A MILLIMETER WAVE OSCILLATOR USING NEWLY DEVELOPED HERMETICALLY SEALED IMPATT DIODE

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Abstract

A millimeter wave oscillator that utilizes a silicon DDR IMPATT diode hermetically sealed in a mechanically -rugged ceramic type package with a diamond heat sink, has been developed. The oscillator is capable of delivering 100-150mW output power at 80 GHz band.

Introduction

Silicon DDR (Double Drift Region) millimeter wave IMPATT diodes have been generally assembled by using a quartz stand-off as a lead wire post, and the entire circuit, such as an oscillator, has been hermeticlly sealed.[1] This kind of construction is difficult to give a reproducible microwave performance and a high reliability of the device due to a poor electrode contact and hermetic sealing. Another way of mounting a millimeter wave IMPATT diode is to employ a quartz ring as a package,[2] but the quartz ring is not easy to be hermetically sealed, and it is also not strong enough for assembly of oscillators and amplifiers.

Purpose of this paper is to demonstrate that the millimeter wave IMPATT diodes can be packaged in a ultra miniature ceramic package without any serious deterioration of the microwave performance. The packaged device with a diamond heat sink made it possible to construct a reliable and reproducible millimeter wave oscillator. The developed oscillators delivered output power of 100-150mW at 80 GHz band with a junction temperature rise of 180°C.

New Package and Chip Mounting

Figure 1 shows the structures of the developed millimeter wave ceramic package and the initial diode chip to be mounted in the package. The outside and inside diameters, and the height of the ceramic ring are 0.8mm, 0.5mm and 0.3mm, respectively. There is a diamond heat sink whose size is $0.2x0.2x0.1mm^3$ inside of the ceramic ring to reduce the thermal resistance of the device.

The IMPATT diode chips with 100um diameter as shown in Figure 1 are cut out by a chemical etching from a p^+-p-n-n^+ structure silicon wafer. The p^+-p layers were prepared by boron diffusion and boron ion-implantation , respectively. The chip is mounted on the diamond heat sink by a thermo compression bonding and two gold tapes (100μm x 10μm) are bonded on the top of the chip by crossing each other.
The mounted diode chip is etched again to remove the damaged periphery region and to adjust the junction capacitance to an optimum value. After cleaning and baking, the packaged diode is hermetically sealed by a seam welder.

The packaged devices were examined by the MIL standard environmental tests as shown Table 1.
There was no failure due to the thermal and mechanical shocks. An addition, the lid pull strength and the case compression were 2.0 Kg and 1.0 Kg, respectively. The parasitic package capacitance is 0.15 pF.

The thermal resistances of the packaged millimeter wave IMPATT diodes with a diamond heat sink were measured by on ordinary method. The results are shown in Figure 2 as a function of the junction capacitance. The thermal resistance of the diode whose junction capacitance is 0.7 - 0.8 pF is about 50°C/W. This is considerably lower than that of the diode without a diamond heat sink.

Oscillator Circuit

Since the diode is packaged well, there was no problem in mounting and charecterizing the packaged device in a coaxial waveguide type oscillator circuit. The details of the oscillator structure is shown in Figure 3. A coaxial type impedance transformer, which is also used as the DC power supply, is pressed on the top of diode cap. This is possible due to the rugged ceramic package. A RF absorber (brand-EPOIRON) was inserted behind of the coaxial transformer to provent undesired frequency oscillation.

The maximum output power was obtained by adjusting the short-circuited position of the wave guide and also the position of the diode. A high Q oscillator can be obtained by replacing the short circuit of the wave guide by a high Q sylindrical cavity of TE_{012} mode.

RF performance

The output powers versus the junction temperature rise of the ceramic package device were compared with those of the quartz ring package device and of the device with a quartz stand-off. The diamond heat sink could not used for the device with a quartz stand-off because the quartz stand could not be mounted on the diamond. Almost the same junction capacitance devices were examined. The results are shown in Figure 4. The performance of the ceramic package device is the best and delivered about 140mW at 80 GHz , simply because that the ceramic package device is most stable due to a good electrical contact and a low thermal resistance. Figure 5 shows the performance of high Q and low Q oscillators, and the operation voltage of the diode as a function of the bias current. For the low Q oscillator(curve 1), the output power of 21.5dBm with 4.5% efficiency is obtained at 79.8 GHz for a bias current of 160 mA. The junction temperature rise ΔTj for this bias current was less than 180°C. Since the loaded Q of this oscillator was about 20, the oscillator can be used as an injection locked amplifier.

