Extended Abstracts of the 2009 International Conference on Solid State Devices and Materials, Sendai, 2009, pp952-953

RF Small Signal Characterization of Active Transmission Lines Load by InGaAs/AlAs Resonant Tunneling Diodes

Koji Kasahara, Takashi Ohe, Masayuki Mori, Koichi Maezawa

Graduate School of Science and Engineering, University of Toyama
3190, Gofuku, Toyama 930-8555, Japan
Phone: +81-76-445-6725 E-mail: maezawa@ieee.org

1. Introduction

Resonant tunneling diodes (RTDs) are most promising quantum effect devices. Their negative differential resistance (NDR) has been demonstrated to persist up to THz frequency range [1]. Various applications, including analog and digital circuits, have been proposed and demonstrated using RTDs. An interesting application of the RTDs is an active transmission line (TL). The nonlinear transmission lines (NLTLs) loaded by Schottky diodes or varactors are used to ultrashort pulse generation [2]. Using RTDs the NLTLs can posess a gain due to the NDR. This gain together with ultrahigh frequency nature of the RTD makes the NLTLs loaded by RTDs (RTDTLs) promising for various ultrahigh frequency applications [2-4]. Recently, We have also proposed an ultrawide band amplifier using such NLTLs [5]. In this paper, we will report on the fabrication and characterizaion of the RTDTLs. We will also discuss the possibility of an RF switch using the RTDTLs based on experimental results.

2. Design and Fabrication of the RTDTLs

Figure 1 shows a basic configuration of the RTDTLs. In the small signal regime the RTDTL can be regarded as a "lossy" transmission line with a negative loss when the size of the unit cell is much smaller than the wavelength of the signal. In other words, this transmission line works as an amplifier. On the other hand, it has a large nonlinearity in the large signal regime, which can be used in various applications, for example, the pulse generation. In both cases, it is very important for designing circuits to clarify RF properties of the RTDTLs. Here, we fabricated and characterized RTDTLs having various parameters.

We fabricated the RTDTLs with InGaAs/AlAs epitaxial layers grown on an InP substrate employing conventional photolithography and lift-off process. The emitter area of the RTDs used was 8 μm^2. Two types of RTDTLs were fabricated, where the length of the signal wire in the unit cell is different. The inductances in the unit cells are estimated to be 45 pH and 90 pH for short and long wires, respectively. The RTDTLs were fabricated with various numbers of unit cells (1 to 10). Figure 2 shows the microphotograph of the fabricated RTDTLs having 10 RTDs. The *I-V* characteristics of the fabricated RTD are shown in Fig. 3. The current density was about 2.5x10^4 A/cm^2.

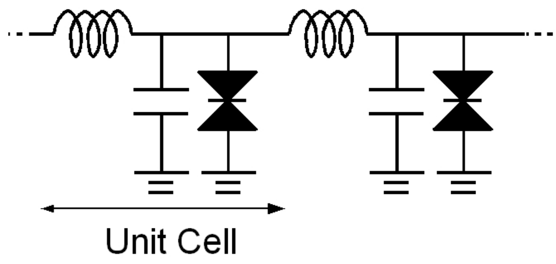

Fig. 1 Basic configuration of the RTDTLs.

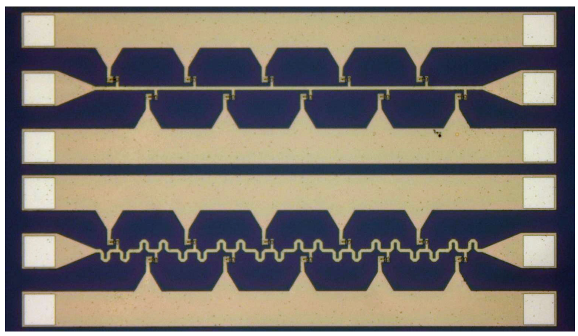

Fig. 2 Microphotograph of the fabricated circuits. The inductances in the unit cell are estimated to be about 45 pH and 90 pH for upper and lower circuits, respectively.

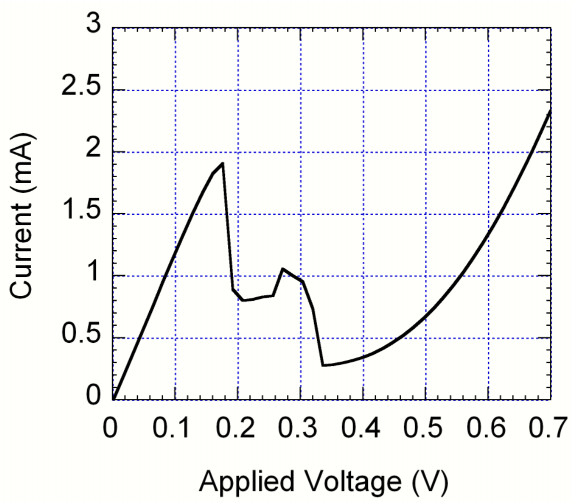

Fig. 3 *I-V* characteristics of the fabricated RTD.

3. Circuit Properties

We measured the RF small signal characteristics of the fabricated circuits from 40 MHz to 40 GHz. The measurements were carried out on wafer using Anritsu 37369C vector network analyzer. Figure 4 shows an example of the S11 and S21 of the RTDTLs having 10 unit cells (short wire) with bias voltage of 0V. The RTDs work as a simple resistor at this bias, so that the TL is lossy. Therefore, the reflection (S11) is large and the transmission (S21) is small (less than -17 dB).

