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E-1-2 High Power and Stable Oscillations in the RTD Pair Oscillator ICs Fabricated with Metamorphic RTDs

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I Introduction

A resonant tunneling diode (RTD) is an ultrahigh frequency device showing a negative differential resistance (NDR). Oscillators using this NDR is one of the promising applications of the RTDs [1, 2]. The RTD oscillator operating at 712 GHz has been already reported [3]. However, conventional RTD oscillator has a significant problem that RF power is so small [4]. This is due to the fact that the NDR exists from dc to THz range, different from the transistor oscillator. This causes a low-frequency spurious oscillation and bias instability. To suppress these problems the area of the RTD, and hence, the output power is restricted so small (less than around 1 μm^2 and a few tens of microwatts).

Recently, we proposed a novel resonant tunneling oscillator using series connected RTDs, which has a potential to overcome this problem [6]. In this paper we demonstrate high power and stable oscillation of this oscillator fabricated with metamorphic RTDs on GaAs substrates.

II RTD pair oscillator

Figure 1 shows the basic circuit configuration of the RTD pair oscillator. This oscillator consists of two RTDs connected serially, and the resonator connected to the node between two RTDs. The series connected RTDs are biased by the voltages having a same absolute value with opposite sign. A most significant advantage of this is that it separates the oscillation node from the bias nodes. This permits us to connect large capacitors (C_b) to the bias nodes, which make these nodes stable, while they have no effects on the high-frequency oscillation. This is in contrast with the conventional RTD oscillators, where the bias line is connected to the oscillating node. Due to small parasitic inductance in the bias line this causes low frequency spurious oscillation. To avoid this spurious oscillation the absolute value of the NDR must be large. Consequently, the area of the RTD is restricted to be so small in the conventional RTD oscillator circuits. On the other hand, our proposed circuit can use large area RTDs without bias instability problem.

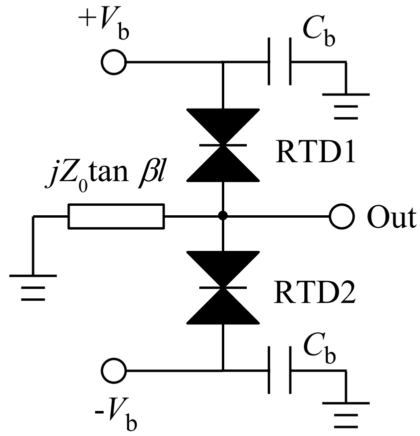

Fig. 1: A series-connected RTD oscillator.

The calculated dc I-V-characteristics of two RTDs connected serially is shown in Fig.2, which shows the current flowing into the center node as a function of the center node voltage for various bias voltages. There is a negative resistance region at low voltages. It is also shown that the amplitude of this negative resistance is controlled by the bias voltage. These facts relax the severe restriction on the RTD area, and make it possible to supply higher power to a load.

III Experiments

We fabricated test circuits using AlAs/InGaAs/InAs RTDs to demonstrate stable oscillation of the proposed circuit. The RTD structure was similar to the previously-reported one, and was grown by molecular beam epitaxy on metamorphic GaAs substrates [5]. The RTD consists of n-$In_{0.53}Ga_{0.47}As$ collector and emitter layers, 1.6 nm strained AlAs barriers and a 1.5 nm strained InAs subwell at the center of an $In_{0.53}Ga_{0.47}As$ well. The total well thickness was 4.1 nm. Undoped spacer layers of 1.5 nm thickness were grown outside the barriers. The devices were fabricated with the conventional wet etching and lift-off processes.

