NOISE DIAGNOSTICS OF SOLAR CELLS

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Abstract: PN junction is one of the most important parts of solar cells. Its quality affects lifetime and efficiency of solar cells. Local defects which appear in PN junctions during the manufacture process are very important from this point of view. Measuring method of narrow-band noise current RMS value with reverse bias junction were used in this paper. This method allows detection of local defects and volume degradation in PN junctions of solar cells and it can be used for detection of microplasma noise.

Keywords: solar cell, microplasma noise, reverse voltage, PN junction

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 which 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 solar radiation energy to electric energy conversion efficiency. 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 neighborhood of the defects, which in turn may lead to heavy current densities in the low-cross-section regions. This phenomenon can give rise to a heavy local temperature increase and, consequently, local diffusion or thermal breakdown, which may result in the cell destruction.

There are several basic methods designed to detect the mentioned defects: Reverse current versus reverse voltage plots, reverse *U-I* curve measurements, narrow-band noise current RMS value measurements, reverse current noise power spectral density measurements, local defect region emitted radiation measurements, and local irradiation induced electrical response measurements. Supplementary information can be gained from both near-field optical microscope and electron microscope measurements.

2. ANALYSIS

2.1. MEASURING METHODS

Noise diagnostics of solar cells in this case was carried out by effective value of narrow-band noise current with PN junction polarized in reverse bias. Reverse voltage U_R may not be higher than the avalanche voltage of the whole non defect area of the junction. Because of the wide junction-plane, and numerous amount of defects, it is uneasy to analyze recorded noise and single noise sources. Because of these reasons we measure not the whole solar cells but their 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 has the shape of two or more levels of pulse current with constant amplitude, random time of appearance and random time of pulse duration.

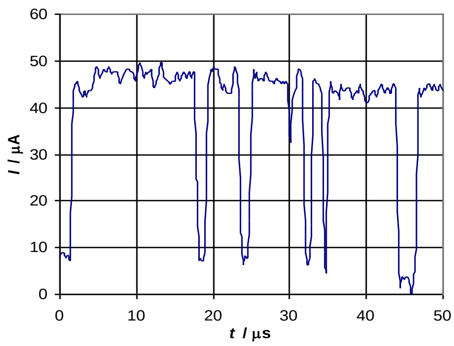

Figure 1: Microplasma noise (A-type)

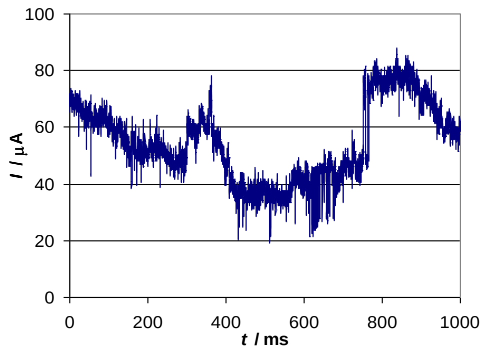

Figure 2: Heavily non-stationary noise (B-type)

Another type of noise is B-type (Fig. 2) is non-stationary and this noise can occur as a result of thermal breakdowns of PN junction [2].

2.2. EXPERIMENTAL SET-UP

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, whose time average 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 center frequency 420 Hz, the effective bandwidth 49 Hz). The voltage U_N is measured by a digital voltmeter DV.

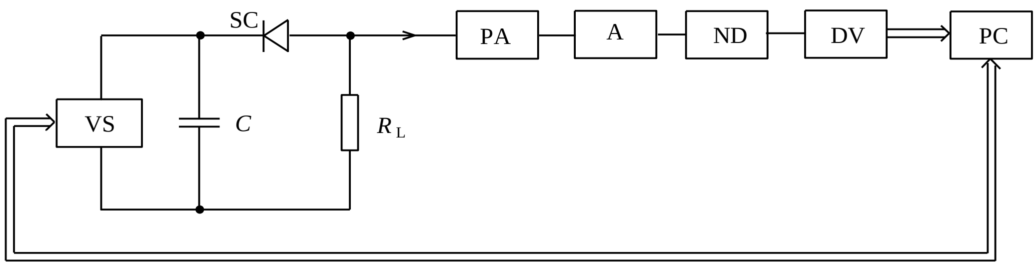

Figure 3: Model of the measurement system

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

2.3. RMS VALUE OF THE NARROW-BAND NOISE CURRENT

Figures 4 – 8 show the noise current RMS value I_N versus the ramp reverse voltage U_R plots for solar cells with different structure. The samples with homogeneous (H) and selective (S) emitter were used for analysis. Silicon nitride (S) or silicon oxide (H) was applied as passivation and ARC layer [3].

The noise characteristics of a solar cell with the structure H1 is in Fig. 4. Measuring was performed for the reverse current I_R up to 150 mA (reverse voltage 3.5 V). We can observe local defects activity from the threshold voltage of about 2.1 V. The reached noise current maximum value is 330 nA.

