PLANAR DOPED BARRIER MIXER AND DETECTOR DIODES AS ALTERNATIVES TO SCHOTTKY DIODES FOR BOTH MICROWAVE AND MILLIMETRE WAVE APPLICATIONS

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ABSTRACT

Planar Doped Barrier diodes with extremely low barrier heights and highly asymmetric I-V characteristics have been developed using MBE grown GaAs material. This paper reports upon the RF performance of these devices and discusses the significant advantages offered by PDB devices over conventional Schottky diodes for mixer and detector applications at both microwave and millimetre wave frequencies.

INTRODUCTION

The advent of molecular beam epitaxial (MBE) growth techniques has enabled GaAs planar doped barrier (PDB) diode structures (n^+-i-p^+-i-n^+) to be grown (Fig. 1). These consist of a thin p^+ acceptor region within an undoped semiconductor region, bounded by n^+ donor layers. By variation of the thickness and doping concentrations of the p^+ and intrinsic regions, the barrier height and degree of asymmetry of the structure can be independently varied (1).

Recent development work at MEDL and GEC Hirst Research Centre has formulated a model for the design of a range of GaAs planar doped barrier diodes. The validity of the model has been investigated and the sensitivity of the structures to variations in material growth parameters has also been studied (3).

The design model was used to generate the material specifications for two asymmetric PDB devices: a zero bias detector diode and a low bias mixer diode. A symmetrical subharmonic mixer specification was also produced.

MATERIAL GROWTH

A number of MBE wafers were grown to the specifications generated by the design model (Fig. 2). The growth process was performed at 650°C, with silicon and beryllium introduced as the respective n and p type dopants. The typical current-voltage characteristics of these materials are shown in Figures 3-5. These were designed to operate as i) a zero bias detector (Fig. 3), ii) a low drive mixer (Fig. 4) and iii) a subharmonic mixer (Fig. 5). It can be seen that either symmetrical or highly asymmetrical structures can be grown. A range of barrier heights (determined by I-V-T measurements)from 0.2eV to over 1eV have been achieved, with the most highly asymmetrical structure grown having a reverse to forward voltage ratio of 14:1.

DEVICE MANUFACTURE

To evaluate the PDB materials at microwave frequencies test structures were fabricated, these consisted of chips with 20 µm diameter etched mesas and Au-Ge-Ni metallisation. These were mounted and wire bonded into ceramic LID packages for testing. The DC performance of the devices are summarised in Table 1. The low series resistance and low junction capacitance imply suitability for operation at microwave frequencies. However, at millimetre wave frequencies a reduction in the junction capacitance is required. For this reason an existing process for the manufacture of coplanar mixer diodes (2) was adapted for the PDB structure. The design and construction of the millimetric coplanar PDB structure has been described in detail previously (3). The planar doped barrier MBE material has thus been fabricated into the coplanar structures shown in Figures 6-8.

RF ASSESSMENT

Zero Bias Detector

Figure 3 shows that it has been possible to produce a PDB diode with the maximum curvature of the I-V characteristic close to the origin. This curvature provides the basis for the direct rectification of the incoming microwave signal in a zero bias detector. The performance of the diode, operated as a zero bias detector at 9.4GHz, is shown in Table 2. Comparison is made with a zero bias silicon Schottky diode. Although similar voltage sensitivities are achieved, the PDB diode offers a 2 dBm improvement in Tangential Sensitivity.

Results of the millimetric performance of the PDB material will be presented at the Conference. Silicon Schottky diodes are presently used as zero bias detectors at millimetre wave frequencies. It is envisaged that the GaAs PDB device will offer not only improvements in Tangential Sensitivity at these frequencies, but also an increased voltage sensitivity and increased dynamic range.

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Low Drive Mixer

The performance, at 9.4GHz, of the PDB structures in a single ended mixer circuit are shown in Table 3. Comparisons are made with a Standard GaAs Schottky mixer diode. It can be seen that the PDB diodes are capable of achieving low overall noise figures with local oscillator drive levels ranging from 280µW to 1.4mW, depending upon the PDB barrier height. This should offer advantages to systems where limited local oscillator power levels are available, in particular at millimetre wave frequencies.

An initial assessment has shown that the low frequency noise generation (IF<1MHz) is significantly less for the PDB diode than for either Si or GaAs Schottky diodes. A detailed study is currently being undertaken to accurately assess 1/f noise.

Figure 9 compares the performance of DC1301 GaAs Schottky diodes with CB46 PDB diodes. Measurements were made in a balanced mixer circuit over the frequency range 9-11 GHz. Similar performances were achieved under the operating conditions shown. However, upon a reduction in the input power level lower conversion losses were achieved by the PDB devices.

