IV Characteristics of a Stabilized Resonant Tunnelling Diodes

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***Abstract* — The presence of parasitic oscillations found in the negative differential region (NDR), which can distort the current-voltage (I-V) characteristics of the device is one of the main problems when designing resonant tunnelling diode (RTD) circuits. A new method for RTD stabilization is proposed based on work done previously on tunnel diodes and results show that there is a significant difference between the I-V characteristics of a tunnel diode and that of an RTD. This work shows promising potential for further increasing the RTD's output power, DC-RF conversion efficiency and provides the basis for an accurate model of the NDR region.**

I. Introduction

The terahertz (THz) technology is of interest because of its potential use in applications such as security imaging, wireless communication, medical imaging, etc. The resonant tunnelling diode (RTD) is one of the fastest solid-state electronic devices with a demonstrated primary oscillation frequency of up to 1.92 THz [1].

In this paper a method for direct measurement of the RTD's I-V curve is presented, which can be adapted for oscillator designs that significantly improves the DC-RF conversion efficiency. The RTDs are fabricated on a low negative differential conduction material, resulting in an increased NDR region, therefore reducing the external bias circuit requirements. It is expected that these efforts will further increase the RTD oscillator's output power and efficiency in the near future.

II. Stabilized RTD

RTDs are affected by instability along the NDR region resulting in unwanted parasitic oscillations [2]. This critical region is used in determining essential device characteristics. However, the oscillations make it difficult to determine the characteristics of the device [3]. One method to stabilize an RTD is to employ a shunt resistor across the device, such that the combined resistance is positive when biased in the NDR region. The characteristics are then indirectly estimated by de-embedding the value of the resistor. Furthermore, because of these oscillations, all planar (THz) RTD oscillators which use a shunt stabilizing resistor have poor DC-RF conversion efficiency.

In this work, the RTD characteristics are directly determined with the help of a stabilizing capacitor (C_b) connected in series with the shunt resistance (R_b) shown in Fig. 1. The component values are chosen to achieve both low and high-frequency stability, as described by Liquan *et al*. [3] and the device is presented in Fig. 2.

III. Resutls and discussion

The direct I-V measurements results of 16 μm^2 RTD stable and unstable devices plotted in Fig. 3. In comparison with an Esaki type tunneling diode [3], the drop in current at the beginning of the NDR region is sharp suggesting a very low value of negative resistance. The precise mechanism is not well understood [4] and further work needs to be undertaken in this area in order to predict better stability and output power capabilities.

A common method for showing stabilization is to plot the first and the second derivative of the I-V curve and they are presented in Fig. 4. The derivatives will show sharp valley /peaks where parasitic oscillations are expected, independent of the parasitic [3]. The stabilized diode I-V curve derivative shows *a single* valley / peak corresponding to the sharp drop in current at the beginning of the NDR region.

IV. Conclusion

A new method for DC stabilization and direct measurement of the I-V characteristics of RTDs has been presented. The results show for the first time the true RTD characteristics in the NDR region. The stabilizing circuit can be used in THz RTD oscillators to replace the shunt resistor and dramatically improve the DC-RF conversion efficiency by reducing the resistor's losses. Last but not least, accurate modeling of the NDR region will be possible with this technique.

[1] T. Maekawa , H. Kanaya , S. Suzuki , and M. Asada , "Oscillation up to 1.92 THz in resonant tunneling diode by reduced conduction loss", Appl. Phys. Exp. , vol. 9 , no. 2 , p. 024101 , 2016.
[2] M. Asada, S. Suzuki, and N. Kishimoto, "Resonant Tunneling Diodes for Sub-Terahertz and Terahertz Oscillators", Japanese Journal of Applied Physics Vol. 47, No. 6, 2008, pp. 4375–4384
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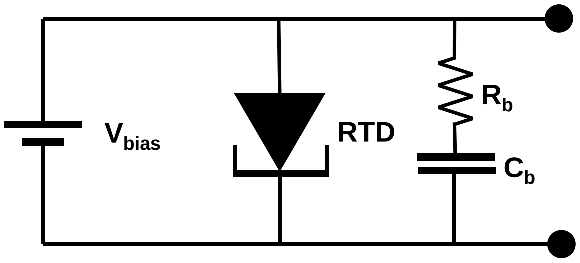

Figure 1 – Direct I-V measurement circuit.

