2-3 30 GHz GaAs Schottky Barrier IMPATT Diodes

Masatoshi MIGITAKA, Michiharu NAKAMURA, Katsutoshi SAITO and Yoichi KANEKO
Central Research Laboratory, Hitachi Ltd.
Kokubunji, Tokyo

Recently GaAs IMPATT diodes have been noted for their high power, high efficiency and low noise oscillation at C- and X- bands. The best results up to date are 4.5 W at 5.5 GHz with an efficiency of 13 % and 2.1 W at 9.2 GHz with an efficiency of 9 % with Schottky barrier IMPATT diodes[1,2], and an AM noise of -140 dB at C-band with a p^+n IMPATT diode.[3] These results are superior to those of conventional Si IMPATT diodes, and GaAs IMPATT diodes are supposed to be a promising microwave source.

In this work we tried to make 30 GHz GaAs Schottky barrier IMPATT diodes and succeeded in obtaining high efficiency, high power diodes operating in mm-wave region. For IMPATT diodes in mm-wave region, a thin high-quality GaAs epitaxial layer is required. In our experiment Sn-doped epitaxial layers were grown on (100) oriented Te-doped substrates by the liquid phase epitaxy. By using the sliding method, the thickness of the epitaxial layer was controlled to be 1.5-2 μ within the error of 0.1 μ , and the roughness of the surface was less than 0.05 μ . The doping density was $4\text{-}6\times10^{16}/cm^3$ and was controlled within the error of 15 % by the amount of Sn in Ga melt. The doping profile was measured by the differential capacitance method and was found to be flat in the epitaxial layer. The transition from the epitaxial layer to the substrate was abrupt and the thickness of the transition layer was less than 0.03 μ .

In order to form a Schottky barrier, Pt, Mo and Au were successively evaporated on the chemically etched surface of the epitaxial layer. Diodes were made by two kinds of method for making heat sink. In one method, the slice was thinned by lapping and etching to about 30 μ to reduce the series resistance of the substrate and devided into small dice, which were alloyed onto Au-plated Cu studs (alloyed diodes). In this case the thermal resistance of the diode was found to scatter around 1.5 times the theoretical value. In the other method, Cu was plated on Pt-Mo-Au Schottky metal to the thickness which was enough to use the plated metal as a heat sink, then the slice was thinned to 10-20 μ and devided into small dice (PHS diodes). By the latter method, the thermal resistance was reduced close to the theoretical value.

Typical diodes had a breakdown voltage of 20-23 V and a junction area

S_j of $2\text{-}4 \times 10^{-5}$ cm^2. The thermal resistance was 30-40 °C/W for PHS diodes and 60-80 °C/W for alloyed diodes. The RF characteristics were measured using an end hat cavity. The oscillation frequency of the diodes was found to be controlled up to one octave of the optimum frequency by the radius of the end hat. Table 1 shows the characteristics of GaAs IMPATT diodes obtained in this work. Because of the small thermal resistance, the PHS diodes gave the output power which was about twice larger than that of the alloyed diodes, while the efficiency was as high as 10-12 % on both diodes. From Table 1 the maximum power is 725 mW at 27.48 GHz and the maximum efficiency is 11.9 % at 29.70 GHz.

The computer simulation of GaAs IMPATT diodes predicted a maximum efficiency of 20 % at 30 GHz. The degradation of the efficiency in the experiment was supposed to be mainly due to residual resistance of the substrate. By reducing the thickness of the substrate to less than 10 μ , an efficiency more than 15 % can be expected for the the diodes with S_j=3-4x 10^{-5} cm^2.

References

1) J.C.Irvin et al. : Proc. IEEE, vol.59, 1212 (1971)

2) Y.S.Lee and C.K.Kim : Proc. IEEE, vol.58, 1153 (1970)

3) P.A.Levine et al. : Proc. IEEE, vol.59, 1128 (1971)

Table 1. Characteristics of 30 GHz GaAs Schottky barrier IMPATT diodes

V_B (V)	V_0 (V)	I_0 (mA)	P_{out}(mW)	η (%)	f (GHz)	Heat Sink
21.0	28.8	180	600	11.9	29.70	PHS
21.0	29.4	220	660	10.4	30.80	"
21.0	30.3	235	725	10.4	27.48	"
21.0	30.5	220	710	10.6	29.41	"
20.5	28.4	140	438	11.0	27.76	alloy
20.5	27.8	100	320	11.5	30.00	"