Extended Abstracts of the 2007 International Conference on Solid State Devices and Materials, Tsukuba, 2007, pp. 796-797

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Ultra-Short Pulse Generators Using Resonant Tunneling Diodes and Their Integration with Antennas on Ceramic Substrates

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1. Introduction

Ultra-wideband (UWB) systems are attracting a great deal of attention for radar and wireless communication applications. One of the most noted implementation of the UWB is impulse radio (UWB-IR). Impulse radio using very short pulses for information carrier enables higher data transmission rates with lower power consumption. In the UWB-IR, a key component is a pulse generator. Such circuits generating sub-10-ps pulses enable various applications such as vehicle radar, Gb/s point-to-point links, and wireless-LANs based on UWB-IR [1].

In this paper we report ultra-short pulse generators using resonant tunneling diodes (RTDs) and their integration with antennas on ceramic substrates.

2. Pulse Generators Using RTDs

We fabricated two kinds of pulse generators shown in Fig. 1. One is a simple resistor-RTD series circuit (circuit A), and the other is a circuit consisting of an RTD pair in place of the RTD in circuit A, here the center node of the RTD pair is connected to the resistor (circuit B).

Figure 2(a) shows a load curve diagram for the circuit A. When the input voltage increases, the output voltage jumps from the stable point 1 to the stable point 2. Similarly, when the input voltage decreases, transition occurs from the stable point 3 to 4. Since these transitions take extremely short time owing to the nature of RTDs, one can easily obtain 10-ps class pulses using a high-pass filter.

The load curve diagram of the circuit B is shown in Fig. 2(b)[2]. When the input voltage is applied, transition occurs similarly to the case of the circuit A. The positive and negative edge transitions are symmetric according to the symmetry of the circuit. Therefore the obtained pulses should have a same strength for rising and falling edges of the input voltages. This is convenient for some applications, for example, biphase encoding and decoding.

The circuits were fabricated with InGaAs/AlAs RTD on the InP substrate (Fig. 3). The size of the RTDs was 3 x 8 μm^2, and the peak current was 25 mA. The series resistor was fabricated using HEMT layers grown under the RTD layers, and the resistance of which was designed to be 60 Ω. The cutoff frequency, f_c, of LC high-pass filter was designed to be about 35 GHz.

The circuit was tested on wafer using RF probes. The

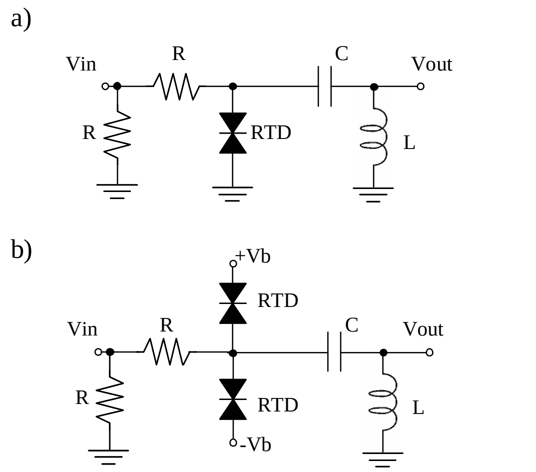

Fig. 1(a) Circuit configuration of the circuit A and (b) the circuit B

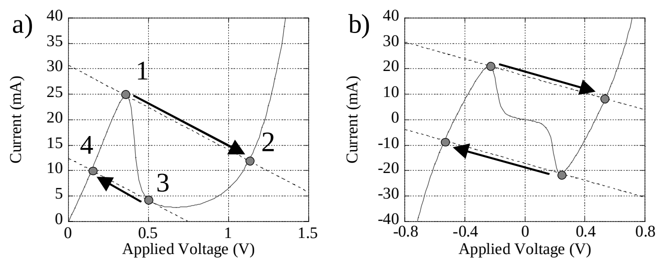

Fig. 2(a) A load curve diagram for the circuit A and (b) circuit B

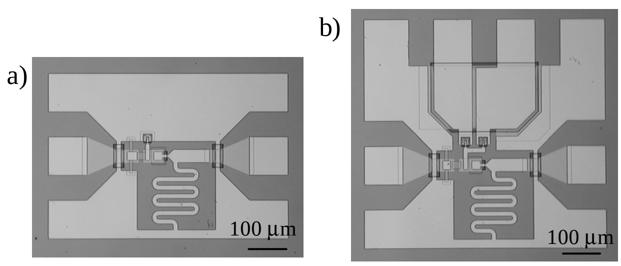

Fig. 3(a) Microphotograph of the fabricated circuit A and (b) circuit B output signal was observed by the Lecroy SDA100 sampling oscilloscope with a 100-GHz sampling module. A 5-GHz sine wave was used for the input signal. A dc offset voltage of 1.0 V was added to the input signal for the circuit A, while no offset bias was used for the circuit B.

