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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  $0.6 \pm 0.1 \mu\text{m}$  thick n<sup>-</sup> absorbing layer ( $N_D = 2 * 10^{16} \text{ cm}^{-3}$ ) over an underlying  $2 \mu\text{m}$  thick n<sup>+</sup> buffer and contact layer ( $N_D = 3 * 10^{18} \text{ cm}^{-3}$ ). 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  $250 \mu\text{m}^2$ . 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<sup>-</sup>-GaAs layer.

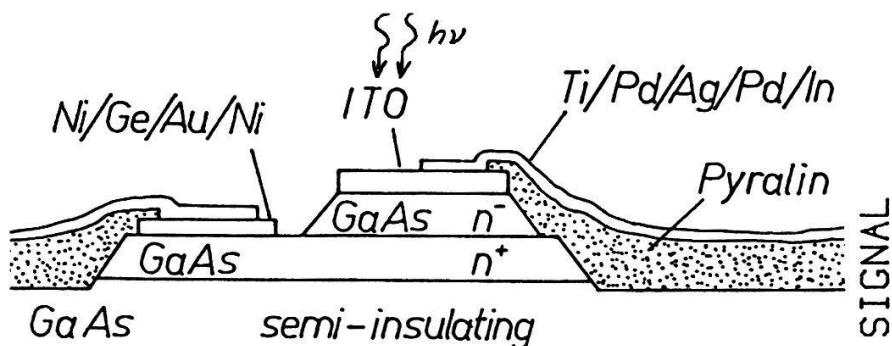


Figure 1: Schematic section through the device.

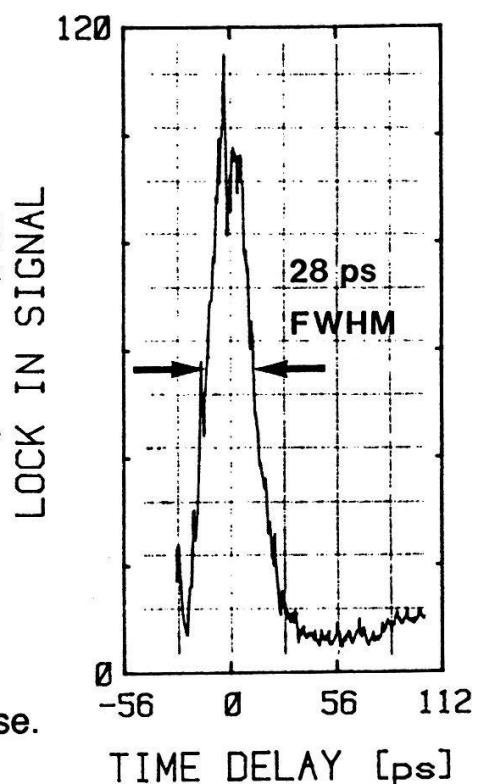


Figure 2: Autocorrelation signal of the photodiode's impulse response.

### 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  $\tau$  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  $\tau$  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 method is that the only high-speed part of the experimental system need to be the optical pulses themselves.

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