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High Speed Dual-Msm Photodiodes On InP: Fe

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Abstract

Metal-Semi Conductor – Metal (MSM) Photo detectors on semi–insulting Inp: Fe with a lateral planer structure (double Schottky photodiode) have been fabricated . the detector exhibits low dark currents of about 6 nA, an impulse response time of 15 psec., Full width at half maximum (FWHM)(25 Psec.), and an internal quantum efficiency of 70%, all at 10V bias .

. Response time is almost independent on biasing voltage, while the dependence of photocurrent on biasing reflects the increasing in the quantum efficiency. The photocurrent increase linearly with incident power radiation for all bias voltage greater than 0.6v.

كواشف ضوئية ثنائية عالية السرعة على فوسفيد الانديوم المشاب بالحديد

الخلاصة

تم تصنيع كواشف ذات تركيب معدن/شبه موصل /معدن على فوسفيد الانديوم شبه العازل (InP: Fe) باستخدام تركيب الجانب الطبقي (كواشف ضوئية ثنائية الشوتكي). ابدت الكواشف تيارات واطئة بحدود (6nA) ، وزمن استجابة نبضية (15Psec.) ، العرض في منتصف النبضة (25 Psec.)، الكفاءة الكمية الداخلية 70% عند جهد انحياز (10v). كذلك ظهر ان زمن الاستجابة لايعتمد على جهد الانحياز، بينما يعكس اعتماد التيار الضوئي على الجهد المسلط الزيادة في الكفاءة الكمية . يزداد التيار الضوئي خطيا مع قدرة الاشعة الساقطة ولكل قيم الجهد الاكبر من (0.6 v) .

Keywords : Lateral photodiode , Planer Schottky

I – Introduction

The availability of simple and economical picoseconds light sources like directly modulated or mode-locked semiconductor laser (1) has increased rapidly and created a demand for equally simple and sensitive methods to detect such pulses.

High speed planer Metal – Semiconductor- Metal double –

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Schottky diode is a viable low – coast alternative to the P-I-N photo detectors fabricated with a process technology that is potentially compatible with electronic systems devices fabrication process are key elements of multi gigabit photonic systems.

High- performance of MSM photodiodes have been demonstrated on n-type Si (2), GaN(3) ,GaAs(4) , on n-type InGaAs using lattice-matched(5-7) and mismatched surface layers to enhance the Schottky- barrier height(8,9).

In this paper, we report the fabrication of lateral inter digit MSM detectors on semi-insulating InP doped with Fe, useful for GaAs laser diode with low leakage current, good responsivity and requiring only one metal deposition for both the Schottky contact an the bond pad metal .

II- Device Fabrication

The MSM detectors are made on bulk Fe doped Inp material which was grown by the liquid encapsulated czochralski technique. The resistivity of the Inp: Fe is approximately 10^7(Ω cm).

The inter digitized contact structure is realized by optical lithography and lift-off techniques. Schottky- contacts are formed by the evaporation of (Al) under high vacuum about 10^{-7} Torr. The fingers of the detectors have 2 μm width and are separated by 2μm gaps as shown in Fig .(1) .

The devices are mounted on 50 Ω microwave package based on wiltron k-connectors which have anominal bandwidth of 46GHz. The detector is wire bonded to the connectors.

III- Measurements

The current-voltage characteristics measured using "H. P." 4145B semiconductor Parameter analyzer .The photocurrent response of the MSM photodiode to laser pulses emitted by GaAs of λ= 0.8μm injection laser is monitored by a 40 GHZ digital sampling oscilloscope (tektroni x 11802, sampling head SD – 30). The quantum efficiency is measured for 0.8 μm irradiation using a calibrated Si detector as a reference, the quantum efficiency (η) is calculated as

$$\eta = \left(\frac{I_e}{q p_i A} * \frac{1.24}{\lambda} * 100 \right) \tag{1-1}$$

where I_L is the photo generated current, p_i the optical power density on the detector, A is the interdigital area ,q is the electron charge and λ is the wavelength .

VI - Results

Figure (2) shows the current-voltage characteristics under dark conditions of the photo detector . the characteristic of the double schottky photodiode exhibits an almost symmetric behavior with dark current less than 10 nAmp at 10 V bias, the voltage break down is typically 14 V.

The temporal photocurrent response at different bias Voltage is shown in Figs.3(a-d). The measured FWHM of the photocurrent pulse and rise time is almost independent of biasing voltage as shown in Table (1).

