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10 Gbit/s Monolithic Integrated Optoelectronic Receiver using an MSM Photodiode and AlGaAs/GaAs HEMTs

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Abstract

A 10 Gbit/s monolithic integrated optoelectronic receiver has been fabricated with a metal–semiconductor–metal (MSM) photodiode and enhancement/depletion 0.5 μm recessed–gate AlGaAs/GaAs HEMTs. A –3 dB bandwidth of 11.3 GHz has been achieved.

1. DESIGN AND FABRICATION

Several research groups have reported on the technology of monolithic integration of MESFETs on GaAs with photodetectors for light of wavelength 0.85 μm [1,2]. In this paper we present the first photoreceiver which is based on an MSM photodiode and AlGaAs/GaAs HEMTs [3]. The photoreceiver was fabricated using our established 0.5 μm recessed–gate process for double delta–doped quantum well HEMTs [4,5]. Now this standard process includes MSM photodiodes.

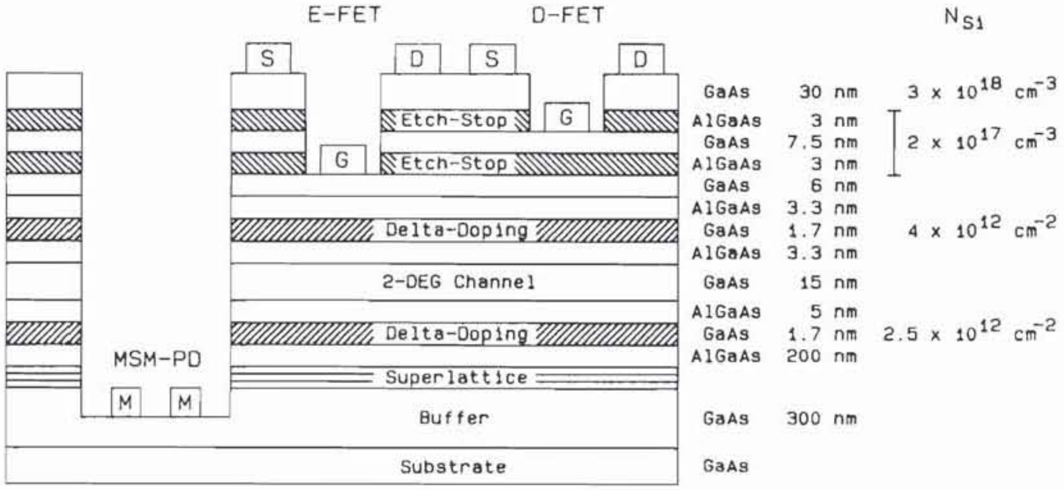

Figure 1. Schematic cross section of an MSM photodiode integrated with enhancement and depletion AlGaAs/GaAs HEMTs.

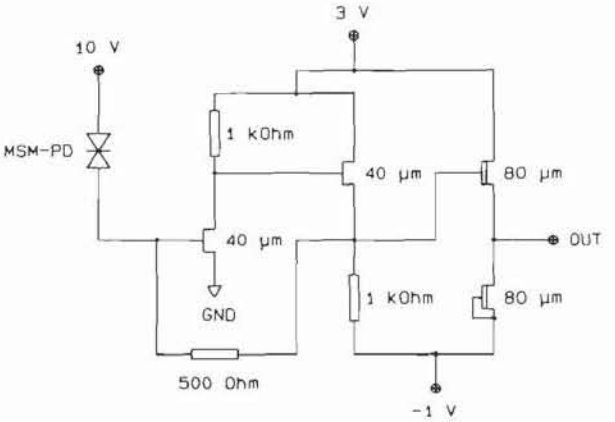

Figure 2. Circuit diagram of the photoreceiver. The receiver consists of an MSM photodiode, a transimpedance amplifier with two enhancement transistors and three NiCr thin film resistors, and an output buffer with two depletion transistors.