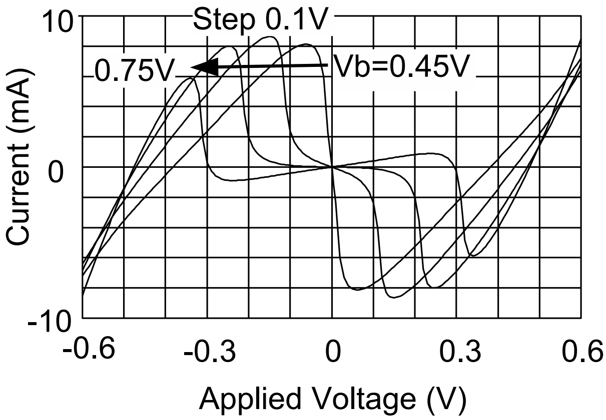

Fig. 2: $I - V$ characteristics of the RTD pair.

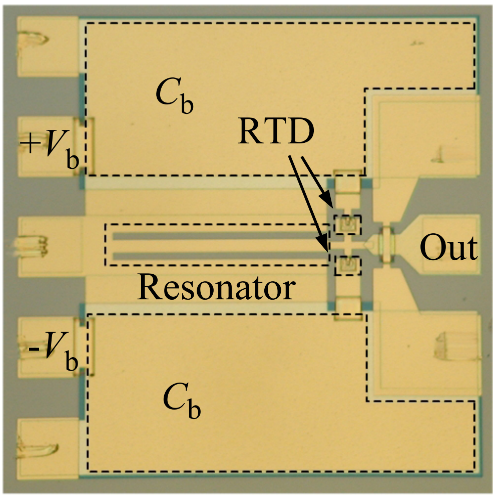

Fig. 3: Chip microphotograph of the fabricated circuit.

The peak voltage and current density of the RTDs were 0.5 V and 1×10^5 A/cm^2, respectively. Large area RTDs of 10 μm^2 were used in the circuit. The chip microphotograph of the circuit is shown in Fig. 3. The resonator was made of a shorted coplanar wave guide (CPW), whose characteristic impedance and length were 50 Ω and 320 μm, respectively. The bias stabilization capacitors, C_b, of 30 ps were integrated to the bias terminals. The circuit was measured on wafer using coplanar probes. Measurement system was connected to the output terminal directly.

Figure 4 shows an example of the output spectrum. The bias voltage was 0.75 V. A sharp oscillation at 23 GHz is clearly seen. A large peak power of -4 dBm ($\sim$400 μW) was obtained. This is made possible by using large area RTDs owing to the novel circuit configuration. It should be noted that the circuit can drive a 50 Ω resistive load directly.

IV Summary

High power and stable operation was demonstrated for the RTD oscillator circuit fabricated with metamorphic RTDs. The circuit consisted of series connected RTDs with shorted coplanar wave guide resonator. In this configuration, the bias instability problem of the conventional RTD oscillators can be solved by separating the bias nodes from the oscillating node. This made it possible to use large RTD area of 10 μm^2, and supply large power of about 400 μW to the 50 Ω resistive load.

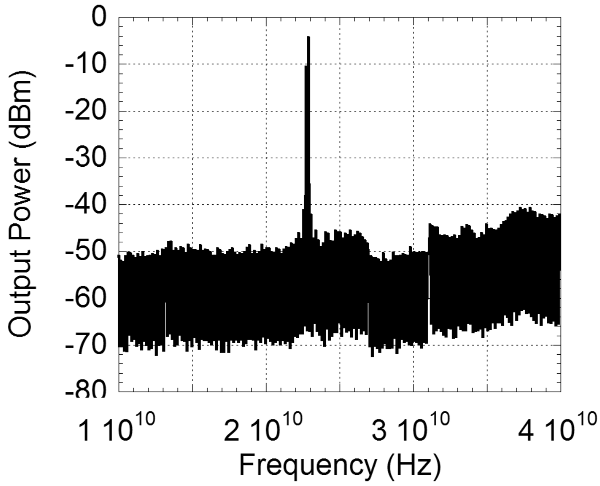

Fig. 4: Output power spectrum of the fabricated circuit. The measured power was corrected taking the loss of measurement system into account.

Acknowledgment

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