Self-aligned 0.8ps FWHM MSM traveling wave photodetector using low-temperature-grown GaAs

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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 novel self-aligned metal-semiconductor-metal TWPD under different biases and pumping levels are performed.

OCIS codes: (999.9999) metal-semiconductor-metal photodetectors; (999.9999) traveling-wave photodetectors; (999.9999) low-temperature-grown GaAs; (999.9999) self-alignment; (999.9999) ultra-high speed photodetectors

Introduction

High-power high-speed photodetectors are a key component in high performance analog fiber optic links. Traveling-wave photodetectors have been shown to have high saturation power and high bandwidth. Recently, Chiu *et.al.* achieved a record bandwidth of 560GHz at near infared optical wavelength (0.8um) 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 utilizing a self-aligned technique, the distance between the signal (top) metal and ground (side) metal of the co-planar waveguide line (CPW) can be minimized and thus enhance the electric field strength in the photoabsorption layer to increase the efficiency of the detector. By using the electro-optic sampling technique [2], the impulse response of the photodetector is shown to vary form 0.8ps to several ps. Preliminary results show that the impulse responses of this photodetector have a sub-picosecond FWHM pulse width and internal efficiency of 2%.

Device Structure

Fig 1(a) and Fig 1(b) show the cross sectional and top view of the device structure respectively. A three micron thick layer of $Al_{0.5}Ga_{0.5}As$ is grown to isolate the absorbing layer and substrate. The absorbing layer is a 500nm thick LTG GaAs layer grown on top of a 1um thick $Al_{0.35}\ Ga_{0.65}$ As waveguide layer. The AlAs layer prevents the out-diffusion of As defects to other epi-layers [3]. The lateral optical wave guide is an etched mesa ridge below the center metal strip. Three strips of metals act as a CPW line to collect the photo-generated microwave signal. The center strip (signal line) naturally separated with ground planes by the depth and under cut profile of etch ridge mesa. A small distances between metal strips enhances the electric field strength and will also increase the efficiency of detector. The fabricated detector is integrated with a CPW line on semi-insulating GaAs substrate for EO sampling measurements, and a top-view is shown in figure 1(b).

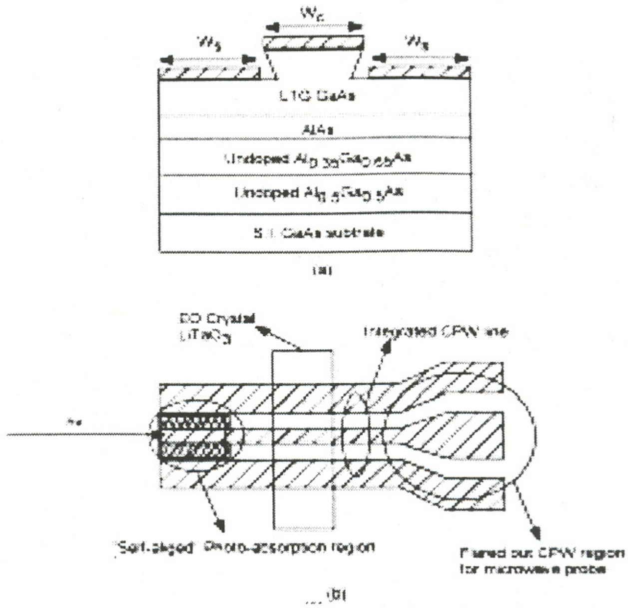

Fig. 1. Device structure of the self-aligned metal-semiconductor-metal TWPD.

Measurement setup

In the experimental setup, the device under test (DUT) is terminated by a 50Ω-40GHz bandwidth microwave probe for DC bias and monitoring of the impulse response by a 50GHz sampling oscilloscope. A 100fs, 800nm pulse from a Kerr-lens Modelocked Ti: Sappire laser is split into pump and probe beam. The pump beam was directed to excite the DUT and generate a pico-second electrical pulse. This electrical pulse will propagate along the CPW line and modulate the polarization of the probe beam when the electrical pulse overlaps with the probe beam in the EO crystal ($LiTaO_3$) which has been placed on the CPW line. The polarization modulation of the probe beam can be converted into intensity modulation and measured by a slow photodetector as a function of the propagation delay between electrical pulse (pump beam) and probe beam. In order to improve the signal-to-noise ratio, lock-in detection was used. The pump beam was modulated by an acoustoptic modulator at 1MHz before impinging on the DUT and the signal from the slow photodetector is sent to a lock-in amplifier to extract the desired signal.

