BEAM-LEAD SCHOTTKY-BARRIER PLANAR MIXER DIODES FOR MILLIMETER WAVE APPLICATIONS

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ABSTRACT

Millimeter wave planar Schottky barrier mixer diodes with beam leads, low parasitics and one micron fingers have been developed for 35 GHz, 95 GHz and 140 GHz operation. Preliminary characterization of dual-finger mixer diodes has resulted in a double sideband noise figure of 4.0 dB at 36 GHz and 8.9 dB at 94 GHz (including 1.6 dB NF from the IF preamp). Design, fabrication, and experimental performance of these diodes is reported for 35 GHz and 95 GHz balanced mixers.

Introduction

Planar, beam-lead Schottky-barrier diodes offer a low cost alternative to whisker contacted diodes for millimeter wave mixer applications. The reproducible planar approach provides high yields with most of the processing similar to that of GaAs FETs. The proton-implant device isolation technique first reported by workers at Lincoln Labs is used to confine the active area.(1) Schottky barrier, beam-lead diodes have been designed and fabricated with minimum metallization to further reduce the parasitic capacitance.

Design Considerations

Broad band, low noise performance at millimeter wave frequencies requires a diode of very low capacitance as well as high cutoff frequency. Although junction capacitance is relatively easy to reduce by restricting the size of the Schottky fingers, parasitic capacitance due to lead metallization must also be minimized. Figure 1 shows a dual-finger diode with a $16\mu m^2$ active area with both leads optimized for minimum parasitic capacitance near the junction. The width of the ohmic contact metallization ($3\mu m$) surrounding each Schottky barrier finger was limited to twice the current transfer length ($L_T = \sqrt{\rho_c/R_\square}$), to further reduce the parasitic capacitance. Four diodes of different design were fabricated with progressively smaller junction areas. The two largest junctions ($32\ \mu m^2$ and $16\mu m^2$) were formed with two fingers to reduce the effective line resistance of the $1\mu m$ wide Schottky barrier metal.

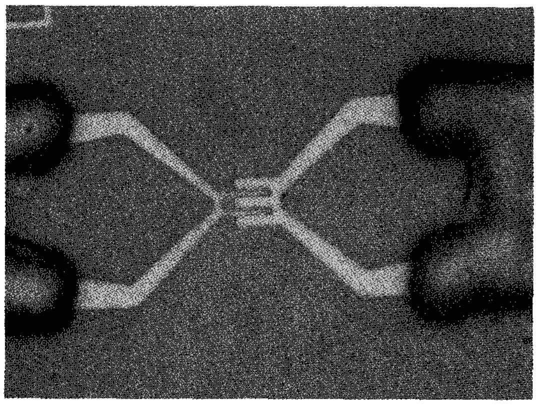

FIGURE 1: MICROPHOTOGRAPH OF BEAM-LEAD SCHOTTKY BARRIER DIODE WITH DUAL ONE-MICRON FINGERS.

Fabrication

Diodes were fabricated on two-layer VPE material grown by the hydride process (AsH_3,HCl,Ga,H_2) on GaAs:Cr substrates. The first n^+ layer was doped 2×10^{18} cm^{-3} and was $2\mu m$ thick. While the top layer was $8 \times 10^{16} cm^{-3}$, thinned down to 1000Å, forms a Mott barrier when metallized. The transition from the low doped to high doped region were reproducibly 200 ± 50Å per decade. The junction capacitance of diodes fabricated on this material is nearly independent of voltage and has been shown to result in a low LO power requirement, when properly matched.(2)

A direct liftoff technique was used to form both the Schottky barrier (TiW/Au) and ohmic contact (Au/Ge/Ni/TiW/Au) metallizations, thus limiting the metal thickness to 2000Å. The diode active area was isolated using the proton bombardment technique with a $3\mu m$ thick Au film to protect the active region.