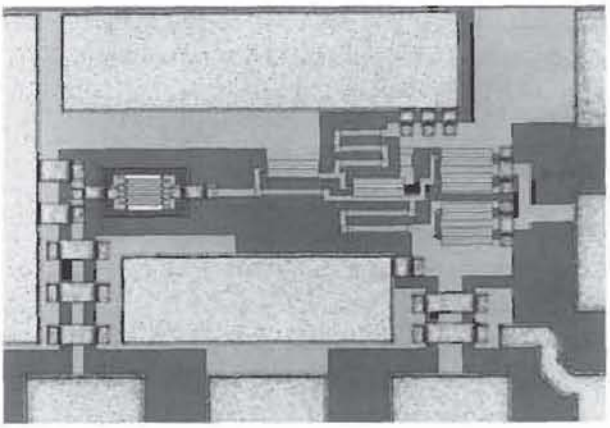

Figure 3. Photograph of the fabricated photoreceiver. The depicted chip area measures 500x350 μm^2. The MSM photodiode at the left side has an active area of 25x25 μm^2.

Figure 1 shows a cross–section of an MSM photodiode integrated with enhancement and depletion type transistors. The vertical structure was grown on the semi–insulating GaAs substrate by molecular beam epitaxy [4]. The AlAs mole fraction of the AlGaAs layers was 0.3. By means of etch stops and a selective reactive ion etch process, exact control of the transistor threshold voltages was obtained [5]. The site of the MSM photodiode was etched down to the undoped buffer layer by a wet etch prior to the fabrication of the photodiode fingers. The 1 µm wide fingers with a 1.5 µm separation were defined by electron beam lithography and subsequent evaporation and lift–off of Ti/Pt/Au metal.

As shown in Figures 2 and 3 the photoreceiver consists of an MSM photodiode, a transimpedance amplifier with a 500 Ω feedback resistor, and an output buffer. Airbridges connect the photodiode to the electric circuit. The layout also includes blocking capacitors for the supply voltages.

2. DEVICE AND CIRCUIT PERFORMANCE

Figure 4 shows the current–voltage characteristics of an MSM photodiode irradiated by light of various intensities at a wavelength of 0.84 µm. The DC responsivities of the photodiode were

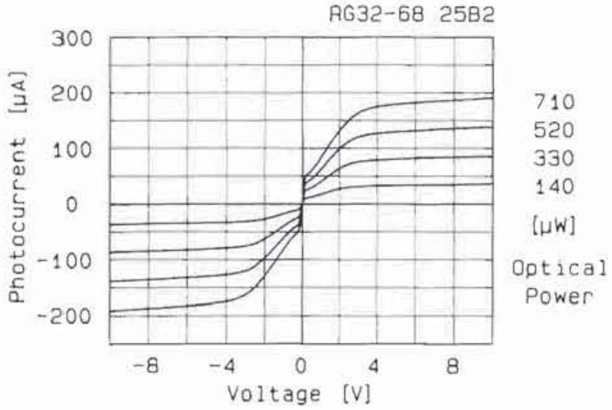

Figure 4. Current–voltage characteristics of an MSM photodiode for different intensity of the laser diode irradiation.

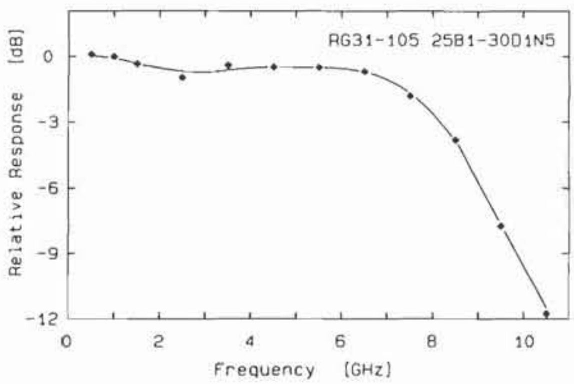

Figure 5. Measured frequency response of the photoreceiver. The measured –3 dB bandwidth lies at 8.2 GHz.