Burnout Capability

The CW and pulsed burnout performance of the PDB diodes are shown in Table 4. The devices were matched into a 50Ω microstrip circuit at low incident power levels, but at high levels the measurements do not take into account the extent of the reflected power. Relatively, however, it can be seen that under pulsed conditions the PDB diode offers a considerable improvement over conventional Schottky diodes and even over Schottky diodes protected by a NIP limiter diode in parallel.

CONCLUSION

It has been possible to design and manufacture planar doped barrier diodes for operation as mixer and detector diodes at microwave and millimetre wave frequencies. Results obtained to date have suggested considerable advantages may be offered by the use of PDB diodes. In particular by the reduced mixer driver levels, the reduced low frequency noise generation, the improved detector Tangential Sensitivity and the general reliability improvements as a result of the burnout performance.

ACKNOWLEDGEMENT

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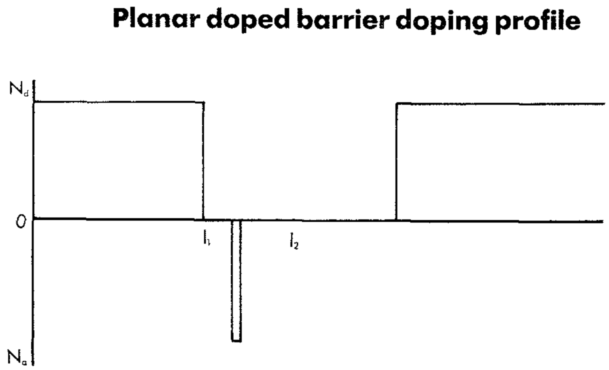


Figure 1.

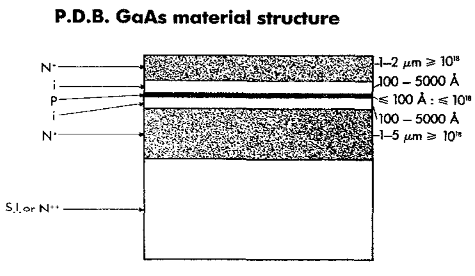


Figure 2

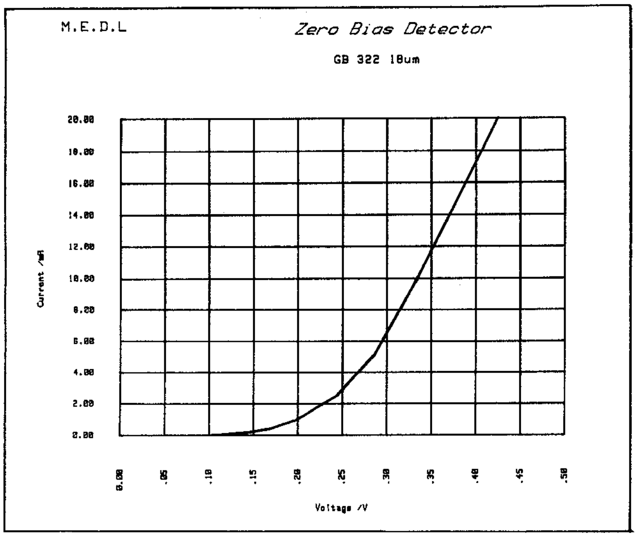


Figure 3a.

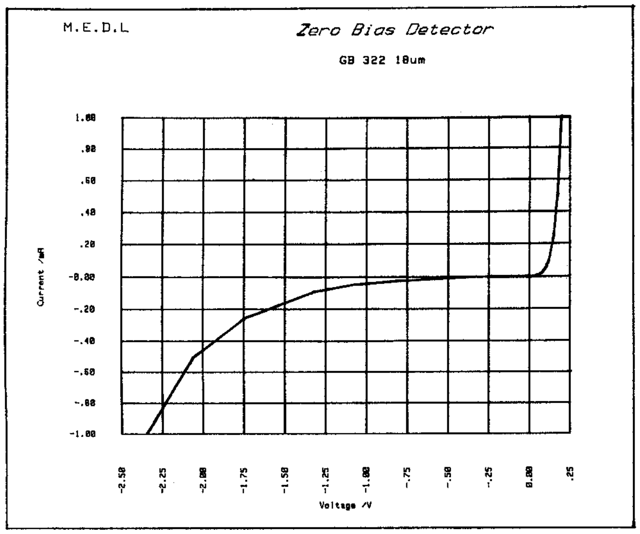


Figure 3b.

