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FABRICATION OF HIGH-SPEED GaAs PHOTODIODES WITH TRANSPARENT INDIUM TIN OXIDE (ITO) SCHOTTKY GATE

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Abstract: High-speed (FWHM 20 ps) GaAs photodiodes have been fabricated using transparent indium tin oxide (ITO) Schottky gates. The use of ITO results in responsivities of 0.30 A/W (external quantum efficiencies of 45%) at 830 nm. The photodiode's intrinsic response speed has been determined by nonlinear autocorrelation measurements.

1. Introduction

With photodiodes based on semitransparent metal Schottky gates it is difficult to achieve high responsivities due to the often poor transmittance of the metal layer. A better solution uses transparent contacts such as indium tin oxide (ITO) as a highly transparent Schottky gate.

Thin films of ITO have found wide-ranging applications in numerous opto-electronic devices [1], recently, in high sensitivity photodiodes [2].

2. Device Fabrication and Characteristics

The ITO/GaAs mesa photodiodes (Figure 1) consist of a 0.6±0.1 μm thick n^- absorbing layer ($N_D = 2 \cdot 10^{16}$ cm^{-3}) over an underlying 2 μm thick n^+ buffer and contact layer ($N_D = 3 \cdot 10^{18}$ cm^{-3}). In order to minimize parasitic capacitance the GaAs material is grown by liquid phase epitaxy (LPE) on a semi-insulating substrate. The transparent electroconductive ITO layer (Schottky gate) is deposited by reactive rf ion-beam sputtering. Since the refractive index of ITO is ~2 [1], the 1000 Å thick ITO layer acts as an ideal antireflection coating to GaAs at 830 nm.

Five photolithographic process steps were necessary to fabricate the mesa structures. Typical diode areas were 250 μm^2. The GaAs-chips were incorporated into coplanar waveguides and flip-chip mounted onto a sapphire substrate, which allows broadband electrical transmission [3].

The electrical diode characteristics show excellent rectifying action with a forward bias turn-on voltage of approximately 0.5 V and a reverse-bias breakdown voltage of 23 V. The leakage current is less than 1 nA at 10 V reverse bias. At 830 nm the photodiodes exhibit responsivities of 0.30 A/W at -12 V bias. This responsivity is limited by the depleted width of the active n^--GaAs layer.

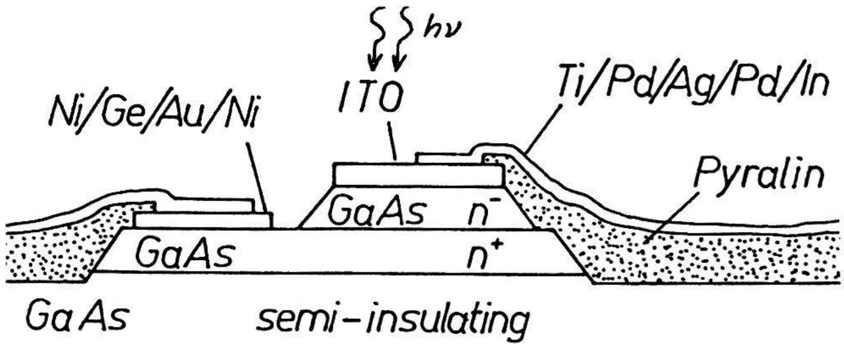

Figure 1: Schematic section through the device.

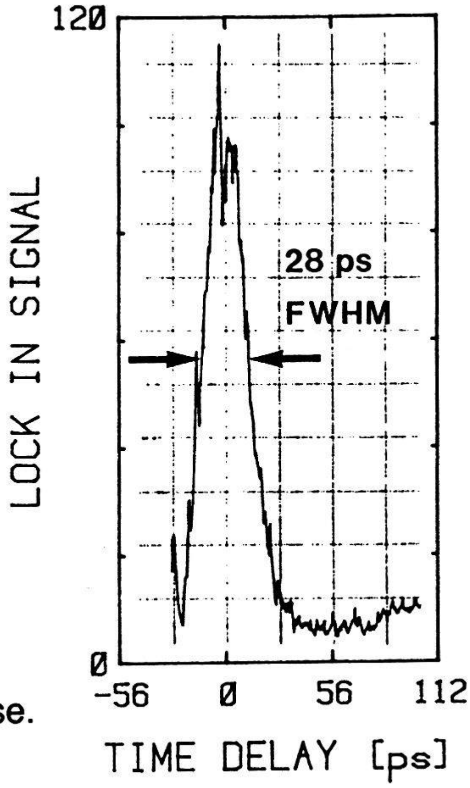

Figure 2: Autocorrelation signal of the photodiode's impulse response.

3. Nonlinear Autocorrelation Measurements

A beam of 4 ps optical pulses at a wavelength of 583 nm is split in two, and one beam is delayed a variable time τ with respect to the other. The two beams are chopped at different frequencies f_1 and f_2 and are focused to overlapping spots onto the photodiode. Signal components at the sum $f_1 + f_2$ of the chopping frequencies are detected using a lock-in amplifier. Such measurements yield directly the autocorrelation function of the temporal response of the device [4, 5].

Figure 2 shows the nonlinear response of the photodiode as a function of the relative delay time τ between the optical pulses. Assuming Gaussian pulses, deconvolution of the photodiode's autocorrelation signal (FWHM 28 ps) leads to an intrinsic response of FWHM 20 ps, which corresponds to a -3 dB bandwidth of 24 GHz. The appeal of this methode is that the only high-speed part of the experimental system need to be the optical pulses themselves.

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