AUTOMATED DIAGNOSTICS OF SOLAR CELLS

Petr Paracka
Doctoral Degree Programme (1), FEEC BUT
E-mail: xparac01@stud.feec.vutbr.cz

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

ABSTRACT

To examine solar cells in our laboratories we use nondestructive testing, which is of great importance nowadays. The aim of this test is to determine if the product meets requirements of norms and standards without its damage or functional parameters changing. To this diagnostics the method of measurement of effective value of narrow-band noise current was used. This method is very perspective from the efficiency point of view.

1. INTRODUCTION

In a semiconductor PN junction there are localized regions featuring increased concentration of donor or acceptor impurities, other element admixtures or other defects cause the PN junction reverse breakdown voltage to be reduced and affect the total minority charge carrier lifetime. These regions may give rise to local fluctuations of the PN junction potential barrier thus reducing the conversion efficiency of the solar radiation energy into electric one. If a certain part of the cell operating in a solar panel happens to be in a local shade, this particular cell will get into reverse-bias condition. Due to the existence of reduced breakdown voltage local defects, local breakdowns may occur in the neighbourhood of the defects, which in turn may lead to heavy current densities in the low-cross-section regions. This phenomenon can give rise to an intensive local temperature increase and, consequently, local diffusion or thermal breakdown, which may result in the cell destruction.

The analysis of determination of microplasma noises sources is very difficult because of large solar cell surface and uncountable number of local regions. Due to these reasons we measure not the whole solar cell but its separate fragments. The experiments show that it is possible to observe two types of noise using our method. The A type of noise [1] (microplasma noise) is shown in Fig. 1. This noise is in a shape of two or more pulse of current with constant amplitude, random time of appearance and random time of pulse duration.

Another type of noise is B-type (Fig. 2). It is not stationary and this noise can occur as a result of thermal breakdowns of PN junction.

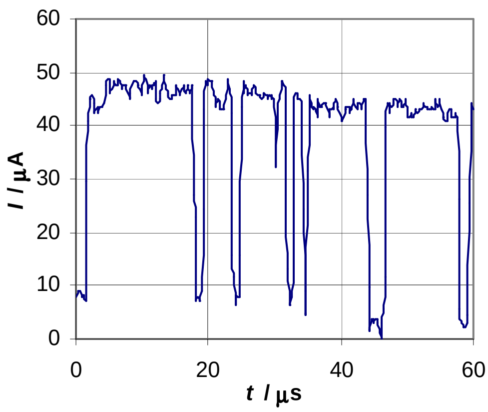

Figure 1: Microplasma noise (A-type)

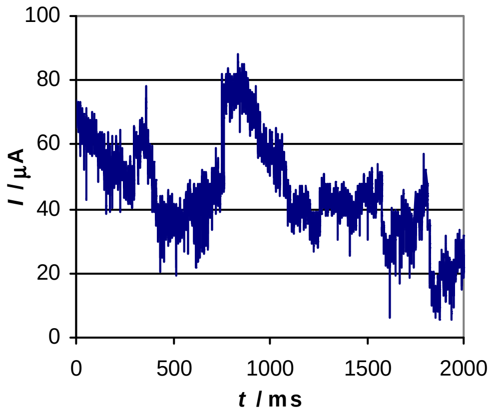

Figure 2: Intensely non-stationary B-type

2. ANALYSIS

2.1. SOLAR CELLS UNDER INVESTIGATION

The studied solar cells were made on a monocrystal substrate of P type. Its parameters are: 1.2 Ω.cm of resistivity, 240 µm of thickness, sizes of 125 × 125 mm and the surface area of 148 cm^2, produced by Czochralsky process. The lifetime of minor charge carriers was measure by MWPCD. Its value was over the range 20 to 25 µs before the first heating up to the high temperature.

The solar cells surface was at first cleaned from damaged surface layers and then it was textured by etching in alkaline solution. The samples with homogeneous (C) and selective (A, B, D) emitter were used for analysis. Passivating ARC layer was made from silicon nitride (A, B, D) or silica (C). Contacts on the front side were made by metallization with the use of silver paste. There is a layer of Al BSF with Ag/Al contacts on the back side of solar cells

2.2. MEASUREMENT DEVICE

From the viewpoint of noise diagnostics, suitable features are RMS values of narrow-band noise current I_N versus reverse voltage U_R or reverse current I_R plots, because each local extreme of these plots corresponds to an active local defect region.

