MICROPLASMA NOISE – COEFFICIENTS OF GENERATION AND RECOMBINATION

Michal Raška, Vladislav Holcman
Doctoral Degree Programme (2), FEEC BUT
E-mail: xraska04@stud.feec.vutbr.cz

Supervised by: Pavel Koktavý
E-mail: koktavy@feec.vutbr.cz

ABSTRACT

The occurence of microplasma regions in PN junctions is attributed to crystal lattice imperfections. As a rule, these regions feature lower strong-field avalanche ionization breakdown voltages than other homogenous PN junction regions [1]. The existence of such regions may lead to local avalanche breakdowns occuring in reverse-biased PN junctions at certain voltage. These local avalanche breakdowns may exhibit as a current impulse noise. These impulses are usually represented by constant amplitude, random pulse width and pulse origin time points. The current impulse noise is dependent on voltage. When the reverse voltage on PN junction increases, frequency and width of impulses are also increasing. The microplasma bistable behaviour may be described with two-state stochastic process of generation-recombination type.

1. INTRODUCTION

The article deals with a study of a diodes exhibiting two level current impulse noise. The diodes show an unstable behaviour only in the certain range of reverse voltages,

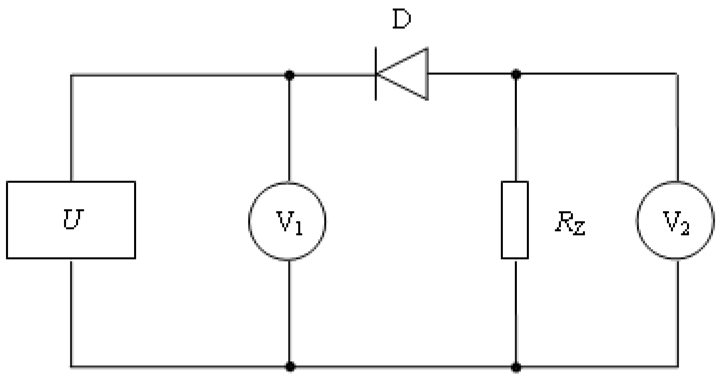

Fig. 1: The circuit for the microplasma noise measuring.

the voltage range depend on the junction defect region properties. When the reverse voltage increases within this interval the current impulse amplitude are showing a quasi-linear growth, the average impulse width is increasing, whereas the average impulse separation is decreasing. This phenomenon is generally ascribed to local avalanche breakdowns originating in p-n junction defect regions called microplasma regions [1]. Fig. 1 shows the circuit for measuring current impulse noise, microplasma noise.

This behaviour can be described with a two-state stochastic process of generation-recombination type (G-R process) [4]. The coefficients generation g and recombination r can be determined by several methods. The first of them is usage the distribution of the probability density $f(\tau_0)$ of the impulse separation τ_0 and the probability density $f(\tau_1)$ of the impulse width τ_1. The next method, how find out the generation and recombination coefficients, depends on transition probabilities from state 0 to 1 and back from state 1 to 0 [1].

2. STATISTICAL CHARACTERISTICS OF MICROPLASMA NOISE

The characteristics of the impulse random process which arises consequence of the bistable nature of the microplasma conductivity, depend on the type of the load impedance connected in the circuit with diode [3]. The experiment shows that the microplasma bistable behaviour can be described with a two-state stochastic process of generation-recombination type, Markovian type. This type is typical for a voltage source. The resulting impulse process is non-Markovian if the diode power supply behaves as a current source. Two postulates describe the primary process:

- If the system is at a time t in the state *0* then the transition probability to the state *1* within the time interval $(t, t + \Delta t)$ equals $g\,\Delta t + o(\Delta t)$ [1].
- If the system is at a time t in the state *1* then the transition probability to the state *0* within the time interval $(t, t + \Delta t)$ equals $r\,\Delta t + o(\Delta t)$ [1].

The quantities g and r are the generation and recombination coefficients and $o(\Delta t)$ is a transition probability to other states than neighbouring [1].

3. THE DISTRIBUTION OF PROBABILITY DENSITY τ_0, τ_1 AND COEFFICIENTS g AND r DETERMINATION

It can be shown that the distribution of the probability density $f(\tau_0)$ of the impulse separation τ_0 and the probability density $f(\tau_1)$ of the impulse width τ_1 can be expressed as:

$$f(\tau_0) = g e^{-g\tau_0} \tag{1}$$

$$f(\tau_1) = r e^{-r\tau_1} \tag{2}$$

These equations are only for a stationary random process [4]. A curve, which represent results of our experiment for $f(\tau_0)$, is in a good agreement with the proposed model, see fig. 2. The second curve for $f(\tau_1)$ has some divergence, fig. 3. The grey line represents the mathematical model and the black one is from measuring. The numerical values for the generation and recombination coefficients are $g = 7453\ \mathrm{s}^{-1}$ and $r = 6173\ \mathrm{s}^{-1}$.

