Suppression of High Gain GaAs Photoconductive Semiconductor Switch at High Electric Field

Ming Xu, Wei Shi, Xiaoqing He, Zhijing Yan, Hong Liu
Xi'an University of Technology, Xi'an, Shaanxi, 710048, P.R.China

***Abstract*—In order to explore the efficient THz emitter with GaAs photoconductive semiconductor switch (PCSS), it's necessary to achieve the suppression of high gain mode in high electric field. The infrared activation and inhibition of high field domains is achieved and the good hold-off characteristics is obtained with 32 kV.**

I. INTRODUCTION

GaAs photoconductive semiconductor switch is being used in a variety of applications, for the advantageous properties of low jitter, high speed operation and simple structure. As we known, GaAs PCSS can operate in two important modes, i.e., linear and high gain mode. When the bias electric field and energy of trigger laser is above a certain threshold value, the important feature of high gain mode can produce as many as 10^3-10^5 electron-hole (e-h) pairs per absorbed photon, compared to linear PCSS, in which only one e-h pair is generated in per absorbed photon[1-3].

Up to now, however, the utility of GaAs for THz emission depends on the operation of linear mode. There is no report that one uses GaAs PCSS operating with high gain mode as THz emitter. In order to use the GaAs with high gain mechanism as intensive THz emitter, it should allow to form the photoconduction with the feature of high gain mode and radiate the intensive THz emission.

A concept that attempts to bring the carriers' high gain mechanism in high electric field to the linear mode of GaAs is proposed in this paper. We utilize the infrared activation and inhibition of high field domains to interrupt the development of filament current with two excitation beams of same wavelength at 1064 nm.

II. RESULTS

Experiments were performed based on semi-insulating (SI) GaAs which is grown by the Liquid Encapsulated Czochralski (LEC) technique. As shown in figure 1, the PCSS consists of a 6-mm-wide and 0.6-mm-thick piece of SI GaAs. The resistivity in total darkness is larger than $5\times10^7\ \Omega\cdot$cm and the mobility is larger than 5500 $cm^2/(V\cdot s)$. The Au/Ge/Ni electrode forms ohmic contact by using a standard mixture of Ni/Au-Ge/Au for the metallization at 450^0C. The electrode dimensions were 6×3 mm^2 with a 500-nm-deep ledge has been etched with reactive ion etching and 800 nm thickness Si_3N_4 insulator layer is coated on the material. The SI GaAs PCSS mounted upside down on a ceramic sheet of high purity Al_2O_3 with micro-strip line, is maintained in chamber with sulphur hexafluoride (SF_6) which was up to 3 atmospheres. The Nd:YAG nanosecond laser operated with 15 ns full width at half maximum laser pulse, at wavelength of 1064 nm. Current flowing in the circuit was measured with a Rogowski coil, whose sensitivity and minimum response time were 0.1 V/A and 1 ns, respectively. The oscilloscope was TDS-5054 and a 40 dB coaxial attenuator with a bandwidth of 1 GHz was used between the Rogowski coil and oscilloscope. The trigger laser pulses were reflected by a piece of quartz to make sure the intensity of laser is appropriate. This method actually results in two dependent trigger laser spot in the SI-GaAs sample due to the reflection of the upper and bottom surface of quartz, and the relative timing between the two laser pulses is about 100ps based on the thickness of quartz. Those two dependent infrared lasers excite two samples, 12 mm and 14 mm gap sizes, respectively.

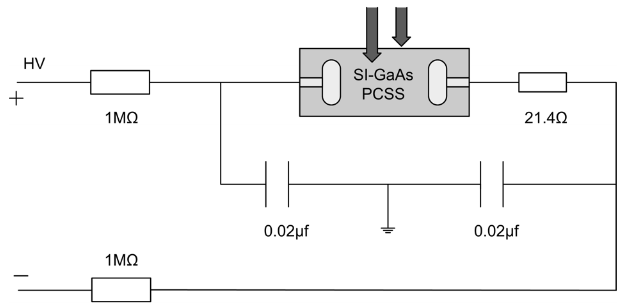

Fig. 1 Schematic diagram of the testing circuit

Figure 2 shows the characteristics of switching controlled by those dependent infrared lasers based on the samples with the 12 mm electrode gap. In this case, the maximum bias voltage can be up to 32 kV with 0.9 kA current switching. When the bias voltage is increased to 34 kV, breakdown of PCSS occurs due to surface flashover. Although the electric field and trigger laser energy meet the critical condition to occur nonlinear mode, somewhat surprising but interesting results appear repeatedly during the whole experiments, that there are no remarkable waveforms with characters of "lock-on" [4].

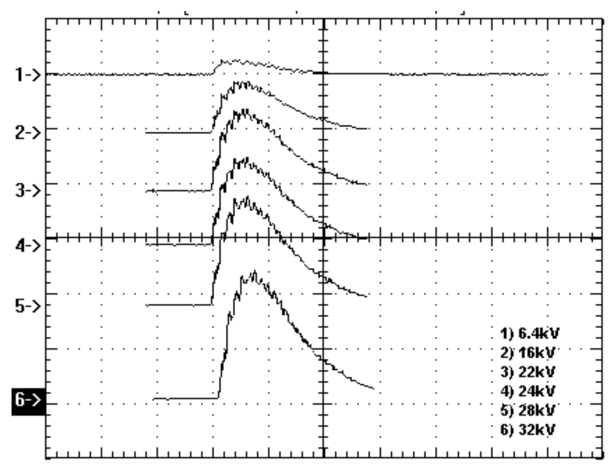

Fig.1 The superposed waveforms at different bias voltages (vertical axis: 20A/V, 10V/div; horizontal axis: 200ns/div)

The hold-off characteristics of the 14mm sample is apparently reduced when triggered in the manner mentioned above, after 239 times shots at 20kV. Figure.4 shows the superposed waveforms of the second sample in longevity experiments based on the sample of 14mm, the maximum current is about 414 A.

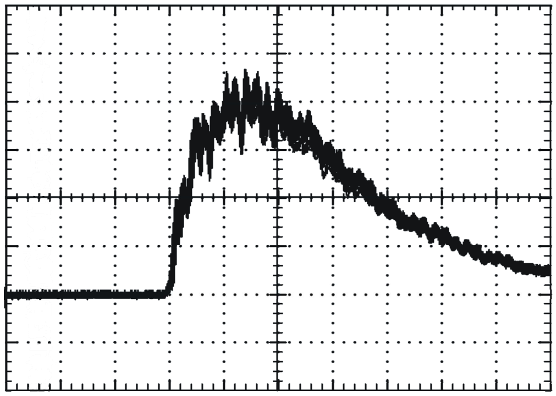

Fig.4 The superposed (230 times) switching waveforms of the second sample biased at 20kV (vertical axis: 10A/V; horizontal axis: 80ns/div)

III. SUMMARY

For extending non-linear mode of GaAs to THz technology, we design a primary setup based on GaAs PCSS. Bias voltage can be up to 32 kV with 0.9 kA switching current and good reproducibility of waveforms about 230 times at 20kV is achieved and results show the process could be performed repeatedly. This method paves the way for future research of utility of high gain mode PCSS for THz emission.

IV. ACKNOWLEDGEMENT

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