Self-aligned MSM low-temperature-grown GaAs traveling wave photodetector for 810 nm and 1230 nm

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Abstract: Traveling wave photodetectors (TWPD) are promising devices for high bandwidth and high efficiency. In this paper, electro-optic sampling measurements of this novel self-aligned metal-semiconductor-metal TWPD under different biases and pumping levels are performed at a wavelength of 810 nm and the electrical sampling measurements are performed at a wavelength of 1230 nm.

Introduction

High-power high-speed photodetectors are a key component in high performance analog and digital fiber optic links. Traveling-wave photodetectors have been shown to have high saturation power and high bandwidth. Recently, Chiu achieved a record bandwidth of 560 GHz at 800 nm by using low-temperature-grown GaAs (LTG-GaAs) as the photoabsorption layer in a p-i-n based TWPD [1]. In this paper, the performance of a novel self-aligned metal-semiconductor-metal TWPD utilizing LTG-GaAs as the photoabsorption layer was investigated under different bias voltages and pumping levels. By using the electro-optic sampling technique [2], the impulse response of the photodetector is shown to vary form 0.8 ps to several ps at 810 nm excitation. The DC quantum efficiency is measured to be 8% at 810 nm. Also, long wavelength (1230 nm) excitation is investigated using a 50 GHz sampling oscilloscope. Preliminary results show that the bandwidth of this photodetector under 1230 nm excitation is limited by the bandwidth of the monitor oscilloscope. The DC quantum efficiency is measured to be 1.0 % at 1230 nm under a bias voltage of 14 V.

Device Structure

Fig. 1(a) and Fig. 1(b) show the cross sectional and top view of the device structure respectively. A 3 μm thick layer of $Al_{0.5}Ga_{0.5}As$ is grown on S.I. GaAs to isolate the optical

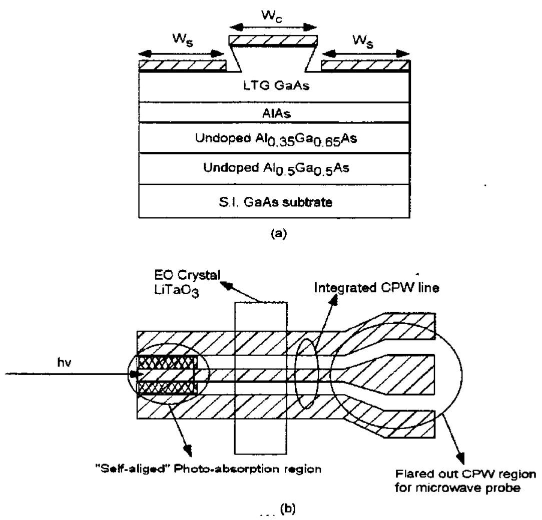

Fig. 1. Device structure of the self-aligned metal-semiconductor-metal TWPD.

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mode from substrate. A 500 nm thick LTG GaAs absorption layer is grown on top of a 1 µm thick $Al_{0.35}Ga_{0.65}As$ cladding layer. By self-aligning after wet etching of the center signal line, the distance between the signal (top) metal and ground (side) metal of the co-planar waveguide (CPW) can be minimized to enhance the electric field strength in the photoabsorption layer to increase the efficiency. Three strips of metals act as a CPW line to collect the photo-generated microwave signal and also for EO sampling measurements, and a top-view is shown in Fig. 1(b).

Measurement setup

Two optical sources were used to excite the microwave signal. One is 100 fs mode-locked Ti:Sapphire at 810 nm, the other is 100 fs mode-locked Cr:Forsterite at 1230 nm. 810 nm source is used for electro-optical sampling measurement, and 1230 nm source is for electrical sampling measurement. The device under test (DUT) is terminated by a 50 Ω-40GHz-bandwidth microwave probe for DC bias and monitoring of the impulse response by a 50GHz-bandwidth sampling oscilloscope. In the EO-sampling measurement, $LiTaO_3$ was used as EO crystal.

