COMPLEMENTARY X-BAND TRAPATT DIODES

T.T. Fong and R.S. Ying

Hughes Aircraft Company
Hughes Research Laboratories
Torrance, California 90509

ABSTRACT

X-band n^+p TRAPATT diodes have been fabricated and have shown better performance than their p^+n complement. The low threshold power densities required to achieve the high efficiency oscillation have greatly enhanced their high duty and CW operation. The fabrication techniques for these high frequency devices and their performance in both pulsed and CW modes will be discussed.

INTRODUCTION

Recent theoretical consideration based on a simple device model[1] has shown that n^+p TRAPATT devices should have superior performance over the p^+n devices because of the lower overvoltage requirement for initiating the trapped plasma. This is due to a lower ionization coefficient of holes than electrons in silicon. A more complete analysis[2] showed that the existence of a negative electric field in the n^+p TRAPATT diode prior to the formation of the trapped plasma state causes carrier injection through the n^+ contact. The injected electron current can greatly enhance the trapped plasma density and thus in turn improve the TRAPATT performance. Experimentally, superior performance has been observed at L-band[3] and recently at C-band[4] frequencies. This paper presents recent results obtained with X-band complementary TRAPATT diodes. In particular, the results pertaining to the high efficiency CW and high duty operations of these devices will be presented.

DEVICE FABRICATION

In order to reduce the interface defects at the epitaxial p and p^{++} substrate to prevent premature burnout and to minimize the out diffusion from the substrate, a buffer p^+ epi-layer is grown on p^{++} substrate prior to the deposition of the p epi-layer. The junction is formed by a shallow phosphorus diffusion at low temperature into the p type epi-layer. The substrate side of the wafer is then thinned chemically to a thickness of approximately 15 μm. Chromium, platinum and gold metallization is applied to both sides of the silicon slice. The wafer is then either large-area thermocompression bonded to a copper disc for pulse mode operation or mesa etched into small pucks to be bonded on metallized diamond heat sinks for CW operation. The finished diodes are then packaged into a mini-disc package consisting of a ceramic ring with 30 mil I.D., 50 mil O.D. and 15 mil in height. Details of the diode fabrication, diamond heat sinks, and packaging will be presented.

DEVICE PERFORMANCE

Some typical microwave test results obtained with the complementary X-band TRAPATT diodes are presented in Table I. The results were obtained in an X-band coaxial oscillator circuit with low impedance tuners. Peak power levels of 12-18 W have been routinely achieved with conversion efficiencies around 30% on copper heat sinks. The junction diameter is typically 4 mils. To illustrate the advantages of the complementary diodes as compared to the p^+n TRAPATT diodes, Fig. 1 presents the peak power output as function of input power density for a complementary diode and a p^+n diode. Both diodes have approximately the same junction area, and both diodes have output powers peaked at about 7.2 GHz in the same circuit. It is seen that the complementary diode has (1) lower threshold input power density and (2) a higher efficiency and peak power. In the CW or high duty operation, the devices must be operated at a reduced input power density because of thermal considerations. In such a case, the complementary diode is seen to have almost a factor of two higher efficiency than the p^+n diode, and therefore is a superior candidate for CW and high duty operation.

In conjunction with the pulsed devices on copper heat sinks, considerable work is also being devoted to the CW mode operation with complementary X-band TRAPATT diodes on diamond. At the time of this summary, power output of 3 W with 14% efficiency has been achieved as an oscillator at 7.2 GHz. Thermal considerations as well as thermal resistance data along with further CW results will be presented.

CONCLUSION

X-band n^+p TRAPATT devices have been fabricated and have shown superior performance as compared to its complement. The low threshold input power density requirement and high efficiency capability at low current density have greatly enhanced the CW and high duty operation of TRAPATT diodes.

REFERENCES

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2. C.A. Lee and J. Frey, "Comparison of Plasma Formation in n^+p and p^+n TRAPATT Diodes," Electronics Letters, Vol 9, No. 14, July 1973.

3. R.W. Bierig, R. Bera, and M.R. Harris, "Complementary TRAPATT Diode Oscillators," presented at 1972 IEEE International Solid State Circuits Conference, Feb. 1972.

4. R.S. Ying and T.T. Fong, "C-Band Complementary TRAPATT Diodes," to be published in IEEE Proc. (Lett.), Feb 1974.

TABLE 1

X-BAND COMPLEMENTARY TRAPATT PERFORMANCE ON COPPER HEAT SINKS

LOT NO.	V_{BD} (VOLTS)	V_{BIAS} (VOLTS)	I_{BIAS} (AMPS)	P_O (W)	η (%)	FREQ. (GHz)	DUTY (%)	C_O
SPA 33	33	24	2.2	14	27	9.4	1	2.7
SPA 34	31.5	21	3.0	18	28	8.9	1	2.8
		21	1.15	5	21	8.7	30	2.4
							(2 μs PULSE)	
SPA 36	27	20	2.0	12	30	10.5	1	2.5
		18	1.3	6	26	11.6	1	2.1
SPA 37	28	19	2.5	14	29	10.2	1	2.6
SPA 38	28	20	2.6	15	29	9.5	1	2.9
		19	1.25	8	33	10.2	1	1.9
		20	1.0	4.5	22.5	9.2	30	2.1
							(2 μs PULSE)	

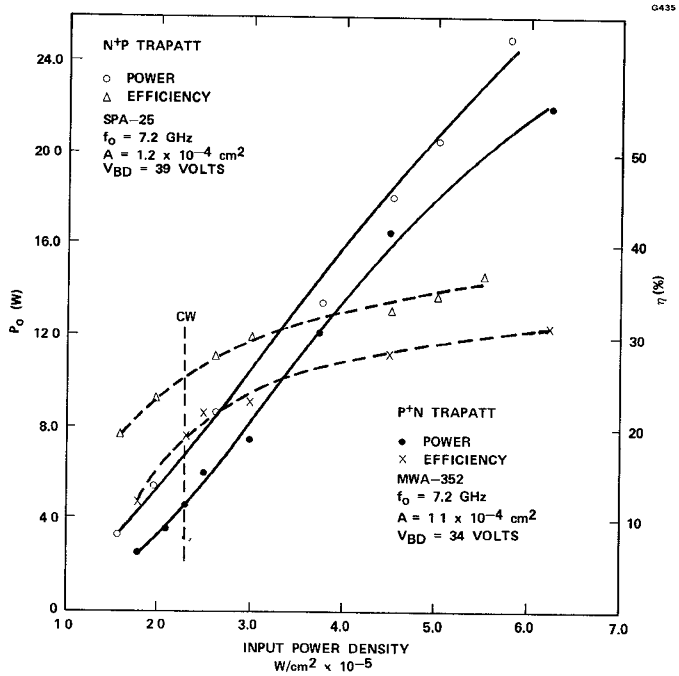

Fig. 1 A comparison of performance of a complementary TRAPATT diode versus a p^+n TRAPATT diode.