MILLIMETER-WAVE MONOLITHIC GUNN OSCILLATORS*

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ABSTRACT

A millimeter-wave monolithic GaAs Gunn oscillator has been designed, fabricated and tested. Epitaxial layers were grown by conventional vapor phase epitaxy on semi-insulating substrate. The matching circuit and bias circuitry were monolithically fabricated on the same chip as the active device. With no external tuning, the oscillator chip delivers 1 mW and 1.5 mW at 68.4 GHz and 44.9 GHz, respectively. The best performance was achieved at 41.6 GHz with 4 mW output power. This is the first fully monolithic Gunn oscillator ever reported at these frequencies.

INTRODUCTION

Interest and activity in low cost, compact size, light weight millimeter-wave systems using planar hybrid integrated circuit technologies has been rapidly increased over the past few years. Components utilizing monolithic integrated circuit techniques on semi-insulating GaAs substrate are being developed to further reduce the components' cost, size and weight. To meet the increasing requirements of compact millimeter-wave systems, high power, high efficiency solid-state planar sources are required for easy adaptation and compatibility in monolithic integrated circuits. Gunn devices can generate sufficiently high power at millimeter-wave frequencies as either local oscillators or transmitters in a FMCW system. However, technological problems associated with providing an efficient heatsinking and electric grounding has prevented thus far the realization of a fully monolithic Gunn device. This paper describes the development of a novel millimeter-wave monolithic oscillator using GaAs Gunn diode as its active device.

DESIGN AND FABRICATION

Design

In theory, converting the discrete Gunn oscillator into a monolithic form possesses no particular difficulties; however, because of poor thermal conductivity of GaAs and low dc to RF conversion efficiency of a Gunn device, efficient heatsinking is essential for the successful realization of a monolithic Gunn oscillator. By using a flip chip design whereby the diode is sitting directly on the heatsink, the thermal problem is greatly reduced. Figure 1 shows a schematic diagram of the developed monolithic Gunn oscillator. The Gunn device is connected to the RF matching circuit on the back side of the substrate through an integrated via hole. The parasitics associated with the via hole form part of a resonant structure which determines the oscillation frequency and provides an impedance match to the matching circuit. Since a Gunn diode operating at millimeter-wave frequencies exhibits a low impedance level, the matching circuit consisting of several transformers was designed to match to the 50 ohms external circuit. The bias circuit is a low pass filter with a cutoff frequency of 20 GHz.

Fabrication

The Gunn structures were grown by vapor phase expitaxy on semi-insulating substrate. The main features of the fabrication techniques for the monolithic Gunn oscillator are shown in Figure 1. First, an ohmic metal was selectively plated onto the wafer to form the top metal contact for the diode. The diode geometry was defined by mesa etching away the unwanted top n+ and the n active layers. Second, a ring geometry of metal was plated onto the bottom n+ layer to form the ohmic contact for the bottom layer of the diode. After the ohmic contacts were alloyed, the diode area was

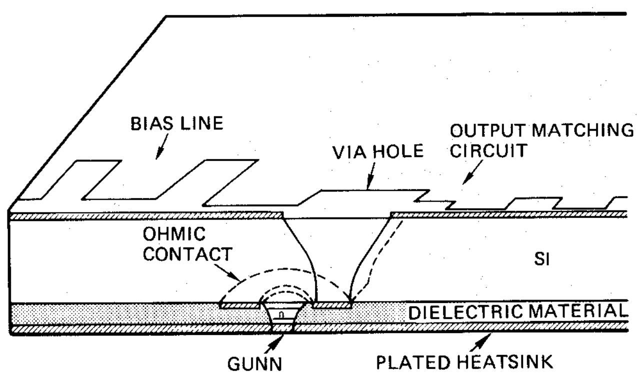


Figure 1. A schematic diagram of a monolithic GaAs Gunn oscillator.

*This work is supported in part by Hughes IR&D project and in part by ET&D Laboratory, U.S. Army LABCOM, Fort Monmouth, N.J. under contract No. DAA101-85-C-0396.