Result and discussion

Pump power dependence

Fig. 2 gives EO sampling data for the self-aligned MSM-TWPD at different pump powers (810 nm) with a bias voltage of 5 V. At low pumping power (2 mW), the FWHM pulse width is 0.8 ps. As the pumping power increases, the pulse width of the impulse response became broader due to charge screening [3]. The FWHM pulse width was doubled when the pumping power was increased to 10 mW and the corresponded excited charge in the photodetector is about 440 fC.

Bias voltage dependence

Fig. 3 shows the EO sampling data for the self-aligned MSM-TWPD at different bias voltages (1 V to 15 V) with a pump power (810 nm) of 1.75 mW. As can be seen in Fig. 3, the pulse shape of the impulse response is similar at different bias voltages. This is the characteristic of the trapping time limited photodetector [4].

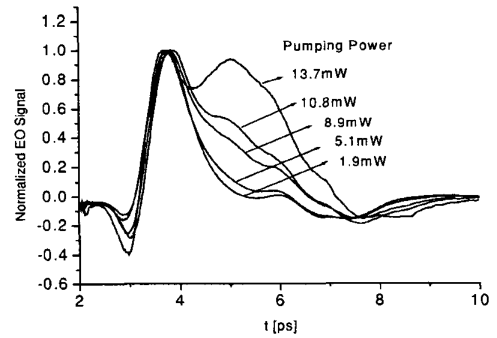

Fig. 2. EO sampling data for the self-aligned MSM-TWPD at different pump powers (810 nm) with a bias voltage of 5 V.

At low bias voltage (1 V to 5 V), the responses remain almost the same. However, the decay rate of the responses begins to decrease as the bias voltage increases from 6 V to 15 V. This decreasing of the decay rate is another indication that the detector is trapping time limited, because the trapping time of the LTG-GaAs increases under high electric field [5].

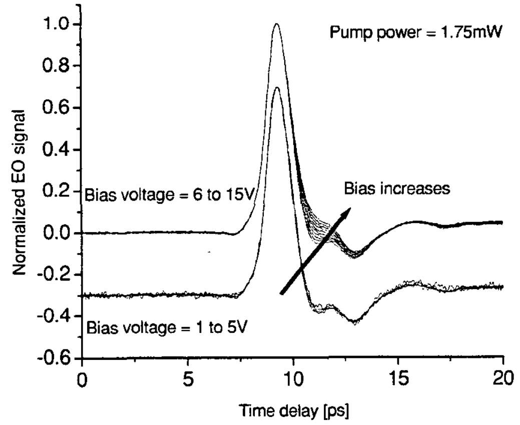

Fig. 3. EO sampling data for the self-aligned MSM-TWPD at different bias voltages under pump power 1.75mW.

Long wavelength (1230 nm) excitation

Fig. 4 shows a typical electrical sampling trace under a pump power (1230 nm) of 5.0 mW and a bias voltage of 2 V. The FWHM of this trace is 21 ps and is limited by the bandwidth of the measurement instrument. The low frequency tail that can be resolved in the measurement is due to the multi-reflections from the interconnection between CPW line and the microwave probe. The DC quantum efficiency is bias dependent and is increased from 0.13 % to 1.0 % when the bias voltage is increased from 2 V to 14 V.

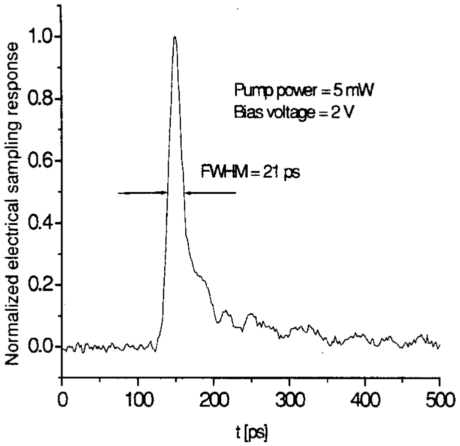

Fig. 4. A typical electrical sampling trace using long wavelength (1230 nm) excitation

Summary

In summary, the performance of ultra-high speed self-aligned MSM-TWPD under different pump powers and bias voltages is investigated by using EO sampling and it was shown that the detector is a trapping time limited photodetector.

Reference

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