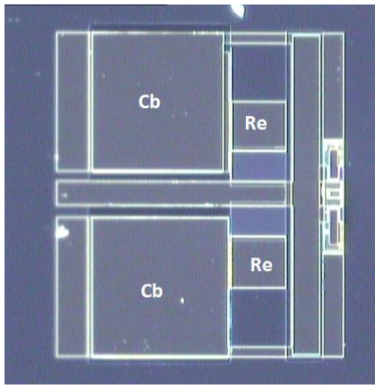

Figure 2 – Fabricated RTD device.

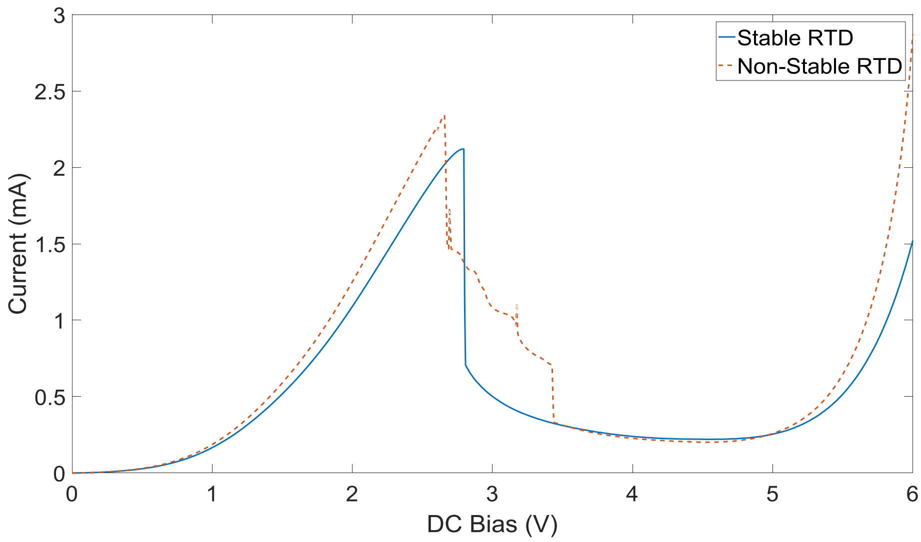

Figure 3 – I-V measurements comparison of stable and non-stable RTD.

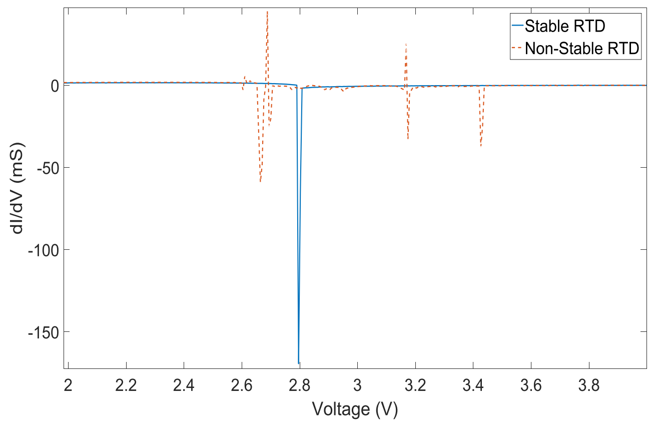

Figure 4 – Second derivative of I-V stable and non-stable RTD.

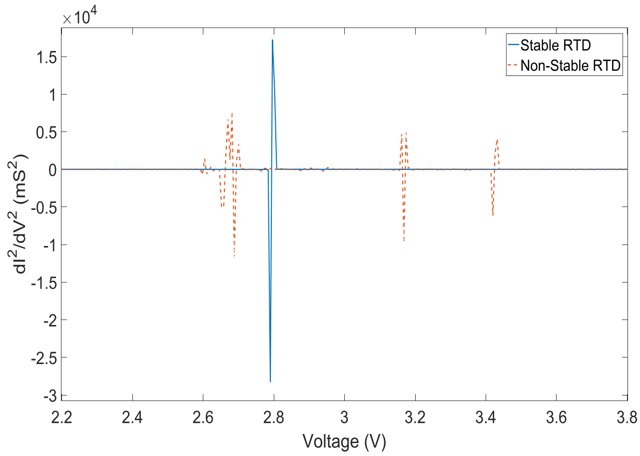

Figure 5 – Second derivative of I-V stable and non-stable RTD.