We investigated the bias voltage dependence of the S-parameters. They change drastically at the peak voltage. Figure 5 compares the magnitude of S21 for the bias voltage at 0 V and that at 0.34 V (near the valley). The transmission increases considerably from that at 0 V. This is due to the high impedance of the RTDs at valley voltage. We also found that the S11 is much small at V=0.34 V, which implies good impedance matching to the 50-Ω load. This phenomenon can be applied to high performance RF-switch. The ON/OFF ratio was about 15 dB for RTDTL having 10 unit cells. We can easily obtain larger ON/OFF ratio by increasing the number of unit cells, because this ratio is proportional to the number of unit cells. We experimentally confirmed this dependence for TLs having 1 to 10 unit cells. This RF-switch has another advantage that the power consumption is very small because only valley current flows when the circuit is biased in ON state. This is in contrast to the conventional diode switch. It should be noted that the S21 reduction at high frequency is due to the wire resistance because of relatively thin wire metal. Ultra wideband RF switch (>100 GHz) can be expected with sophisticated circuit design and fabrication process.

We also observed that the S21 increases when decreasing the bias voltage from the nonresonant current region. However, low frequency oscillations in the NDR region hindered accurate measurements of S-parameters, so that the gain could not be demonstrated. This indicates that RTD pair configuration, which is effective for suppressing such oscillations, is essential for applying the RTDTLs to amplifiers [6].

4. Conclusion

The RTDTLs having various parameters were designed and fabricated on an InP substrate. Small signal RF characteristics were measured. Possibility of the high performance RF-switch using RTDTLs were discussed based on the measured S-parameters.

Acknowledgements

This work was supported by a Grant-in-Aid for Scientific Research (B) 20360155 from The Ministry of Education, Culture, Sports, Science and Technology (MEXT), and VDEC, the University of Tokyo in collaboration with Cadence Design Systems, Inc., and Agilent Technologies Japan, Ltd.

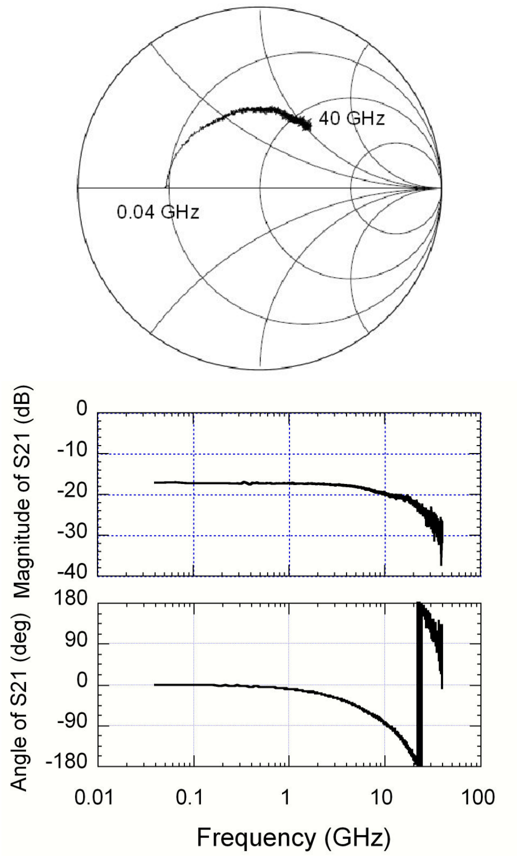

Fig. 4 S11 (upper figure) and S21 (lower figure) of the fabricated RTDTL having 10 unit cells. Bias voltage is 0 V.

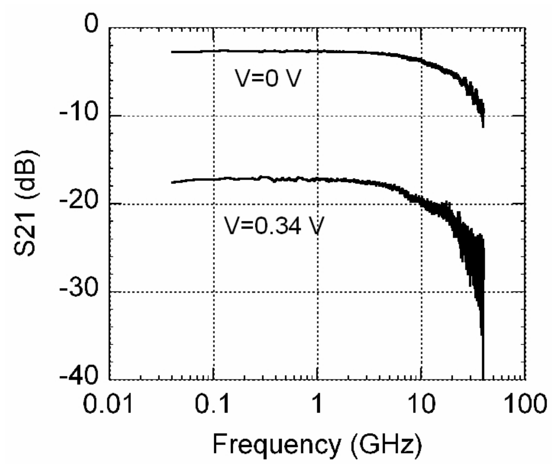

Fig. 5 S21 of the fabricated RTDTL having 10 unit cells. Bias voltages are 0 V and 0.34 V for upper and lower traces, respectively.

References

[1] T. C. L. G. Sollner, et al., *Physics of Quantum Electron Devices*, Berlin: Springer-Verlag, 1990.

[2] M.J.W. Rodwell, et al., IEEE Trans. Microwave Theory Tech., **39**, (1991) 1194.

[3] I. Jeager, et al., Microwave Opt. Tech. Lett., **49**, (2007) 2907.

[4] K. Narahara, et al., Jpn. J. Appl. Phys., **45**, (2006) 5692.

[5] K. Maezawa, et al., presented at 2008 IEICE Society Conference [in Japanese], also in preparation for publication.