V-BAND DOUBLE-DRIFT READ SILICON IMPATTS

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ABSTRACT

Double-drift hybrid Read silicon IMPATTs have been fabricated in the millimeter-wave frequency range with RF performance superior to that of more conventional double-drift flat diodes. State-of-the-art output power of 2.15 W was obtained at 60 GHz with 8.8 percent efficiency. The best DC-to-RF conversion efficiency achieved was 12 percent.

INTRODUCTION

Double-drift silicon IMPATTs have been most widely used for medium-to-high solid-state power source applications in the millimeter-wave frequency range. Although, in theory, the Read structures could generate superior performance, most of the present high performance double-drift silicon IMPATTs have flat profiles,[1-3] partly because of the difficulty in the material growth for the more complex Read structures. There has been steady progress in the performance of millimeter-wave double-drift flat silicon IMPATTs during the past decade. However, the performance of these diodes was somewhat saturated in recent years as the silicon technology became more matured.

Read structures provide a more confined avalanche region, resulting in improved current-voltage phase relationship for the optimum RF performance. As a first step, a double-drift hybrid Read structure was selected for ease of material growth. The n side of this structure has a hi-lo profile while the p side has a flat profile. Figure 1 shows the design profile of a 60 GHz double-drift hybrid Read IMPATT diode.

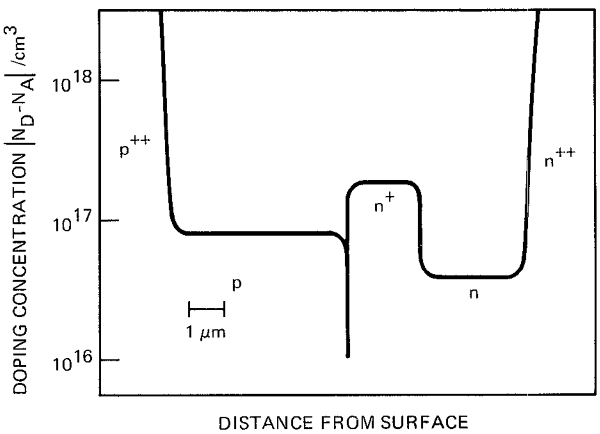

Fig. 1 Doping profile of 60 GHz double-drift hybrid Read silicon IMPATT diode.

DEVICE FABRICATION

The diodes were fabricated by growing an n-type epitaxial layer on an n^{++} arsenic-doped silicon wafer, followed by n^+ and p epi layers. Then, a thin p^{++} contact layer was formed by a low temperature boron diffusion. Cr-Pt-Au contact metallization was utilized on the epi side and Cr-Au metallization on the substrate side of the wafer for reliable diode operation. The wafer was thinned down to as low as 5 μm to minimize the series resistance. Over 10,000 mesa diodes were fabricated from a 2-inch diameter wafer by photolithography and chemical etching.

The diodes were thermocompression-bonded on diamond heatsinks to reduce the thermal resistance. The diodes were then mounted in a miniature quartz-ring package. The lead inductance was controlled by changing the ribbon configuration. The measured thermal resistance of V-band IMPATT diodes, fabricated from a double-drift hybrid Read silicon wafer, is plotted in Figure 2 as a function of diode zero-bias capacitance. The thermal resistance of these diodes was slightly higher than that of double-drift flat diodes because of the narrower depletion width in the n^+ region at zero-bias.

RF PERFORMANCE

The RF performance of the double-drift hybrid Read diodes was evaluated in a coaxially coupled reduced-height waveguide cavity.[4] This circuit has proven to provide wide range of impedance match to the diode over wide frequency range. The circuit impedance was optimized mainly by adjusting the coaxial sections of the cavity and the sliding tuning short. Figure 3 represents a typical RF performance of a double-drift hybrid Read silicon IMPATT diode. The circuit was tuned for optimum output power at each bias level. The diodes were operated especially well at high bias currents maintaining clean output signal up to the highest output power level. A typical spectrum analyzer display at a high power point is shown in Figure 4.

Most of the double-drift hybrid Read IMPATT diode lots fabricated thus far have generated maximum output power over 1.5 W at an elevated junction temperature. The highest output power was 2.15 W at 59.8 GHz. The best efficiency achieved from a smaller size diode was 12 percent.