The photocurrent under CW illumination is shown in Fig.4, I_{ph} increases fairly linearly with increasing bias, after reaching a quasi-saturation value.

V(v)	Rise time(ps)	Fall time(ps)	FWHM (ps)	Id(nA)
5	14	10	23	3
7	15	9	22	4
9	15	12	23	5
11	13	8	24	6

Table (1) Shows the Detector Parameters as a Function of Applied Voltage

IV- Discussion

1. When a potential is applied between the two set of digits, the electric field associated with reverse biased digits extends downwards into the semiconductor material and along the semiconductor surfaces towards the adjacent forward biased digits. Therefore, a field is established in the region to the semiconductor surface where it separates the electrons and holes in that region.
2. Photo detector performance is determined by a low dark current, and a high quantum efficiency, The dark current of ideal diode is determined by generation recombination current (I_{gr}) in the depletion layer and given by

$$I_{gr} = \frac{q * n_i * w * A}{\tau} \qquad (1\text{-}2)$$

Where n_i the intrinsic charge carrier concentration, A the junction area, w the depletion layer width, and τ the carrier lifetime. Therefore the small dark current seems to be due to a large carrier lifetime.

3. The response of inter-digital devices to time-varying carrier photo generation ratio as shown in Figs.(3a-d), shows the limiting value of response time as shown in table (1), and this due to the fully depleted device.
4. The observed photocurrent dependence on biasing voltage can be explained by the decreasing photo generated carriers transit time with biasing and hence more photo generated carriers will contribute to the photocurrent. This decrease reflecs itself in the increase of quantum efficiency since these photo generated carriers contribute to the photocurrent only during their lifetime*

Conclusion

In conclusion, we have demonstrated the fabrication of MSM photodiodes on semi-insulating InP:Fe substrates, Laterally structured photo-diodes are formed with interdigitated contact fingers. The devices show high speed response and low dark current* These excellent device characterristics together with the simple fabrication technology make this MSM diode suitable for monolithic optoelectronic integration.

References

1. J.P.Vander Ziel, Semiconductors and Semimetal» Edited by W- T. Tsang Acadmic, O'rlando. Vol.22, PartB, P.1.(1985)
2. L. Dobrzanski, A. Jagoda, K. Gora and Brzyborowskn; Properties of Metal – Semiconductor –Metal and Schottky Barrier GaN Detectors : Opto-Electronics Review 10(4),P291 (2002).
3. M.Seto,J.V.Leduc and A.M.F.Lammers; Al-n-Si Double–Schottky Photo-diodes for Optical Stoarge System : Internet Explorer (2004)
4. B.J.Van Zeghbroeck, W.Patrick, J.M.Halbout. and P.Vettigert 105-GHz Band Width Metal-semiconductora-metal Photodiodei IEEE Electron Dev.Lett.Vol.9. P.527 (1988).
5. O. Wada, H.Nobuhara, H, Hamaguchi, T, Mikaua, A. Takkeuchi, and T. Fuji; Very High Speed GaInAs Metal-Semiconductor-Metal Photodiode incorporating an Al-InAs / GaInAs Graded Superlattice: Appl.Phys. Lett. Vol.54. PP.16 (1989).

6. J.B.D. Soole, H. Schumacher. H.P. Leblanc, R.Bhat, and M.A. Koza, High-speed performance of OMVCD grown InAlAs/ InGaAs MSM photodetectors at 1.5 µm and 1.3 µm wavelength; IEEE photon.Techn. Lett. Vol.1, P.250 (1989).
7. G.K.Chang, W.P.Hong, J.L.Gimlett, R.Bhat and C.K.Nghyen; High-performance Monolithic Dual-MSM photodetector for long-Wavelength Coherent Receivers; Electron.Lett, Vol.25, P.1021 (1989).
8. W.P.Hong, G.K.Chang,and B.Rajaram; High-performance $Al_{0.15}$ $Ga_{0.35}$ "As/$In_{0.53}$ $Ga_{0.47}$ As MSM photodetertors grown by OMCVD; IEEE Trans-Electron Dev.Vol.36. p.659 (1989).
9. S.R.Forrest: IEEE J. Quant Elect; Vol.17. P.217 (1981).