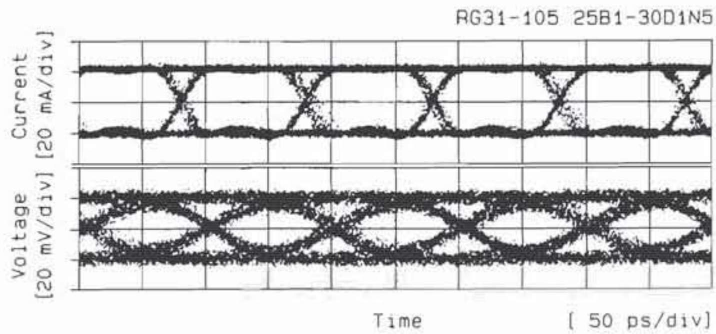

Figure 6. Eye diagrams of the laser diode current and the photoreceiver output voltage for a 10 Gbit/s NRZ pseudorandom data stream (same photoreceiver as that in Fig. 5).

0.25 A/W for 4 V and 0.27 A/W for 10 V bias. The dark current at 4 V was 2 nA for an active area of 25x25 μm^2. The following mean values for the enhancement and depletion HEMT parameters, respectively, have been obtained: threshold voltage = 0.1 and –0.5 V, transconductance = 500 and 390 mS/mm, source resistance = 0.7 and 0.6 Ωmm, transit frequency = 35 and 30 GHz.

All high frequency measurements of the receiver were performed on–wafer using CASCADE probes. The photodiode was irradiated by 0.84 μm light from a high speed ORTEL laser diode via a single mode fiber. The current driving the laser diode was modulated to obtain up to 0.8 mW peak–to–peak modulated optical signals. The relative response versus frequency, measured at

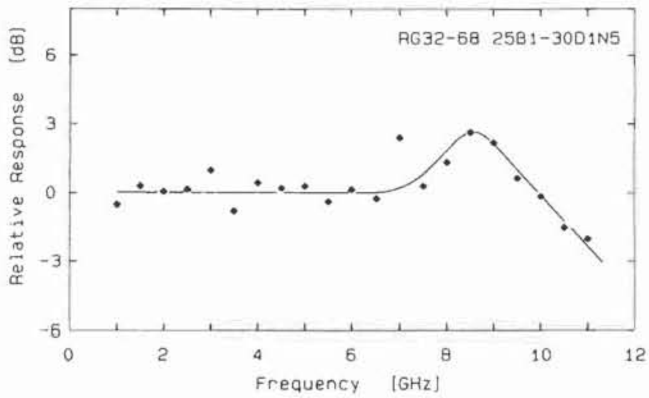

Figure 7. Measured frequency response of a photoreceiver from a different wafer (RG32–68). The measured –3 dB bandwidth lies at 11.3 GHz.

the output of a photoreceiver (wafer RG31–105), is shown in Figure 5. The –3 dB bandwidth of the photoreceiver for sinusoidal modulated incident light lies at 8.2 GHz. The frequency response of the ORTEL laser diode itself was determined using a calibrated GEC photodiode. The circuit response to pulse–modulated non–return–to–zero (NRZ) optical signals was tested at data rates up to 10 GBit/s by means of an ANRITSU pulse pattern generator. The eye diagrams of the laser diode current and the photoreceiver output voltage demonstrate (Figure 6) that the optoelectronic receiver operates successfully for a 10 Gbit/s NRZ pseudorandom data stream of length 2^7–1 bits. Eye diagrams of the same quality were observed for the data stream length 2^{31}–1 bits.

Figure 7 shows the relative response versus frequency of a photoreceiver from a different wafer (RG32–68) from that in Figures 5 and 6. For this wafer the threshold voltages are 0 and –0.7 V for the enhancement and depletion HEMTs, respectively. Due to the different operating point of the transimpedance amplifier the effective transimpedance of the photoreceiver was 330 Ω instead of 440 Ω, i.e. the output voltage was 25 % lower. Furthermore, the frequency response is not as flat as that of the first photoreceiver, however, the – 3 dB bandwidth lies at 11.3 GHz.

ACKNOWLEDGEMENT

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