A noise voltage $u_N(t)$ appears across the load resistance $R_L = 5.17\ \Omega$ through which the noise current $i_N(t)$ is flowing (Fig. 3), being amplified by a pre-amplifier PA (3S Sedlak PA 31) and amplifier CNRL (3S Sedlak). The noise voltage is converted into a voltage, the average time of which is proportional to the RMS value U_N of $u_N(t)$ in the given frequency band, by a noise detector ND (selective nanovoltmeter Unipan 237, the central frequency 420 Hz, the effective bandwidth 49 Hz). The voltage U_N is measured by a digital voltmeter DV.

Effective value of noise current is in the following frequency band

$$I_{\mathrm{N}} = \frac{U_{\mathrm{N}}}{R_{\mathrm{L}}}. \tag{1}$$

The set-point values of the PN junction reverse current being adjusted by means of a PC-controlled voltage supply VS (Agilent E3649A).

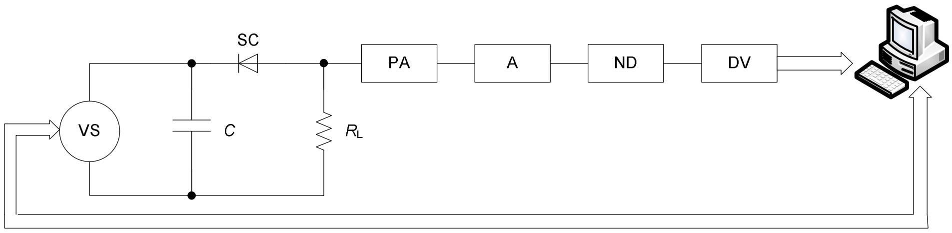

Figure 3: Apparatus for noise current measurement

2.3. RMS VALUE OF NARROW-BAND NOISE CURRENT

Fig. 4 – 8 show the noise current RMS value I_{N} versus the ramp reverse voltage U_{R} plot for solar cells with different structure. Each measuring was performed for the reverse current I_{R} up to 150 mA. It is visible that we obtain very complicated functions $I_{\mathrm{N}}(U_{\mathrm{R}})$ indicating a large number of noise sources in the junctions under investigation, the different sources overlapping each other.

The example of a course measured on a solar cell of the structure A is in Fig. 4. This sample exhibits only bulk noise increasing with the reverse current I_{R} for low voltage. We can observe local defects activity from the threshold voltage of about 3 V. The RMS value of the narrow-band noise current maximum level is about 45 nA in the measured range of the reverse current. This solar cell exhibits relatively high-quality from the view point of noise diagnostics.

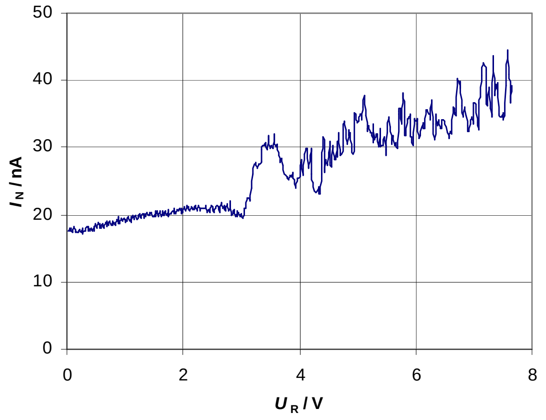

Figure 4: Narrow band RMS noise current versus reverse voltage plot, solar cell A 24

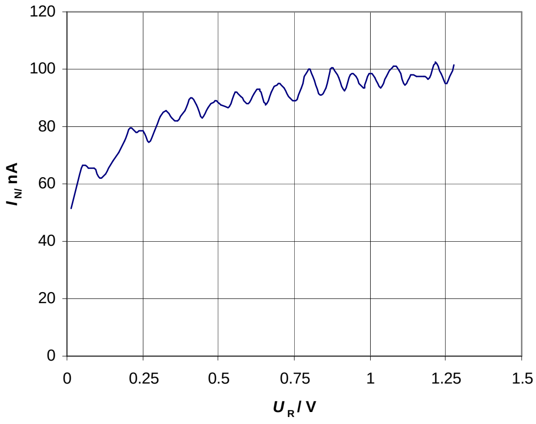

Figure 5: Narrow band RMS noise current versus reverse voltage plot, solar cell B 23

The noise characteristics of a solar cell with the structure B is in Fig. 5. It exhibits increased level of noise in comparison with solar cells of other structures. This fact is probably due to strong bulk degradation of a PN junction area. Solar cells of this group have already the reached maximum reverse current of 150 mA for the reverse voltage of about 1 V. The course of the VA characteristics is in agreement with hypothesis of bulk degradation in the PN junction.

