy to interpret since they are very similar to those obtained by conventional DLTS.

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Modulation Doped Field Effect Transistor

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The success of optical interconnects for computer communications depends critically on the development of a viable monolithic optoelectronic integrated circuit OEIC technology. A key component of any lightwave communication system is the optical receiver preamplifier which converts the low level optical signals into amplified electrical signals. This thesis describes the design, fabrication and characterization of an OEIC receiver based on submicron pseudomorphic modulation doped field effect transistors MODFETs and a metal semiconductor metal photodetector MSM PD. Extensive discrete electronic and photonic device results are presented and related to receiver design. The performance of the overall receiver and individual circuit elements is reported and compared with theory. Pseudomorphic MODFETs based on the InGaAs/GaAs strained layer material system are chosen due to their superior performance compared to the lattice matched GaAs system. The design and fabrication of high speed MODFETs for integrated circuits are presented. Thick highly doped cap layers and selective gate recess etching are the keys to achieving uniform high performance MODFETs. The microwave characteristics are studied using a delay time approach to separate out parasitic effects. A conventional GaAs MSM is investigated and is found to be dominated by surface effects which lead to large dark currents and low frequency gain. Two different MSM designs are presented which eliminate or greatly reduce these anomalous effects. A submicron MSM PD is shown to exhibit a bandwidth

of 70 GHz using a novel integrated photoconductive sampling technique The design and characterization of a transimpedance preamplifier are described in detail taking into account such factors as bandwidth noise and circuit complexity An active feedback resistor consisting of a common gate FET is utilized in the amplifier design This FET however is found to contribute a large parasitic capacitance to the input of the amplifier which limits the bandwidth Nevertheless a 3 dB bandwidth of greater than 3 GHz and as high as 4.5 GHz is measured for the overall receiver *Modulation-doped Field Effect Transistors for High-power Microwave Applications* Ronald Waldo Grundbacher,1997 The need for high power low noise transistors operating at frequencies of 1GHz and above has accelerated over the past several years because applications in consumer markets including telecommunications products have increased dramatically Transistors in the silicon system are having difficulty providing the high power low noise characteristics at operation above 1 GHz Transistors based on InP and GaAs which include HBTs MESFETs and HEMTs have proven to be excellent devices and can provide high power low noise capabilities at frequencies of 100 GHz and beyond Issues of importance for high power microwave transistors include breakdown mechanisms linearity and material selection **Development of Non-alloyed Modulation-doped Field-effect Transistors** Pheng-Piao Liao,1990 **Transport Properties of a Quantum Dot Modulation-doped Field-effect Transistor** N. S. Beattie,2005

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