Several processing and device design patterns were incorporated into the mask design. These patterns include diodes with four terminals to measure individual contributions to series resistance, variable spaced metal bars to measure ohmic contact line resistance and epitaxial layer sheet resistivity, and isolation test patterns to measure the effectiveness of the proton implant.

Results

RF measurements of the $16\mu m^2$ junction area device (D2) have been made at 35 and 95 GHz. The dc characteristics of the diode are; diode ideality, 1.07; junction capacitance, 20fF; parasitic capacitance, 15fF; and series resistance 14 ohms. Two diodes were mounted in a crossbar circuit and tested from 26 to 40 GHz. Figure 2 shows the DSB noise figure (including 1.6 dB NF from the IF amplifier) as measured with a noise source and 30 MHz IF over the band with the best performance (4 dB) at 36 GHz. Mechanical tuning was used for LO and RF matching. Figure 3 shows the noise figure as a function of the LO power. The conversion loss at 35 GHz was 6.4 dB, giving an RF effective diode ideality of 1.4. Such small deviations between the DC and RF measured idealities indicates little contribution to overall noise from the diode itself. The same diode was tested in two different crossbar circuits at 95 GHz. The DSB noise figure dependence on LO power shown in Figure 4 was obtained from Y factor measurements using hot and cold loads. The best result obtained was 8.9 dB.

For balanced mixer applications, a matched pair of diodes is required for optimum performance and maximum RF-LO port isolation. Taking advantage of short range uniformity across a processed wafer, a closely spaced diode pair was designed (Figure 5). The diode pair was fabricated with beam leads for a low cost assembly in a suspended substrate. This device is presently being tested at millimeter wave frequencies.

Conclusion

Planar beam lead diodes fabricated with optimum design criteria have shown excellent mixer performance at mm wave frequencies. The fabrication process is low cost and highly reproducible, and the diode structure is extremely rugged. The circuit designer can now depend upon rigid diode parameters for optimum design and consistent performance.

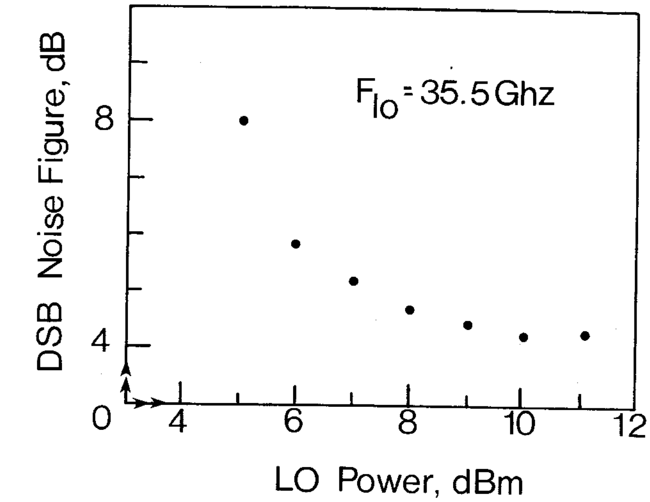

FIGURE 3: NOISE FIGURE DEPENDENCE ON LO POWER.