The curve 2 shows the output powers of the high Q oscillator stabilized by a cylindrical cavity. The loaded Q of this oscillator was about 1000 and the frequency fluctuation by the temperature was 4ppm/°C. The output power of 19dBm is obtained with ΔTj = 180°C. Since the insertion loss of the circulator was 0.5dB at 80 GHz band, the loss due to the frequency stabilization can be estimated to be about 2dB.

Figure 6 shows the oscillation frequency range of the stabilized oscillator controlled by the high Q cavity. The frequency was controlled from 78.8 GHz to 80.4 GHz by a mechanical tuning of the high Q cavity.

Conclusion

A 80 GHz band DDR IMPATT diode has been completely packaged and hermetically sealed in a ultraminiture ceramic type package with a diamond heat sink. This mechanically rugged, packaged IMPATT diode made it possible to construct a stable and repeatable millimeter wave oscillator. The low Q oscillator delivered more than 140mW at 80 GHz band with efficiency of 4.5% and ΔTj = 180 °C. The stabilized oscillator, whose frequency fluctuation is about 4ppm/°C, delivered 19dBm at 80 GHz band with ΔTj = 180°C.

These oscillators have been successfully applied to a practical pump source of parametric amplifiers and to a local oscillator of millimeter wave PCM communication systems.

Acknowledgement

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Reference

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GRO-UP	TESTS	CONDITIONS MIL-STD-750B	CONDITIONS	NUMBER OF SAMPLES	NUMBER OF SAMPLES
1	THERMAL SHOCK (TEMPERATURE CYCLING)	1051.1	-65°C～25°C ～ 200°C 10 CYCLES	10	0
	THERMAL SHOCK (GLASS STRAIN)	1056.1	0 ～ 100°C 10 CYCLES		
2	MECHANICAL SHOCK	2016.2	NON OP. ; 1500G 5 BLOWS OF 0.5msec IN X,Y1,Y2	10	0
	VIBRATION, VARIABLE FREQUENCE	2056	100Hz,2000Hz 20G EACH IN X,Y1,Y2		

FAILURE CRITERIA

END POINT TEST	CONDITIONS	FAILURE CRITERIA MIN.	FAILURE CRITERIA MAX.	UNIT
FORWARD VOLTAGE	IF = 300mA	-20	+20	%
REVERSE CURRENT	VR = 10V	—	50	μA
REVERSE VOLTAGE	IR = 1mA	-20	+20	%
FINE LEAK	MIL-STD-750B METHOD 7071.1, COND.H	—	—	—
FINE LEAK	METHOD 7071, COND.C	—	—	—

Table 1 Enviromental Test results

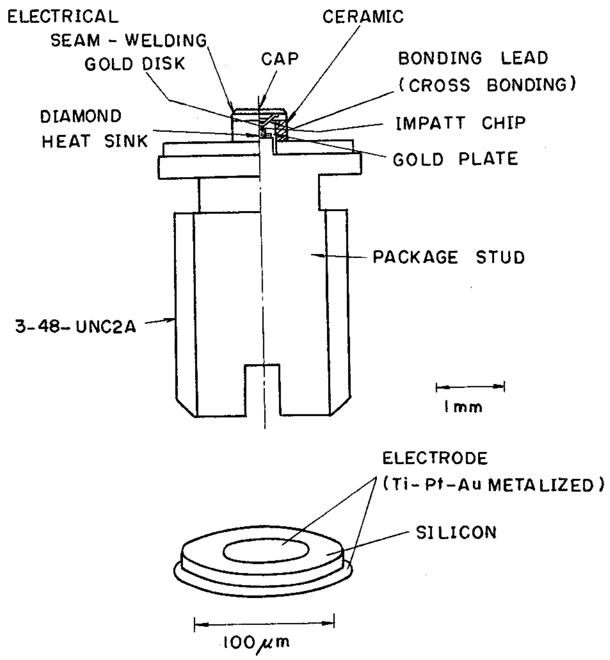

Fig. 1 Structure of millimeter wave ceramic package and diode chip.

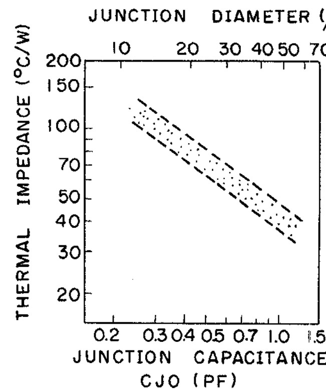

Fig. 2 Test results of junction capacitance and junction diameter vs. thermal impedance.