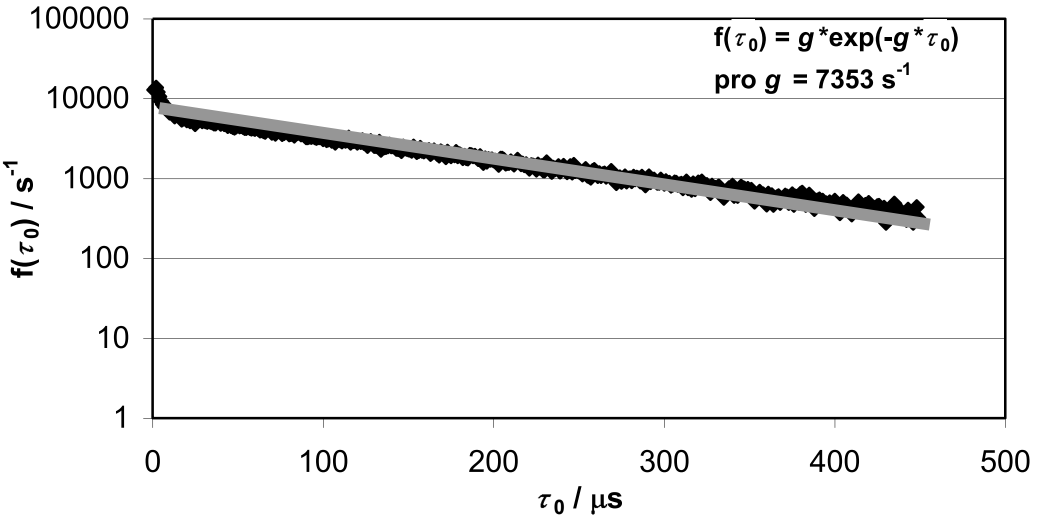

Fig. 2: The distribution of probability density τ_0, the diode E3, $U = 1534{,}6$ V.

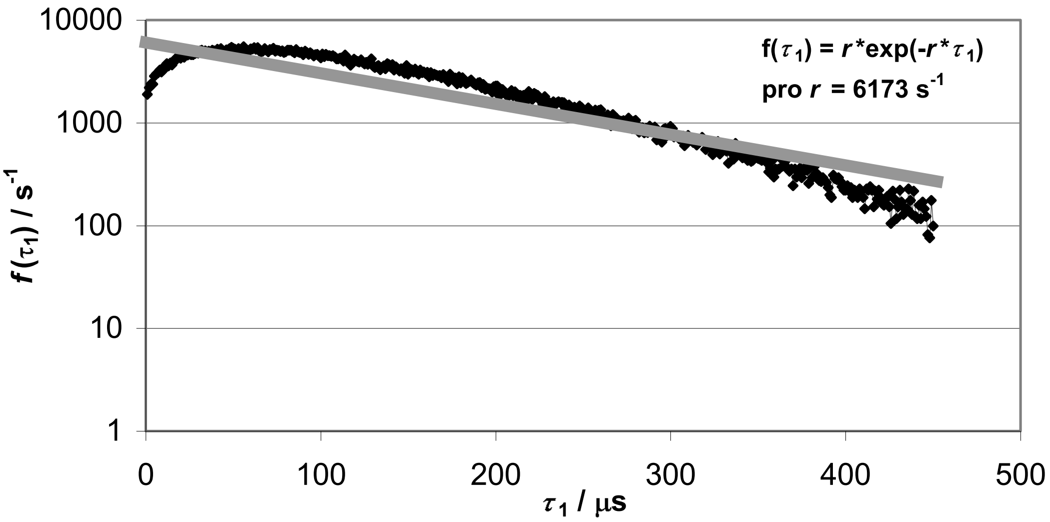

Fig. 3: The distribution of probability density τ_1, the diode E3, $U = 1534{,}6$V.