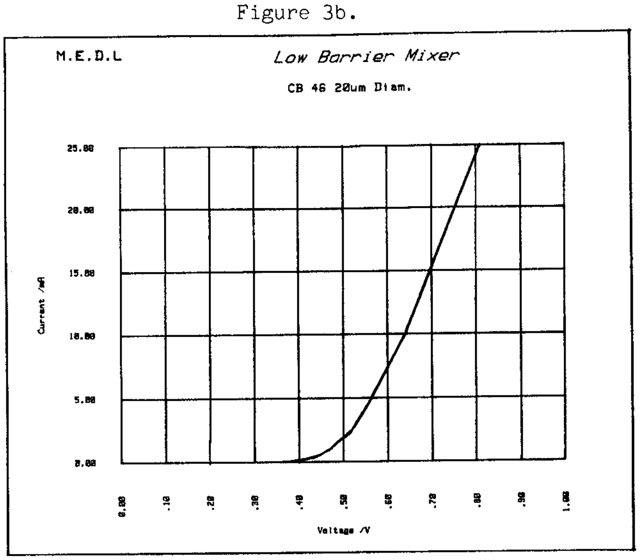


Figure 4a.

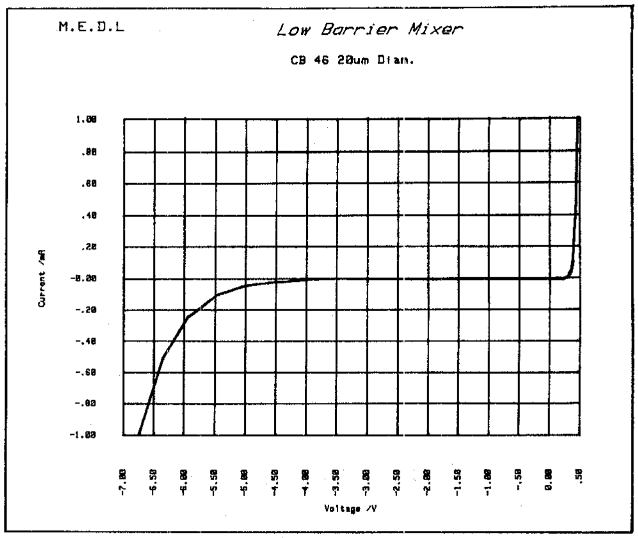


Figure 4b.

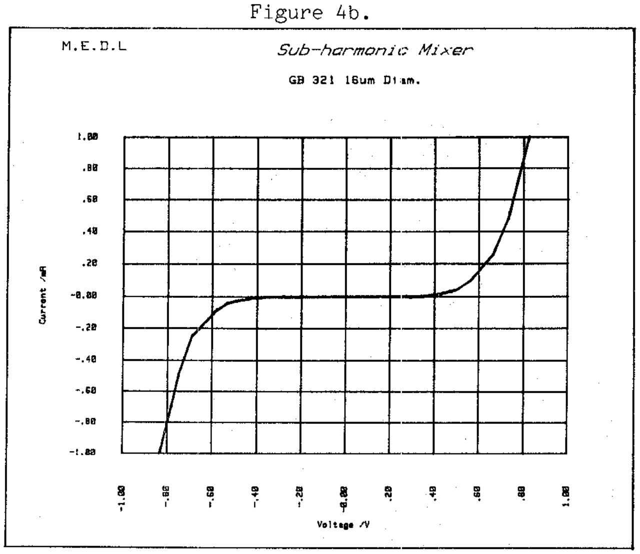


Figure 5a.

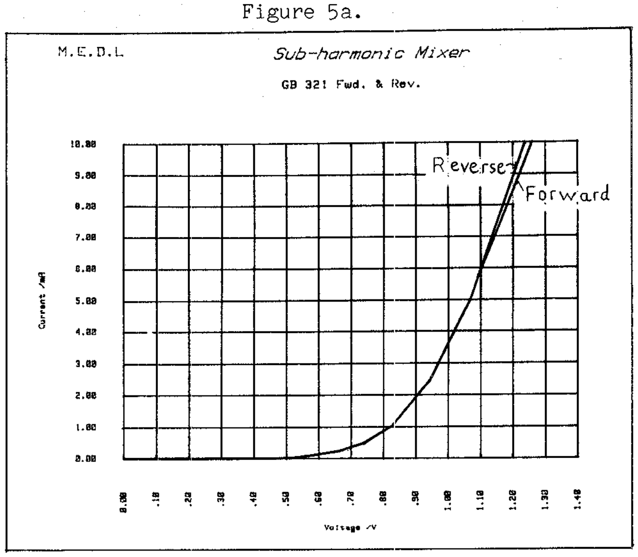


Figure 5b.