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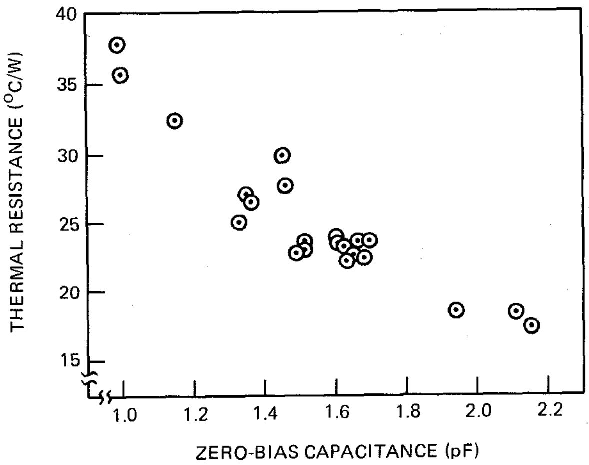

Fig. 2 Measured thermal resistance of V-band double-drift hybrid Read silicon IMPATT diodes.

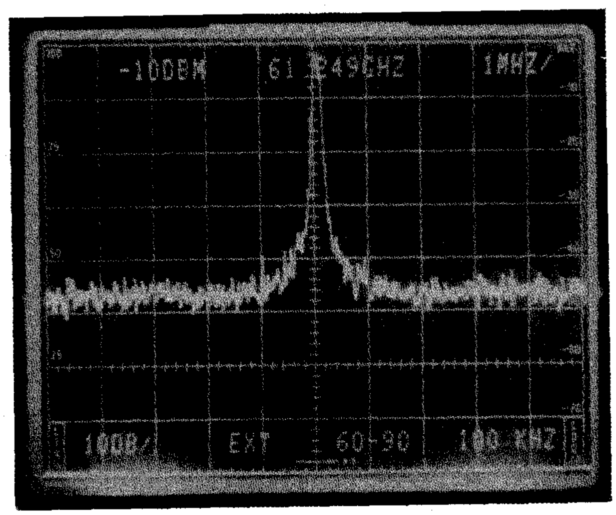

Fig. 4 Spectrum analyzer display of a higher power double-drift hybrid Read silicon IMPATT diode.

CONCLUSION

State-of-the-art RF performance was achieved at 60 GHz from double-drift hybrid Read silicon IMPATTs. The diodes appeared to be operating especially well at higher bias currents and maintained clean signal up to the highest output power level. Read-type structures can be applied for performance improvement of silicon IMPATTs at other millimeter frequencies.

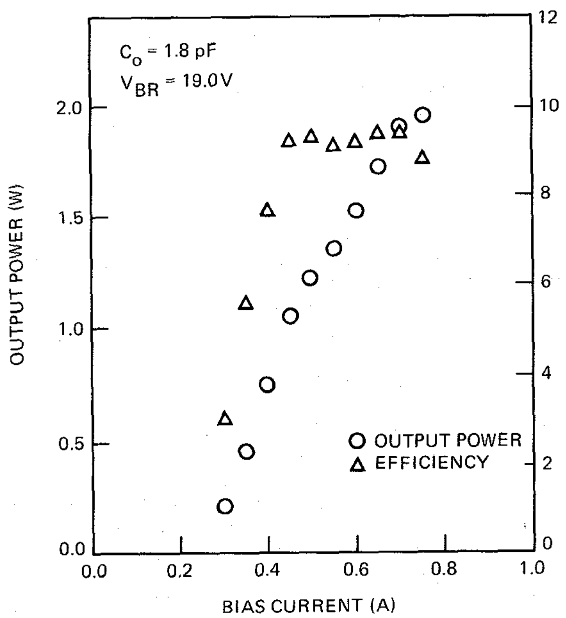

Fig. 3 RF performance of a 60 GHz double-drift hybrid Read silicon IMPATT.

ACKNOWLEDGEMENT

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REFERENCES

(1) T. A. Midford and R. L. Bernick, "Millimeter-wave CW IMPATT Diodes and Oscillators," IEEE Trans. Microwave Theory Technique, Vol. MTT-27, pp. 483-492, May 1979.

(2) H. S. Gokgor, et al, "High-Efficiency Millimeter-wave Silicon IMPATT Oscillators," Electronics Letters, Vol. 17, pp. 744-745, Oct. 1981.

(3) M. Heitzmann and M. Boudot, "New Progess in the Development of a 94 GHz Pretuned Module Silicon IMPATT Diode," IEEE Trans. Electron Devices, Vol. ED-30, pp. 759-763, July 1983.

(4) Y. Ma and C. Sun, "Millimeter-wave Power Combiners at V-band," Proceedings of Seventh Biennial Cornell Electrical Engineering Conference, Vol. 7, pp. 299-308, 1979.