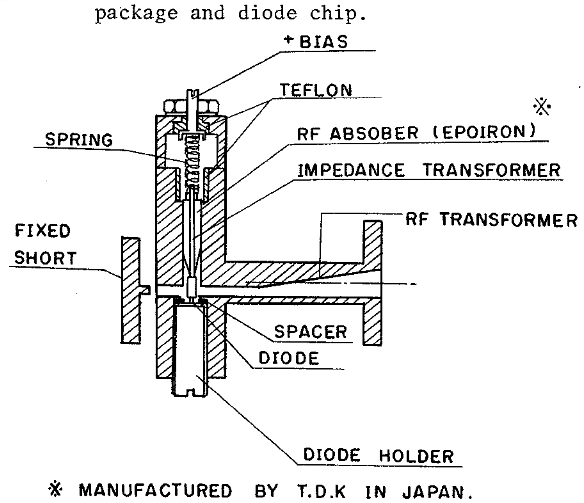

Fig. 3 IMPATT diode oscillator circuit.

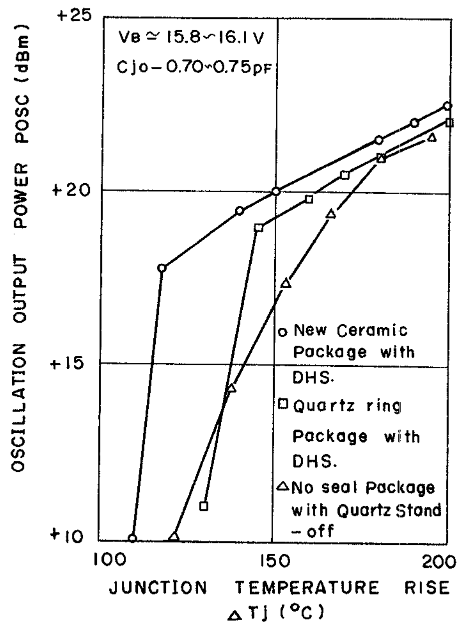

Fig. 4 Oscillation output power characteristics.

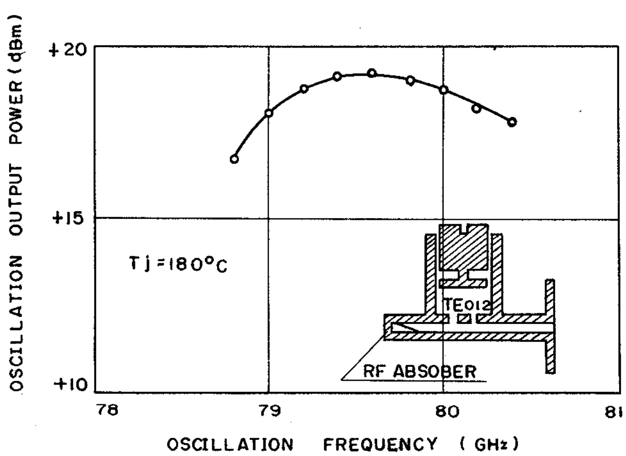

Fig. 6 Oscillation frequency range of a stabilized oscillator.

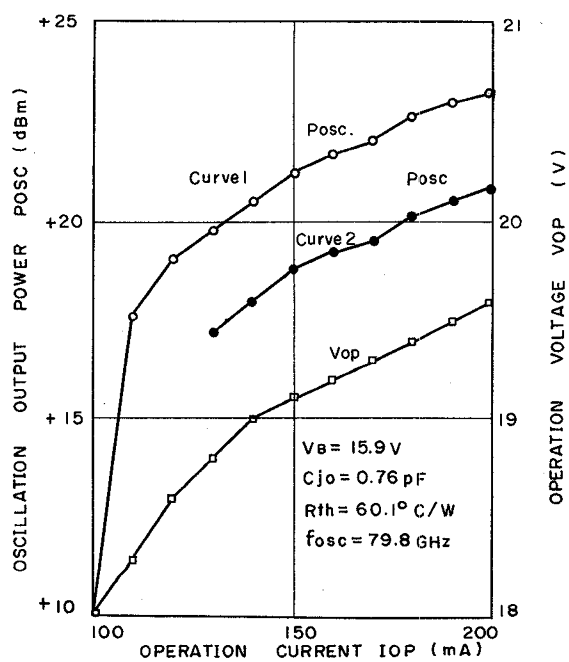

Fig. 5 Performance of high Q and low Q oscillators.