DIAGNOSTICS OF SOLAR CELLS IN SPECTRAL DOMAIN

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ABSTRACT

Our research is focused on the silicon monocrystalline solar sells and this article briefly deals with non-destructive solar cells testing via noise measurement. Several kinds of noise have been discovered. The microplasma noise is patterned with our solar cells samples and it originates in consequence local avalanche breakdowns. Another noise type probably originates as a result of thermal processes. There is shown spectral analysis utilization for classification and description noises in this article.

1. INTRODUTION

The solar cells are very popular tool for obtaining alternative power at the present time. The conversion of sunlight into electrical energy process is based on the photoelectric effect discovered by Alexander Bequerel in 1839. The first solar cell was manufactured mach more later in 1877.

The present-day technology is more advanced and the current solar cells exploited many kinds of semiconductor and organic materials. Nevertheless, over 84% of all the solar cells produced worldwide are composed of the semiconductor silicon material. Our research is focused just on monocrystalline silicon solar cells where *pn* junction is produced by the diffusion process. The top layer of solar cell is doped by phosphorus for creation a thin *n*-type semiconductor. The *n*-type semiconductor is doped by boron and overall thickness is about 250 μm (depletion layer usually may be about 0.6 μm). The total junction area is very large, generally about 100 cm^2. It is clear that a junction like this includes a large number of various defects. Our research aim is junction non-destructive diagnostics and quality assessment via noise measurement.

2. REVERSE BIASED SOLAR CELLS NOISE

Although solar cells primarily do not work in reverse VA characteristic section, it is also important to study this mode of operation [1]. The Solar cell sequencing in solar panels needs to be considered because the shadowed solar cell is able to change its operation mode. We observe these two types of noise. The former is microplasma noise called as A-type noise. It typically occurs in semiconductor devices with the PN junction e.g. silicon diodes, LED diodes (GaAsP) and solar cells [1]. The microplasma noise usually originates with enough high reverse voltage naturally lower than the breakdown voltage of complete defect-free junction regions. It is consequence of local avalanche breakdowns and this noise occurs in a two-level or multi-level current impulse form [1]. This impulses shape is usually rectangular (provided that it is not affected by measuring instruments). The current impulses are characteristic with the constant amplitude, random time duration and random time inception. The typical example is shown in Fig.1.

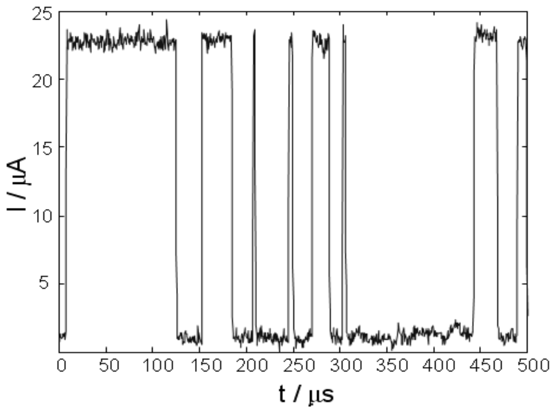

Fig. 1 A-type noise current, sample K2, $U_R = 10.5$ V

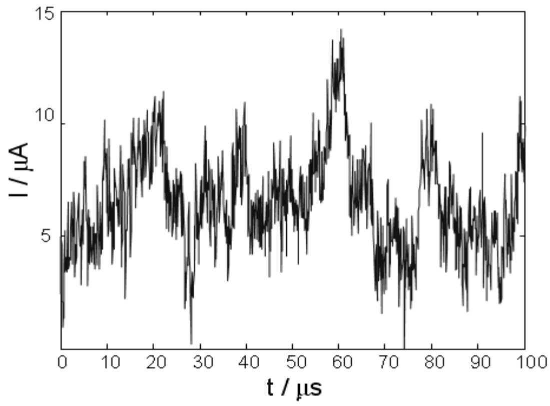

Fig. 2 A-type noise current, sample K11, $U_R = 7.0$ V

Figure 2 shows the latter type of noise marked as B-type. It is clear that we can get a noise signal which is superposition of several noise sources in case of measurement of the real samples. More dominant B-type noise is probably result of the thermal local breakdown of the PN junction.

3. SPECTRAL ANALYSIS OF SOLAR CELLS NOISE

A-type noise correlates from statistic view with Poisson (Marcovian) process and experiments demonstrate that we can think of this noise as a stationary stochasting process. In the spectral domain we observe character of spectrum as in the case of generation-recombination processes. This concrete kind of impulse noise does not originate to all intents and purposes by generation or recombination charge carriers, but we can consider it is impulse stochastic generation and cessation. To this particular purpose of impulse noise we may use the equation (1). There G_i is spectral power density dependent on reverse voltage U_R and frequency f [1]

$$G_i = \frac{4 \cdot {I_M}^2 \cdot g \cdot r}{(g+r)[(g+r)^2 + \omega^2]} \quad . \tag{1}$$

The power spectral density G_i has been measured according to theory, as shown in Figure 3 and 4. There is expected fall of spectral density in the field of higher frequencies in compliance with $1/f^{1,98}$. Perceptible superimposed RF noise is on the Figure 4, which affected measurement. The interesting is low frequency field. There come out process with character $1/f^{1,08}$.

