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Millimeter-Wave GaAs Schottky-Barrier IMPATT Diode

Kiyoshi Nawata, Mutsuo Ikeda and Yasuhiro Ishii
Musashino Electrical Communication Laboratory
Nippon Telegraph and Telephone Public Corpration
Musashino, Tokyo

Introduction. Recent experimental observations on a Schottky-barrier GaAs IMPATT diode for F-band operation are presented. The diode slices were thinned to 10 to 20μm by removing the substrate by precision polishing. Output power of 300 mW at F-band with 4.58 percent efficiency was observed.

Diode Fabrication. The typical wafers consist of 1-μm-thick epitaxial layer with the electron concentration of 1×10^{17} to $2.5\times10^{17} cm^{-3}$ and Te-doped substrate grown on a ⟨1.0.0⟩ oriented. The diode slices were thinned to about 15μm by removing the substrate by precision polishing and were also more thinned by etching. Using the same techniques, Si slices could be more easily able to be thinned to about 10μm than GaAs slice. For GaAs slices, a damaged layer is apt to rise by a polishing process as compared with Si slices, because GaAs is cleavable.

A Schottky barrier was formed on the surface of the epitaxial layer with sputtered Pt. The Pt was covered with evaporated Au to improve bonding qualities. A back ohmic contact consists of an evaporated Au-Ge-Ni alloy. The breakdown voltage of the diode was between 10 - 13 v. The diode wafers shown in Fig. 1 were thermo-compression bonding to the gold-plated copper studs with the quartz standoff.

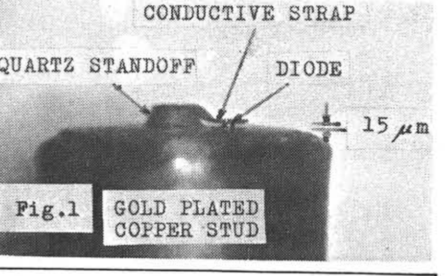

Fig.1

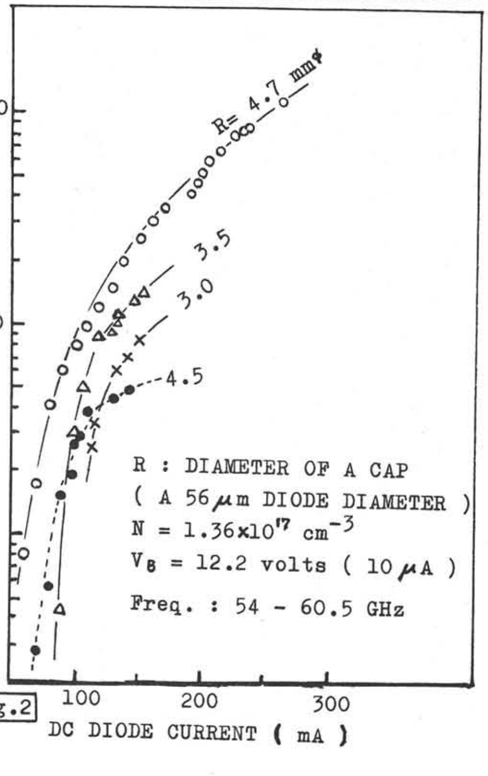

Fig.2

Oscillation Performance. The diodes were tested in the wave guide circuit described by Misawa[1)], using a metal cap that formed a radial-line cavity around the diode. The same type of the cavity was used for both F-band and V-band operation. The geometry of the contacting cap was an important factor in determining oscillator performance. The typiacl effects of the diameter of the cap on power saturation is shown in Fig. 2. The same figure shows, for the same diode, the output power variations versus bias current for four different caps. On each curve we can notice easily the saturation phenomenon. Perhaps, thermal effects appears at high level in the upper curve. In the three other cases, saturation effect appearing for low bias current, it can be clearly seen, neglecting thermal effects, that these caps are not able to deliver high power outputs. Then, we must look for another reason. If the load impedance is too high, the RF voltage across the diode is high enough to introduce carrier velocity modulation and then reduce the efficiency.

According to the large-signal analysis of the Schafetter and Gummel model[2), the diode admittance $Y_d(\omega, V_d)$ is very complicated, and then it is very difficult to realize the optimum condition ($G_d=G_L$) by the passive elements of the wave guide circuit. The circuit in which the diode is imbedded becomes the limit-ing element in the bandwidth as well as in the output power.

The typical output powers at the frequency range of 45 to 61 GHz as a function of the input power are shown in Fig.3 for the various areas of the diodes. The maximum power was 300 mW at 50GHz, with 4.58 percent efficiency. The maximum efficiency was 4.72 percent. By changing the cavity size, oscillation at frequencies as high as 67GHz were obtained with the same diode. The power output at these frequencies was with ± 1 dB of that obtained at F-band.

For the experiments of the harmonic oscillation with the same diodes described in Fig.3, the second harmonic power was very few at V-band. However, for GaAs p^+-n avalanche diodes, the second harmonic oscillation was easily obtained as in the case of abrupt p^+-n junction Si avalanche diodes[3)]. For the diodes of the high doped GaAs wafers, the light-emission due to microplasma was observed around the junction as in the case of similar Si diodes.

References. 1) T.Misawa et al.: IEEE Trans. ED 15 (1968) 741.
2) D.L.Scharfetter et al.: IEEE Trans. ED 16 (1969) 64.
3) K.Nawata et al.: Proc. 3rd Conf. on Solid State Devices, Tokyo, (1971)33.

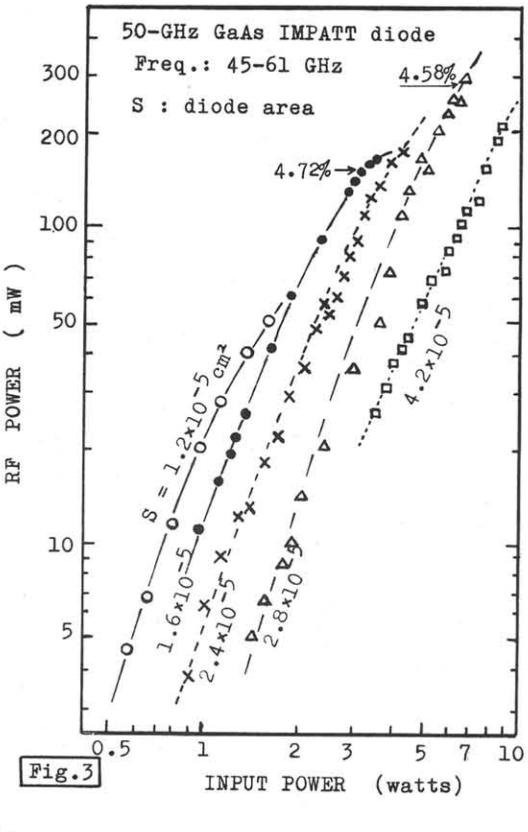

Fig.3