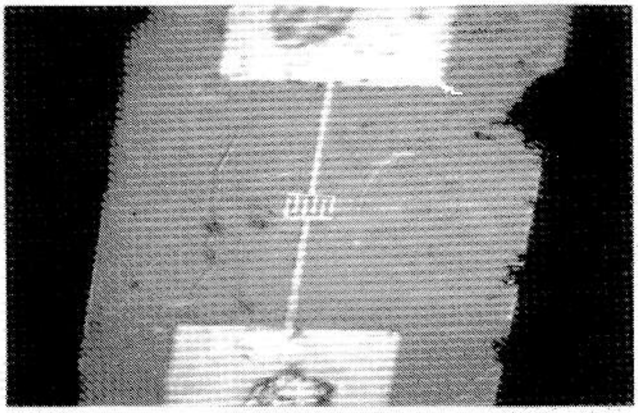

Fig.1: The interdigit photo detector structure

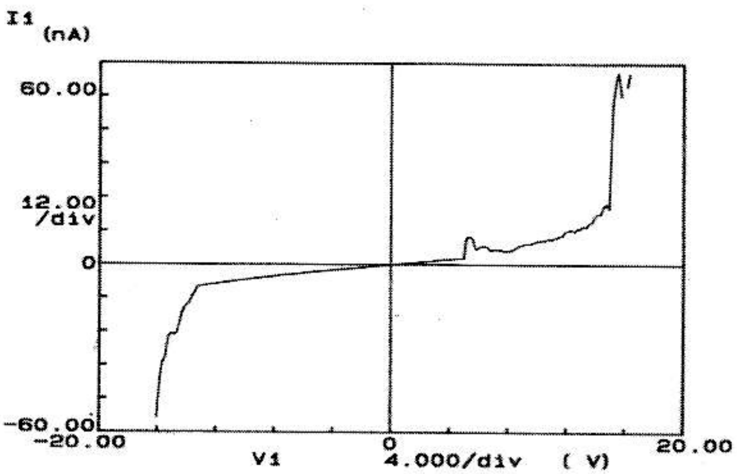

Fig.2: The current-voltage characteristics of the photodetector.

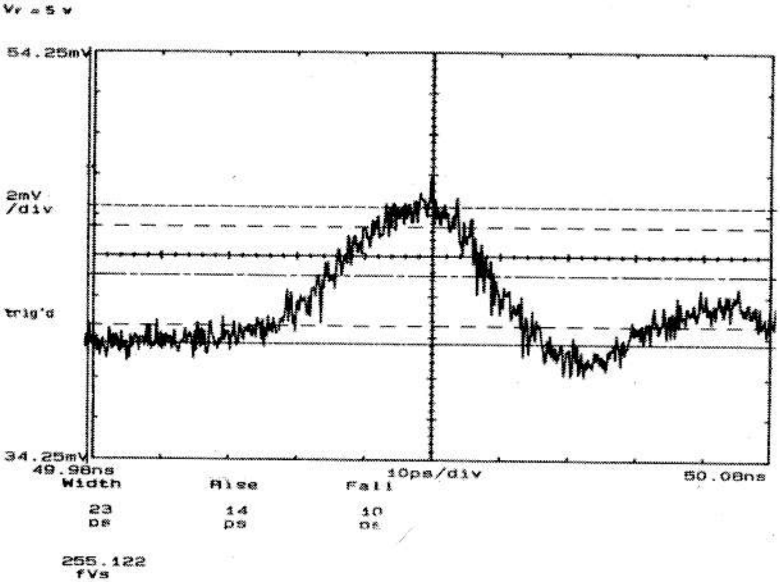

Fig.3a: Temporal photocurrent at 5 volt.