CH2478-6/87/0000-0011$01.00 © 1987 IEEE

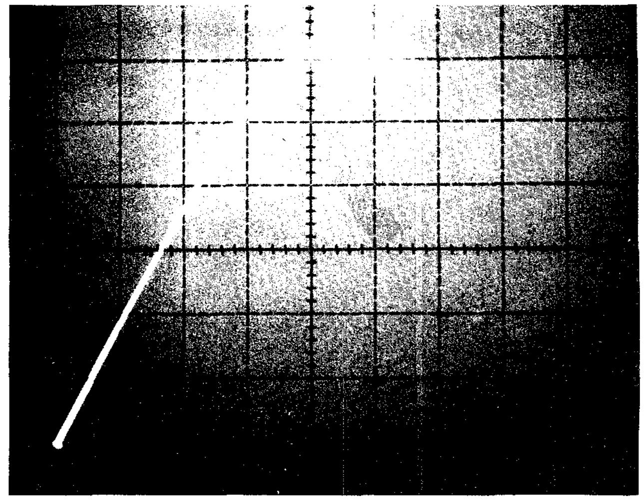
protected by photoresist and any remaining bottom n+ layer was completely etched away. A dielectric layer of polyimide (5-10μm) was deposited over the whole wafer surface, then a via hole was opened in the dielectric layer above the first top ohmic metal. A 2 to 3 mils gold layer was electroplated on the polyimide to form the heatsink. The substrate was thinned to a 4 mils thickness, and the wafer was then flipped over for the backside processing. Another via hole was formed above the second top ohmic metal to enable the device to circuit connection. The metallization for the via hole and the oscillator biasing circuit were formed by selective E-beam and gold electroplating techniques. Finally, individual oscillator chips were separated by sawing with a computerized, high precision microautomation saw.

RF PERFORMANCE

The completed oscillator chip, as shown in Figure 2, was mounted in various test fixtures for dc and RF evaluation. A typical dc characteristic of a monolithic Gunn diode is shown in Figure 3. The RF power generated is coupled to the waveguide through microstrip-coax-waveguide transition. For Q-band operation we achieve an output power of 4 mW and 1.5 mW operating at 41.6 GHz and 44.9 GHz, respectively. For V-band operation, we achieve an output power of 1 mW operating at 68.4 GHz. Frequency spectra of typical monolithic Gunn oscillators at Q- and V-bands are shown in Figures 4 and 5, respectively. Without any external cavity, the spectra are very clean.

SUMMARY

Processing techniques for monolithic two-terminal oscillator were developed and successfully utilized to fabricate monolithic GaAs Gunn oscillators with 1 mW 4 mW power available for Q-band and V-band applications. The results achieved show strong promise for future monolithic integrated system application and work is continuing.



VERTICAL SCALE = 50 mA/DIV
HORIZONTAL SCALE ≈ 0.5 V/DIV

Figure 3. A typical I-V characteristic of monolithic GaAs Gunn diode.

ACKNOWLEDGMENT

The authors would like to thank Mike Barger, Ming Hu and M. Tran for their technical assistance, and Dr. C.P. Wen and Mr. R.S. Ying for their guidance and encouragement. The author would also like to thank Dr. H. Bowers of Hughes and Mr. S. Dixon of Army LABCOM for their support.