Cross section of P.D.B. coplanar diode

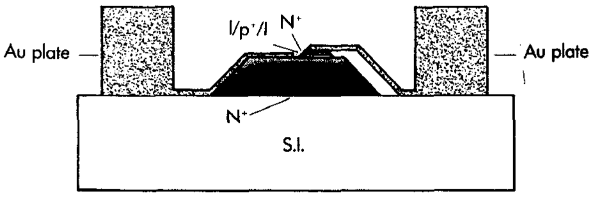
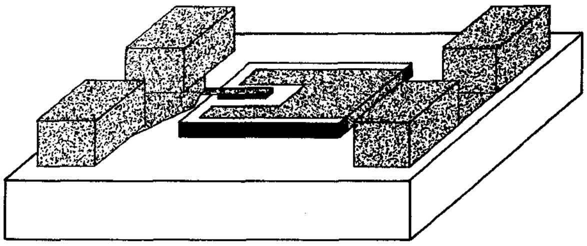


Figure 6.

Schematic P.D.B. coplanar diode



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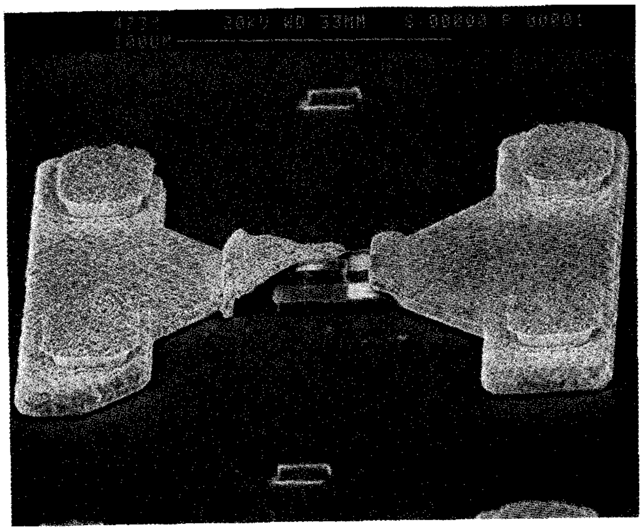

Figure 8: SEM of coplanar PDB diode

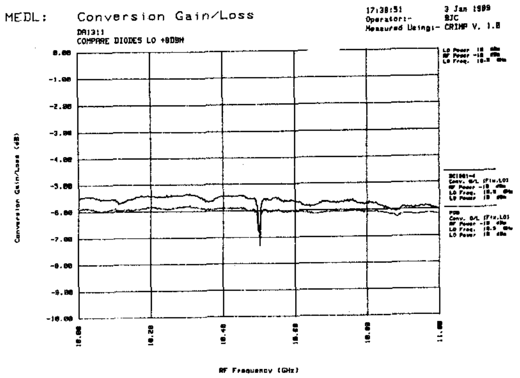

Figure 9.

Measured characteristics of P.D.B. diodes

	Zero Bias Detector (GB 332)	Low Barrier Mixer (CB 46)	Subharmonic Mixer (GB 321)
Reverse Voltage @ 10μA/V	0.45	4.1	0.37
Reverse Voltage @ 100μA/V	1.34	5.45	0.56
Forward Voltage @ 100μA/V	0.13	0.38	0.56
Junction Capacitance ff	53[1]	60	53[1]
Series Resistance @ 10ma/Ω	10	12	35
Ideality Factor 1–10μA	–	1.17	2.5

NOTE: [1] Calculated values

Table 1.

Zero Bias Detection at 9.4GHz

	PDB DB322/DB866	Zero bias Si Schottky DC1553
Video Impedance $I_b = 0$	2-10 kΩ	1-8kΩ
Tangential Sensitivity (1MHz Video Amp Band-width, 4dB N.F.).	56-57dBm	54-55dBm
Voltage Sensitivity $R_L > 10M\Omega$	6500mV/mW	6500mV/mW

Table 2.

9.4GHz Single Ended Mixer Performance

	PDB DB866/DB322	PDB CB46	GaAs Schottky DC1301
O.N.F. (1.5dB pre amp Noise figure)	6.0dB	6.6dB	6.0dB
L.O. Input Power	280μW	1.4mW	1.5mW
V.S.WR.	1.3:1	1.3;1	1.3:1
IF Impedance Zif	260Ω	300Ω	-

Table 3.

Burnout Performance at 9.6GHz

	PDB DB866/322	PDB DB46	Medium barrier Si Schottky diode DC1506	NIP protected Schottky DC1596
Pulsed Burnout Pulse rate 1000 p.p.s. Pulse length .1μs Test time = 1 minute	200-400W	500-600W	0.5-1W	25-35W
CW operation	.4 - .6W	Not measured	.2 - .4W	Not measured

Table 4.