The obtained output was shown in Fig. 4. Ultra short pulses were observed for both circuits, the FWHMs (full width of half maxima) of which were about 10 ps. Good symmetric opposite polarity peaks were obtained for the circuit B, while the peaks for circuit A were asymmetric.

3. Integration with antennas on AlN ceramic substrate

We integrated simple series-connected resistor-RTD pulse generators (circuit A) with antennas on AlN ceramic substrates. The high-pass filter was not integrated because the antenna has its own bandwidth.

First, small RTD blocks were fabricated using mechanical polishing and selective wet etching from the back side of the substrate. The size of the blocks was 54 × 84 μm^2 with a thickness of 2 μm. The blocks were arranged in the recesses on the AlN ceramic substrate by pick and place method. Resistors were fabricated with evaporated NiCr. The antenna pattern and wiring were formed by Ti/Au deposition and liftoff process (Fig. 5). This planar process enables ultra wide bandwidth wiring of more than 100 GHz. The peak current value of RTD was 13 mA. The resistance was 90 Ω.

Sending and receiving experiment was carried out with the fabricated antennas. The receiver has no pulse generator. 5 GHz sine wave was supplied to the pulse generator. Figure 6 and 7 show the output waveform and its spectrum, respectively. 70-GHz short wave packets were observed instead of the 10-ps class pulses shown in Fig 4(a). This difference should be due to the narrow bandwidth of the antenna. Improving the design of antenna is a significant task for realizing the 10-ps class impulse communication.

4. Summary

We demonstrated 10-ps class pulse generation in two types of RTD circuits. Moreover, simple resistor-RTD type pulse generator was integrated with antennas on AlN ceramic substrates. Sending and receiving experiment showed that the 70 GHz wave packet was transmitted between antennas.

Acknowledgments

This work was supported in part by SCOPE, and also supported by VDEC in collaboration with Cadence Design Systems, Inc.

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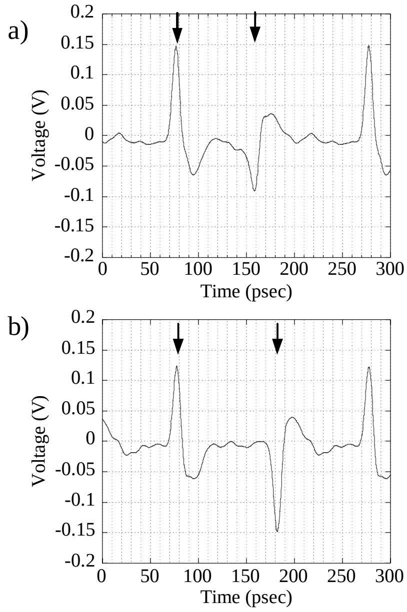

Fig. 4(a) Output waveform of the circuit A after averaging and (b) the circuit B (V_b=0.7V)

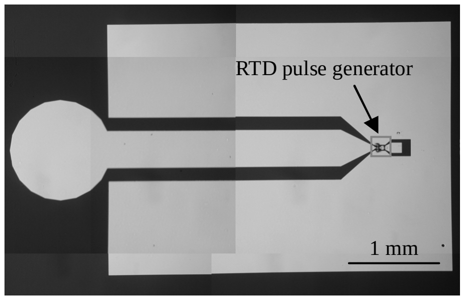

Fig. 5 Microphotograph of the fabricated antenna

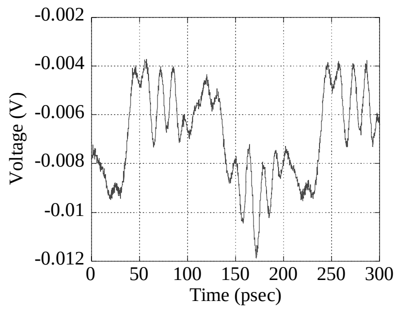

Fig. 6 Output waveform of the antennas

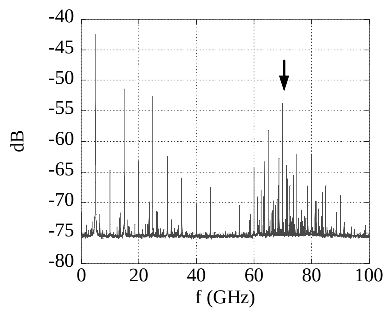

Fig. 7 Frequency spectrum of the output waveform