The example of a course measured on a solar cell of the structure C1 is in Fig. 6. The solar cell exhibits the threshold of the noise current increasing for the reverse voltage of about 3 V. This effect is probably due to strong voltage dependence of local defects activity. The measured noise current maximum value is 250 nA.

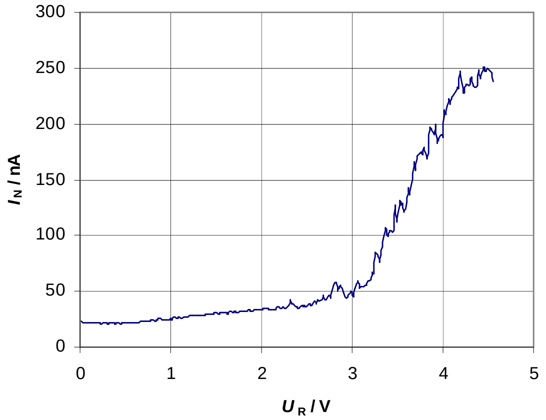

Figure 6: Narrow band RMS noise current versus reverse voltage plot, solar cell C1 16

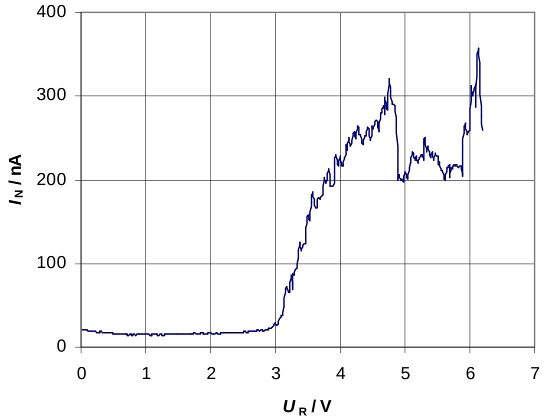

Figure 7: Narrow band RMS noise current versus reverse voltage plot, solar cell C2 8

The noise characteristics of a solar cell with the structure C2 (Fig. 7) exhibits very similar course as the previous solar cell with the structure C1. The difference is in the higher reached reverse voltage of 6.2 V for reverse current of 150 mA. The region of the characteristics over the reverse voltage of 4.5 V shows evidence of strong local defects activity. Noise levels and noise thresholds are probably the same for both mentioned solar cells.

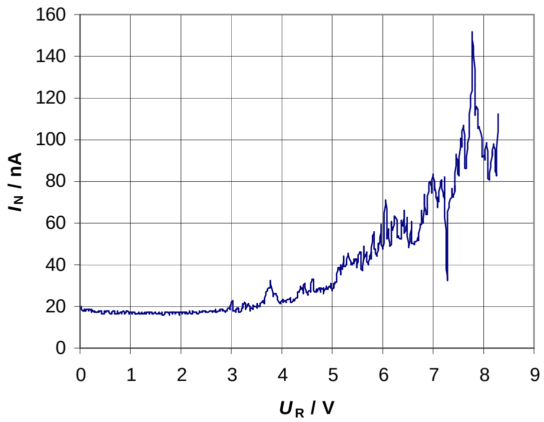

Figure 8: Narrow band RMS noise current versus reverse voltage plot, solar cell D 12

The example of a course measured on a solar cell of the structure D is in Fig. 8. This cell exhibits higher reverse voltage of 8.2 V for reverse current of 150 mA. The threshold of noise current increasing is again for the reverse voltage of about 3 V. Distinctive peaks appear in the region over the reverse voltage of 7 V on the characteristics. The reached noise current maximum value is 150 nA.

3. CONCLUSION

As it was mentioned in the Introduction, due to the manufacturing processes the solar cells PN junction can become degraded. This can lead to the whole photovoltaic panel quality decreasing.

For nondestructive testing of solar cells the method of measurement of narrow-band noise current effective value versus reverse voltage was used. This method is very perspective from the viewpoint of nondestructive noise diagnostics. It is relatively simple, feasible and it can be used for detection of solar cells local defects in PN junction area.

Using this method the monocrystal solar cells of several structures were examined: A, B, C1, C2 and D. The existence of local defects in PN junction of studied solar cells was determined. These defects, which cause occurrence of excessive noise, were detected in all studied samples.

Measurements showed that from the viewpoint of noise diagnostics solar cells of A and D structures have better characteristics. On the other hand solar cells with B structure had distinct volume degradation in the PN junction area.

ACKNOWLEDGEMENTS

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