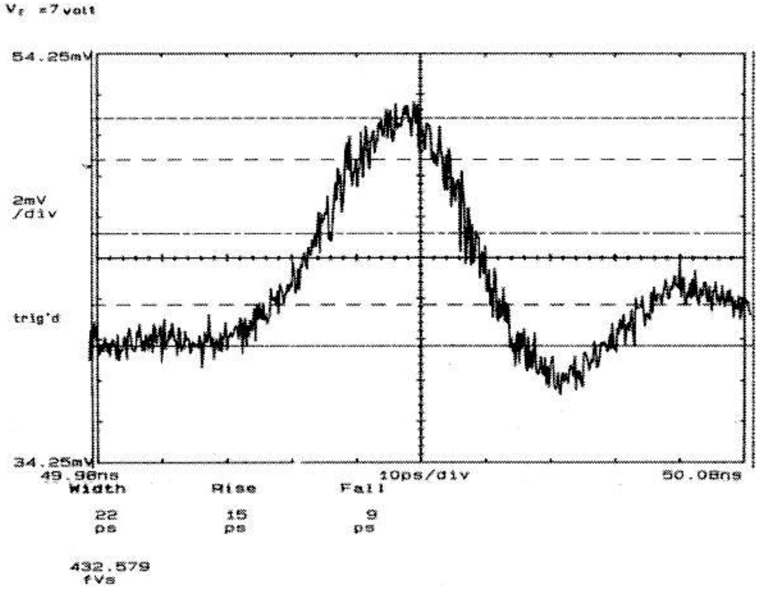

Fig.3b: Temporal photo current at 7 Volt

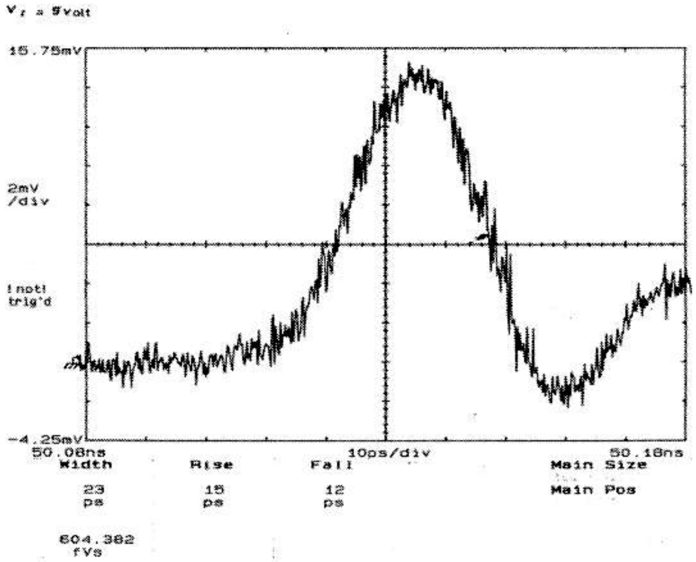

Fig.3c: Temporal photocurrent at 9 Volt.

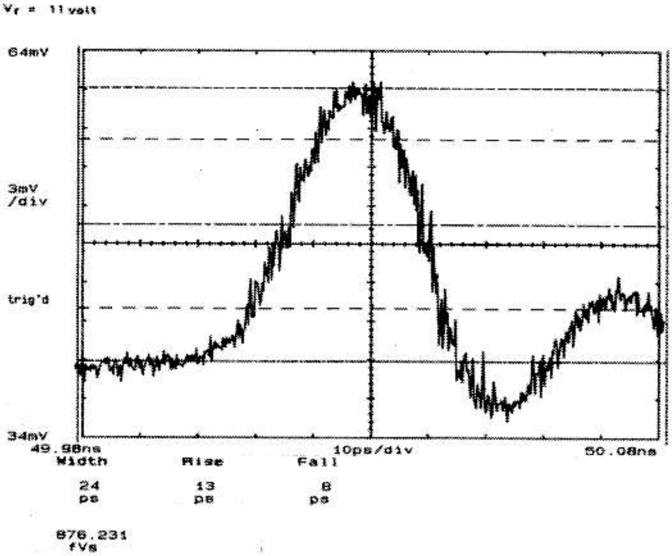

Fig.3d: Temporal photocurrent at 11 Volt

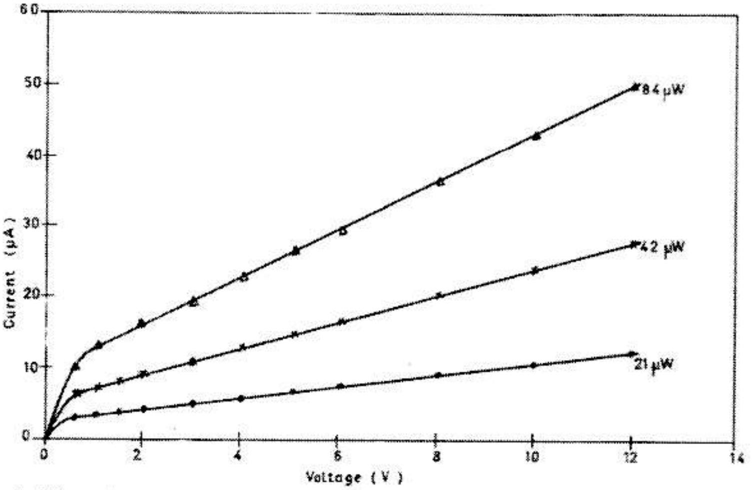

Fig.4: The photocurrent vs bias voltage under CW illumination