Result and discussion

Pump powers dependence

Fig. 2 gives EO sampling data for the self-aligned MSM-TWPD at different pump powers with a bias voltage of 5V. At low pumping power (2mW), the FWHM pulse width is 0.8ps. As the pumping power increases, the pulse width of the impulse response became broader due to charge screening [4]. The FWHM pulse width was doubled when the pumping power was 10mW and the corresponded excited charge in the photodetector is about 440fC.

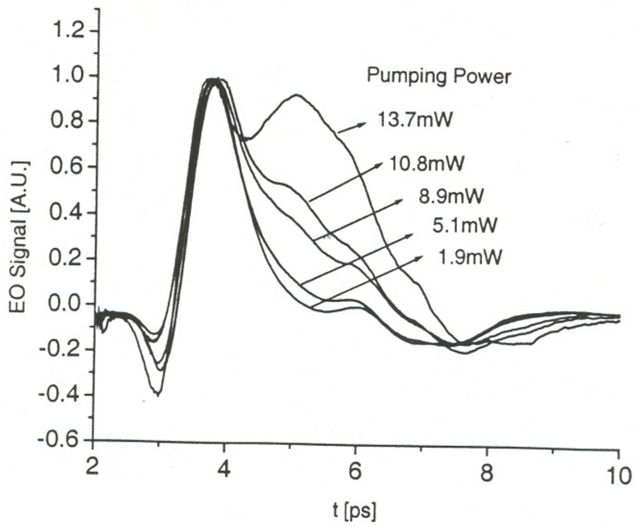

Fig. 2. EO sampling data for the self-aligned MSM-TWPD at different pump powers with a bias voltage of 5V.

Bias voltages dependence

Fig. 3 shows the EO sampling data for the self-aligned MSM-TWPD at different bias voltages with a pump power of 2.8mW. 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 [5]. However, there is a long tail follow the major peak at low bias voltage. This long tail originates from the charge screening effect and carrier hopping transport in the deep level trap of the LTG-GaAs [3]. Fig. 4 shows the data at high bias voltages. It is very clear that the decay rate of the response decrease as the bias voltage increase from 5V to 10V. This decreasing of the decay rate is another indication that the detector is trapping time limited, because the trapping time of the LTG-GaAs increase under high electric field [6].

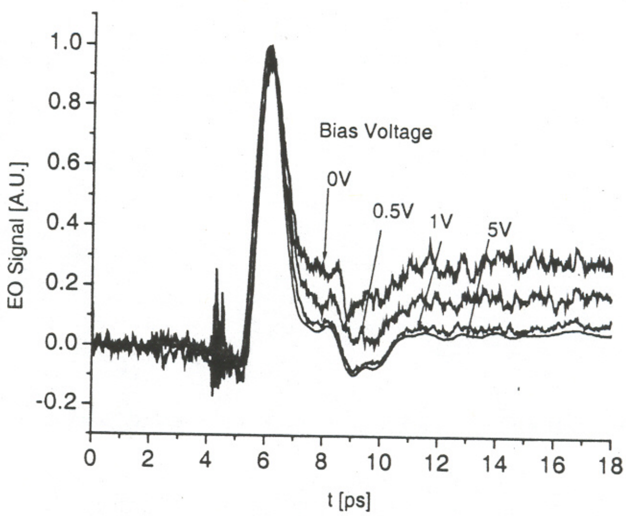

Fig. 3. EO sampling data for the self-aligned MSM-TWPD at different bias voltages under pump power of 2.8mW.

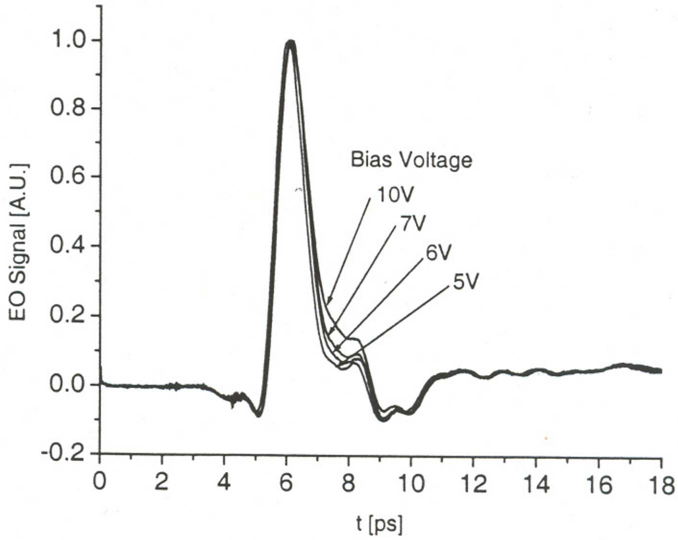

Fig. 4. EO sampling data for the self-aligned MSM-TWPD at high bias voltages under pump power of 2.8mW.

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.

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