Metal-Semiconductors-Metal Traveling Wave Photodetetcors

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Summary:

Low-temperature-grown GaAs (LTG-GaAs) based photodetectors (PDs) merit a lot of attentions due to their ultrahigh electrical bandwidth performances. In this paper, we review the advantages and applications of LTG-GaAs based metal-semiconductor-metal traveling wave photodetectors (MSMTWPDs) and discuss their ultra-high speed and record high power-bandwidth product performances in both short (~800nm) and long (~1300nm) wavelength regimes.

Maximum available power and electrical bandwidth are usually two trade-off parameters in the performances of high-speed photodetectors (PDs) [1]. PDs with high power-bandwidth product can be applied in the millimeter waves or sub-millimeter waves generation [2] and photo-receiver circuits without electrical amplifiers [1]. Edge-coupling combining traveling wave PD structures is one way to achieve high output power by diluting the photo-absorption constant and increasing the device absorption length [3]. However, by using traditional p-i-n TWPD structure with long device absorption length, it suffers high microwave loss, boundary reflection, low microwave velocity, and velocity mismatch bandwidth limitations [3]. In order to improve the power-bandwidth product performance of PDs, we proposed and demonstrated a novel ultra-high speed PD; "LTG-GaAs based metal-semiconductor-metal traveling wave photodetector" [4]. It has lower microwave loss and higher microwave velocity than the structure of p-i-n TWPD [3]. The superior microwave guiding structure also implies that the electrical bandwidth is less sensitive to the photo-absorption volume. Figure 1 (a) and (b) shows the measured impulse response and its corresponding frequency response of MSMTWPD under high bias voltage (30V) and high excitation optical pulse energy (~71 pJ/pulse) at the wavelength of 800nm. The obtained peak output voltage (V_p: ~30V) and electrical bandwidth (190 GHz) product (5.7 THz-V) is the highest among all reported ultrahigh speed PDs. The excellent power-bandwidth product performance is due to short carrier lifetime of LTG-GaAs and superior microwave guiding structure.

By utilizing the mid-gap defect states in LTG-GaAs, the photo-absorption in

0-7803-7500-9/02/$17.00©2002 IEEE

long wavelength regimes (1.3μm~1.55 μm) can also be achieved. The record high power-bandwidth product performance among all reported high speed PDs in long wavelength regime has also been demonstrated with LTG-GaAs based MSMTWPDs [5]. However, compared with the high power performances in short wavelength regime, the demonstrated device exhibits much serious bandwidth degradation effect under ~1.3μm wavelength excitation. The different nonlinear behaviors at 1.3μm wavelength are possibly originated from that the photon energy (~1eV) is much higher than the subband-gap photon-absorption energy (~0.7 eV), which will induce significant hot electrons, inter-valley scatterings, and serious increasing in carrier lifetime. By contrast, the hot electron effect under short wavelength excitation (~800nm) is not evident due to that the photon energy of excitation wavelength is close to the band-to-band photo absorption energy. The detailed theory and experimental results will be given in the conference.

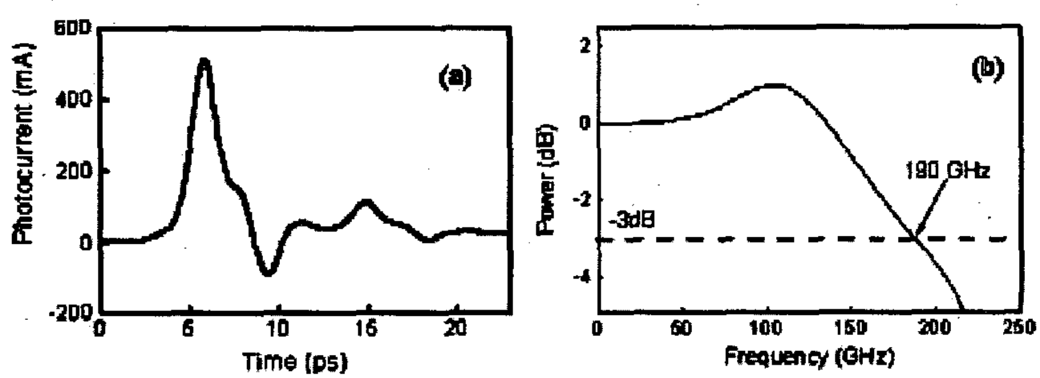

Figure1 (a) EO measured transient response of a 12-μm-long MSMTWPD with a high optical excitation energy (71 pJ/pulse) and a fixed high bias voltage (30V). (b) Its corresponding frequency domain response by use of fast-Fourier transform technique, which shows a 3dB electrical bandwidth of 190 GHz.

[1] K. Kato, *IEEE Trans. Microwave Theory Tech.*, vol. 47, pp. 1265-1281, Jul., 1999

[2] S. Verghese, *et al., IEEE Trans. Microwave Theory Tech.*, vol. 45, pp. 1301-1309, Aug., 1997.

[3] J.-W. Shi and C.-K. Sun, *J. of Lightwave Technol.*, vol. 18, pp. 2176-2187, Dec., 2000.

[4] J. W. Shi, *et al., IEEE Photon. Techno. Letters*, vol. 13, pp. 623-625, June 2001.

[5] J. W. Shi, *et al., IEEE Photon. Techno. Letters*, vol. 14, pp. 363-365, Mar. 2002.