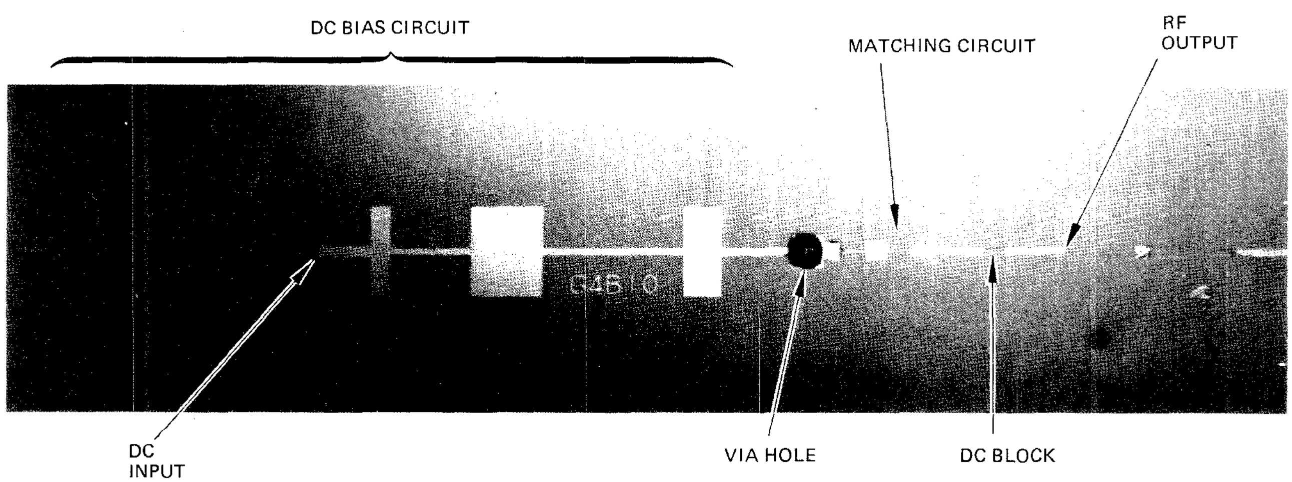


Figure 2. A photograph of a completed millimeter-wave monolithic Gunn oscillator chip.

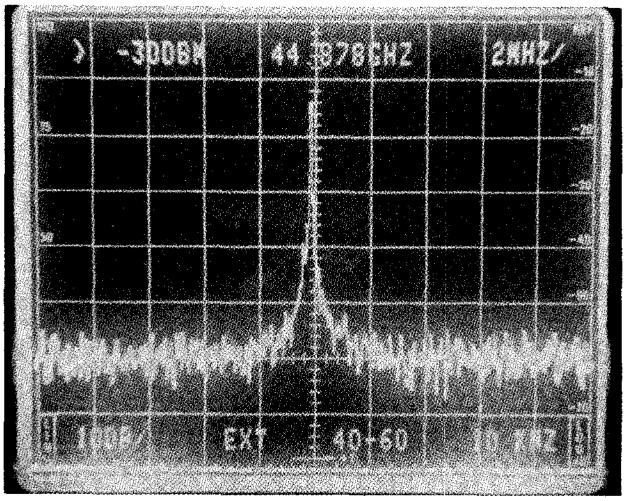


Figure 4. Frequency spectrum of a monolithic GaAs oscillator at Q-band.

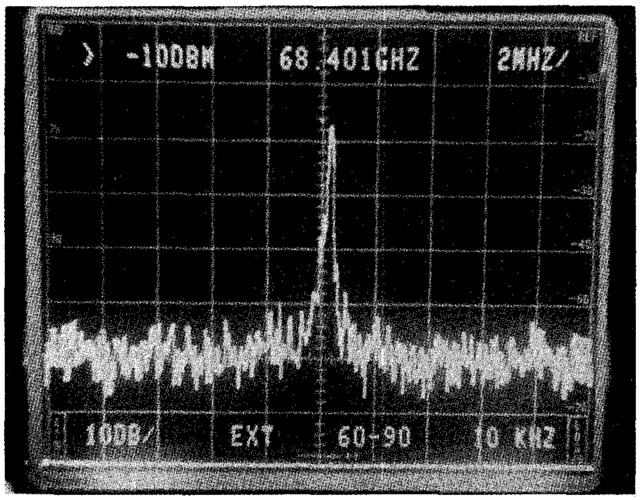


Figure 5. Frequency spectrum of a monolithic GaAs Gunn oscillator at V-band.