High Performance InAlAs/InGaAs Metal-Semiconductor-Metal Photodetectors Grown by Gas Source Molecular Beam Epitaxy

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ABSTRACT

Gas source molecular beam epitaxy have been used in the growth of InAlAs/InGaAs MSM-PD structure, in which InAlAs ultra thin layer was used as Schottky barrier enhancement material. High performance MSM-PDs have been constructed on the grown wafer. High breakdown voltage of >30V, low dark current density of 3pA/μm^2 at 10V bias and fast transient response of <20ps rise time / <40ps FWHM have been measured, which confirm the results that GSMBE is a superior method for the growth of materials with high layer and interfacial quality, especially for InP based InAlAs/InGaAs system.

1. INTRODUCTION

Photodetector with interdigital metal-semiconductor-metal(MSM) structure has attracted much attention because of its high speed properties and plannar structure suitable for the monolithically integration of OEICs. For the InP based InGaAs material widely used in optical communication band, the main drawback of the metal-semiconductor system in MSM-PDs is its low Schottky barrier height(~0.2eV), to solve this problem a suitable barrier enhancement material must be introduced between the InGaAs light absorption layer and the metal electrodes. Many kinds of thin film barrier enhancement layer have been researched on InGaAs[1]-[11], among which lattice matched hetero-structures with wider band gap, such as InAlAs/InGaAs[8]-[11], ought to have better barrier enhancement effects. In a variety of epitaxial growth methods gas source molecular beam epitaxy(GSMBE) is a superior choice in the growth of InP based InAlAs/InGaAs materials. First, the introduction of hydride phosphorus source in the MBE system provide sufficient protection to the InP substrates during the thermal processing prior to growth, furthermore, the decomposition of hydride source rseulting in hydrogen reductive atmosphere in the growth chamber, which is beneficial to the growth of high aluminium content compounds. In this paper we report the experimental results of high performance InAlAs/InGaAs MSM-PD grown by GSMBE.

2. EXPERIMENT

The epitaxial structure of the MSM-PD were grown on a V80H GSMBE system, Fig.1 shows the epitaxial structure. 200nm InAlAs buffer layer, 0.8μm InGaAs light absorption

layer and 50nm InAlAs barrier enhancement layer were grown successively on S.I.InP substrate, all layers were unintentionally doped. Prior to growth phosphorus flux wewe used to prevent substrate decomposition. phosphine crack temperature were 1000 ° C, preasure were set to be 2.5×10^{-5} Torr in the growth chamber. The substrate temperature during growth were 500 °C, arsine crack temperature were 1000 °C, preasure were set to be 3×10^{-5} Torr, growth rate were 0.8μm/hr for InGaAs and 0.9μm/hr for InAlAs. The optimization of the growth condition were taken, resulting in lattice mismatch within 1×10^{-3} for both InGaAs and InAlAs layers by using DCXR measurement. for unintentionally doped layers InGaAs shows carrier concentration $N_D<5\times10^{15}$ cm^{-3} by suing Hall measurements, InAlAs show high risistivity character. Epitaxial wafer shows mirror like surface with low defect density.

UD	InAlAs	50nm
UD	InGaAs	0.8μm
UD	InAlAs	200nm
S.I.	InP Sub.	(100)

Fig.1 Epitaxial structure of the InAlAs/InGaAs MSM-PDs

MSM-PD were constructured on grown wafer by using photolithography, UHV electron beam evaporation and lift-off processes, the electrode materials used were Ti/Pt/Au, line width and space of the electrode were both 2.5μm, light sensitive area of the MSM-PDs were 30×30μm, bonding pads were 70×70μm, no mesa etching and anti-reflaction coating were used. The constructured wafer were thinned and divided, the chip were mounted into SMA microwave package and bonded with gold wire for DC and transient characterization.

3. CHARACTERIZATION AND RESULTS

DC and transient characteristics of the MSM-PDs have been measured. Fig.2 shows its typical dark and illuminated characteristics. The DC characteristics are symmetrical. The turn-on voltage of the MSM-PDs are about 0.5V, with quite flat photocurrent-voltage character. Breakdown voltage of the devices are great than 30V. Dark current of the devices are less than 20nA at 10V bias, correspondent to dark current density about 3pA/ μm^2, as we know this is the best result reported on this material system.

Transient response of the MSM-PDs have been measured on a self-built system. Light pulses (FWHM~40ps) generated from a gain-switched 1.3μm laser diode are focused on the sensitive area of the MSM-PD, light current pulse generated by the MSM-PD is connected to the sampling head of the sampling oscilloscope through a bias Tee with DC block. DC voltage needed for bias the PD is also added through the bias Tee. The sampling head used has 50Ω input impedence and 28ps rise time. Transient response waveform is shown on the oscilloscope and recorded by using a X-Y recorder. Typical transient response of the MSM-PD is shown on Fig.3, in which the rise time is less than 30ps and FWHM is about 50ps, considering the influence of the measure system,