4. CALCULATION OF THE COEFFICIENTS *g* AND *r* FROM THE TRANSITION PROBABILITY P_{01} AND P_{10}

We can find the coefficients of generation and recombination by other way. The generation coefficient depends on the transition probability from the state 0 to 1 and the recombination coefficient depends on the transition probability from the state 1 to 0. When the system is in the state 0 and during the time period Δt goes to another one, in our case to the state 1, we call this transition probability as P_{01}.We compute P_{01} as a fraction between N_{01},

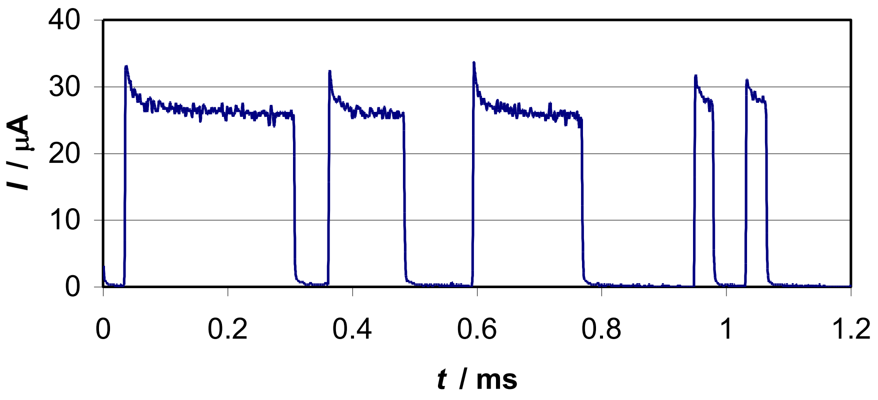

Fig. 4: Microplasma bistable behaviour current noise, the diode E3, $U = 1534{,}6$ V

a sum of every time period Δt, when the state is changed from 0 to 1 and N_0, a sum of the all time period Δt, when the system is in the state 0.

$$P_{01} = \frac{N_{01}}{N_0} \tag{3}$$

Then P_{10} will be the transition probability, when the system is in the state 1 and during the time period Δt goes to the state 0.

$$P_{10} = \frac{N_{10}}{N_1} \tag{4}$$

Here is N_{10} a sum of every time period Δt, when the state is changed from 1 to 0 and N_1 is a sum of the all time period, when the system is in the state 1. There is an illustration of the course on the fig. 4, where we can see a part of the bistable current noise, microplasma noise. The coefficients of generation and recombination are obtained from the shown time behaviour or similar one. We can establish them from these equations:

$$g = \frac{P_{01}}{\Delta t} = 7298\,\mathrm{s}^{-} \tag{5}$$

$$r = \frac{P_{10}}{\Delta t} = 530\,\mathrm{s}^{-} \tag{6}$$

5. CONCLUSION

It was measured one hundred courses of the bistable current noise, microplasma noise, time length 0.5 s for the same input voltage $U = 1548{,}3$ V. We established the distribution of the probability density τ_0, τ_1 from the data and found out that the course is exponential. Some difference was observed on the distribution of the probability density for τ_1. The reason could be a change of temperature in the microplasma area during the local avalanche breakdowns. The verification will be an object for next research. The coefficients of generation and recombination were found out from the exponential distributions of the probability density τ_0 and τ_1.

The second part was focused to the calculation the coefficients of generation and recombination from the transition probabilities P_{01} and P_{10}. The coefficients of generation are very similar in both of the methods, but the coefficients of the recombination have some differences, which could arise from the change of temperature in the microplasma area during the avalanche breakdowns.

ACKNOWLEDGEMENTS

This paper is based on the research supported by the project MSM 0021630503, GACR 102/06/1551 and by the project FRVS 1424/G1.

REFERENCES

[1] Koktavý, P., Šikula, J. Reverse Biased P-N Junction Noise in GaAsP Diodes with Avalanche Breakdown Induced Microplasmas. Fluctuation and Noise Letters, ISSN 0219-4775, 2002, roč. 2, č. 2, s. L65 – L70.

[2] Koktavý, P., Koktavý, B. Local Instabilities In GaAsP Diode PN Junctions. In Noise and Fluctuations, 18th conference on Noise and Fluctuations – ICNF 05. 18th International Conference on Noise and Fluctuations – ICNF 2005. Salamanca, Spain: American Institute of Physics, 2005, s. 393 – 396, ISBN 0-7354-0267-1.

[3] Haitz, RH. Model for the Electrical Behavior of Microplasma. J. Appl. Phys., May 1964, vol. 35, no. 5, p. 1370-1376.

[4] Koktavý, P. Study of Microplasma Noise Statistical Characteristics for GaAsP Diodes. In Proceedings of the 17th International Conference Noise and Fluctuation ICNF 2003. Noise and Fluctuations ICNF 2003 Prague. Prague: CNRL, s.r.o., 2003, s. 437 – 440, ISBN 80-239-1055-1.