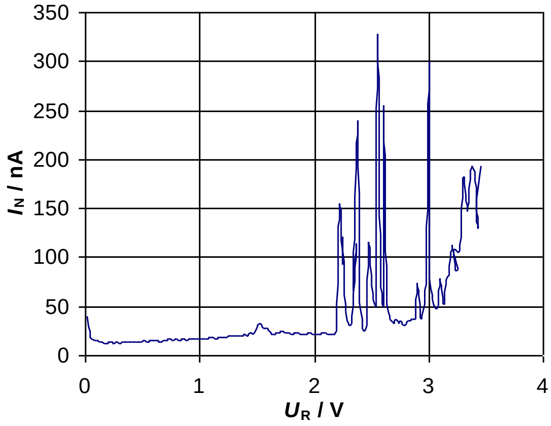

Figure 4: Narrow-band RMS noise current versus reverse voltage plot, solar cell H1

The example of the course measured on the solar cell of the structure H2 is in Fig. 5. Measuring was performed for the reverse current I_R up to 300 mA. The solar cell exhibits the threshold of the noise current increasing for the reverse voltage of about 3.7 V [4]. The measured noise current maximum value is 1900 nA.

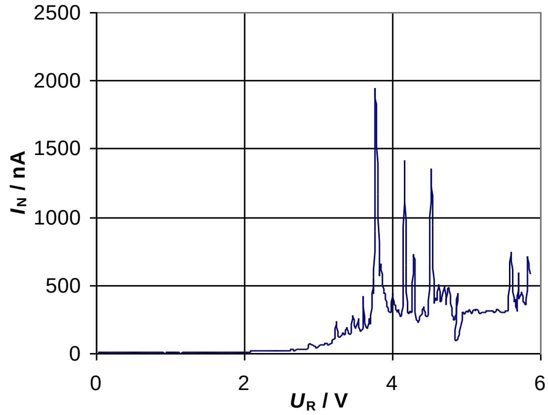

Figure 5: Narrow-band RMS noise current versus reverse voltage plot, solar cell H2

The sample H1 has less fill factor, parallel resistance, lower efficiency and lower maximum power, who can deliver, than the sample H2. These informations are mentioned in manufacturer's datasheet.

The example of the course measured on the solar cell of the structure S1 is in Fig. 6. Measuring was performed for the reverse current I_R up to 150 mA. We can observe local defects activity from the threshold voltage of about 3.5 V. The reached noise current maximum value is 150 nA.

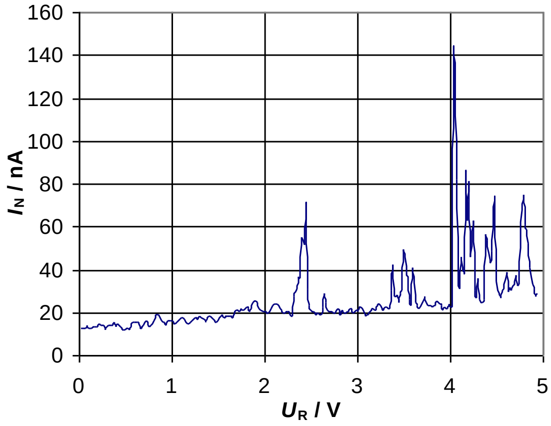

Figure 6: Narrow-band RMS noise current versus reverse voltage plot, solar cell S1

The noise characteristics of the solar cell with the structure S2 is in Fig. 7. The solar cell exhibits the threshold of the noise current increasing for the reverse voltage of about 4.8 V. The difference is in the higher reached reverse voltage of 7.8 V for the reverse current of 150 mA. The measured noise current maximum value is 3700 nA. The sample S1 has much smaller parallel resistance than the sample S2.

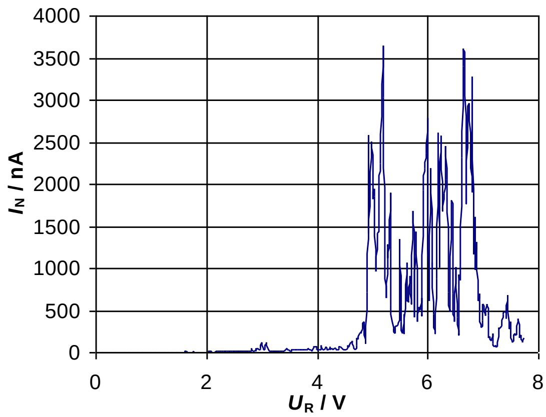

Figure 7: Narrow-band RMS noise current versus reverse voltage plot, solar cell S2

3. CONCLUSION

RMS value of narrow-band noise current measuring method vs. reverse voltage was used for solar cell diagnostics. This method is very perspective from the viewpoint of non-destructive noise diagnostics. It is very simple method which can be easy realized and can be used to the detection of local defects in the PN junction area.

By this method monocrystalline solar cells with selective and homogeneous emitters were diagnosed. According to our measurements, the solar cell properties differ significantly regardless to its structure. Measurements showed that; solar cells of S1 and H1 structures have better characteristics from the viewpoint of noise diagnostics. Expressive peaks characteristics of the studied samples reveal the possible presence of microplasma noise.

The information about these effects can be used in noise diagnostics of structural defects of PN junctions and then it can be used for quality and lifetime estimation of samples with these parameters.

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