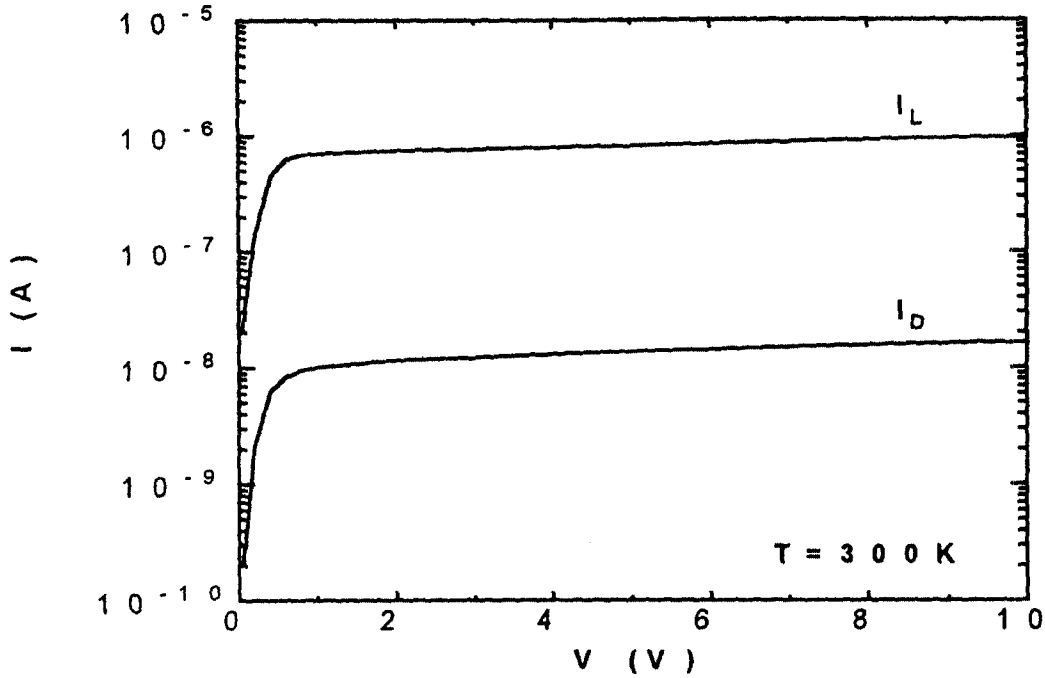

Fig.2 DC Characteristics of InAlAs/InGaAs MSM-PD

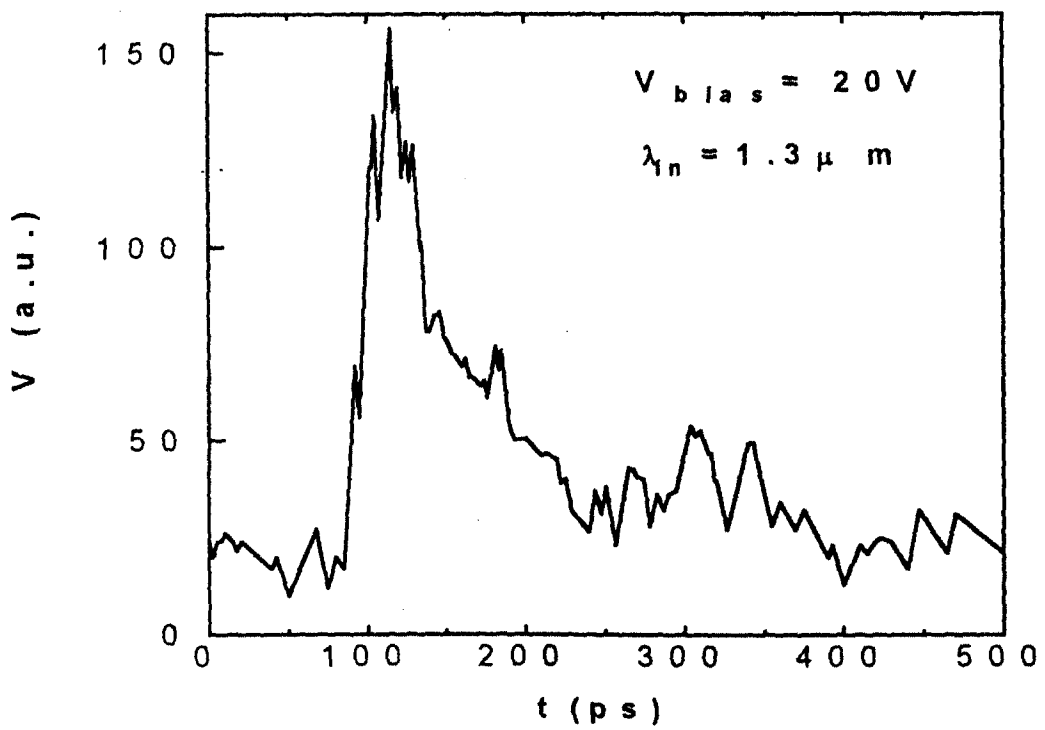

Fig.3 Transient Response of InAlAs/InGaAs MSM-PD

corrected rise time and FWHM should be less than 20 and 40 ps respectively, this results have reached the time limit of the measuring system.

4. CONCLUSIONS

GSMBE have been used in the growth of InAlAs/InGaAs MSM-PD structure, in which InAlAs ultra thin layer was used as Schottky barrier enhancement material. High performance MSM-PDs have been constructed on the grown wafer. High breakdown voltage of 30V, low dark current density of 3pA/μm^2 at 10V bias and fast transient response of 20ps rise time / 40ps FWHM have been measured, which confirm the the results that GSMBE is a superior method for the growth of materials with high layer and interfacial quality, especially for InP based InAlAs/InGaAs system.

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