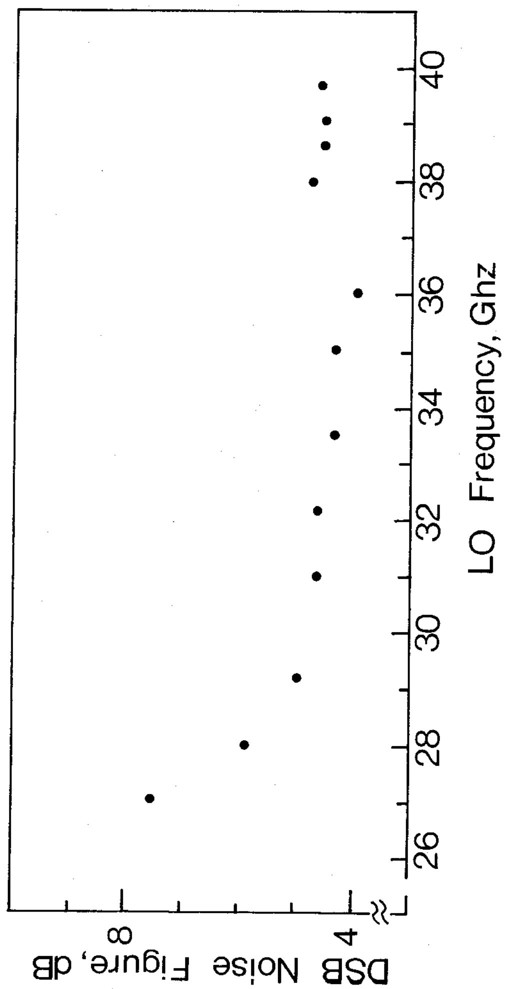

FIGURE 2: MEASURED DOUBLE SIDEBAND NOISE FIGURE VS. LO FREQUENCY FOR DUAL FINGER PLANAR MIXER DIODE AT K_A-BAND (MECHANICAL TUNING)

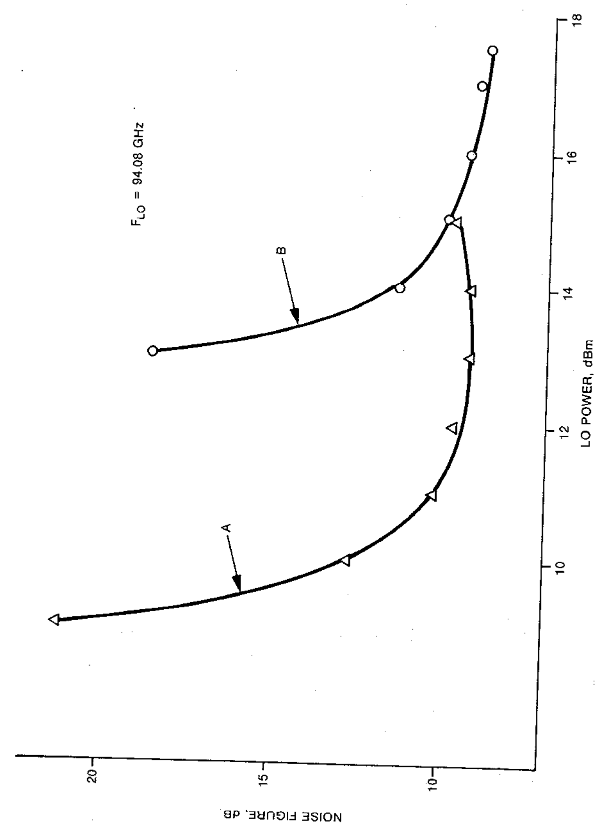

FIGURE 4: NOISE FIGURE DEPENDENCE ON LO POWER FOR TWO CIRCUITS.

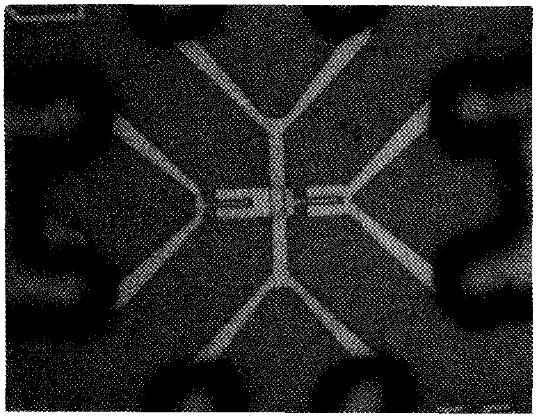

FIGURE 5: MICROPHOTOGRAPH OF PROXIMITY MATCHED BEAM LEADS DIODE PAIR.

Acknowledgements

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References

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