Figures 3 and 4 have been measured for 53 minutes on the same specimen of the solar cell K2. The second process originates with a long time constant and it is not conformable with thermal processes. It is possible that this effect is a relaxation process in a semiconductor material of a solar cell.

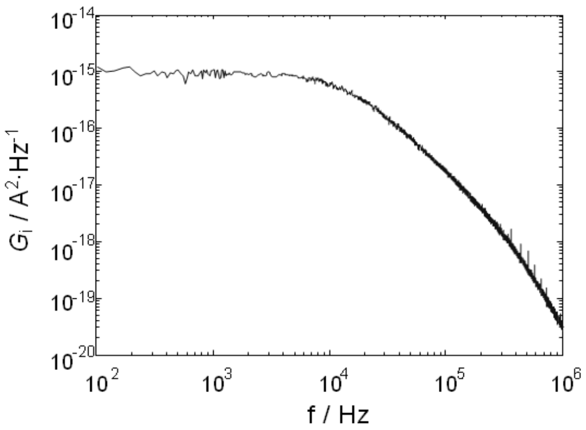

Fig. 3 Spectral power density of A-type noise, sample K2, U_R = 10.5 V, time = t min

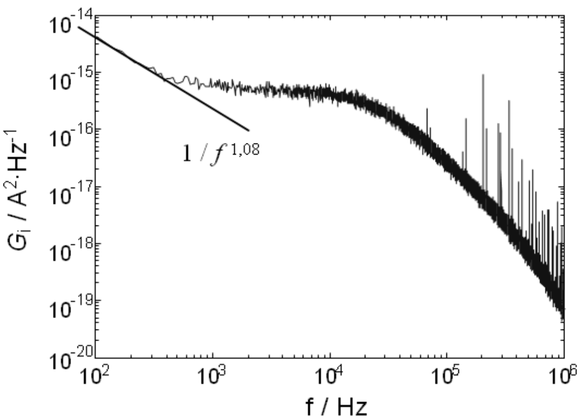

Fig. 4 Spectral power density of A-type noise, K2, U_R = 10.5 V, time = t + 53 min

B-type noise, mentioned above, is strong non-stationary. Its power spectral density is illustrated in Figure 5. Spectral power density falls approximately with $1 / f^{1}$ and this fall is probably caused by thermal instabilities in a specimen. It is necessary point out, that this type of noise is still a research subject. A and B type noise superposition is shown in Figure 6, again for the same sample of a solar cell but for another region with local avalanche breakdowns (reverse voltage U_R = 11.86 V). It stands to reason that a generation-recombination process is not dominant here and arises at the background of B-type noise. It is observed in the time domain as a two-level current amplitude reducing compare to other region (maximum of current noise I_N = 24 μA, see Figure 1). We can also see that power spectral density of B type noise is only weakly dependent on reverse voltage U_R (see Figure 5 and 6).

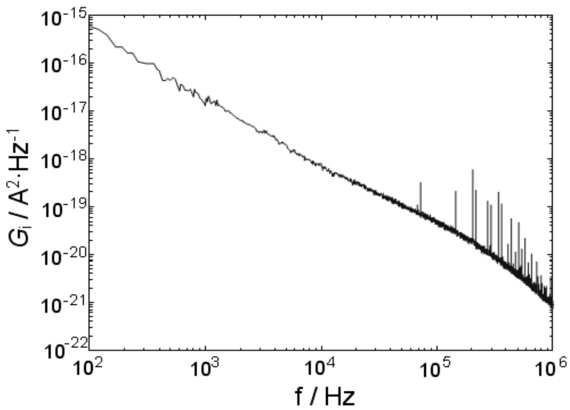

Fig. 5 Spectral power density of B-type noise, sample K2, U_R = 12.86 V

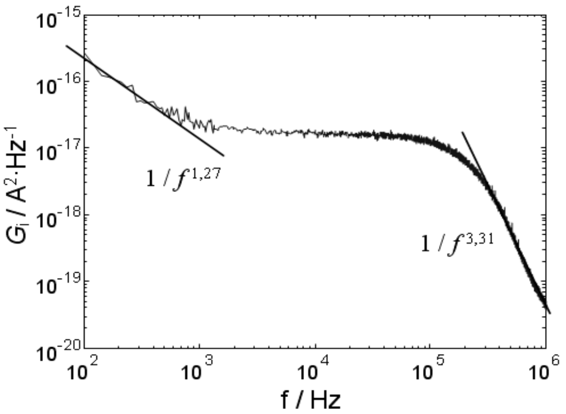

Fig. 6 Spectral power density of A and B type noise, sample K2, U_R = 11.86 V

In some cases B-type noise inception is very good bounded. We can observe it in VA characteristic where sharp break is evident. It is probably effect of a thermal breakdown in a junction. This process result is just increased non-stationary B-type noise. Figure 7 visually demonstrated spectral power density in 3D space. The Measurement has been made for wide range of reverse voltage U_R and measured sample has been thermal stabilized. The thermal stabilization is necessary because reverse current may be as many as hundreds of milliamperes and power dissipation is generally about 1.8 W. The mentioned sharp break in the VA characteristic occurred approximately for U_R = 10.6 V.

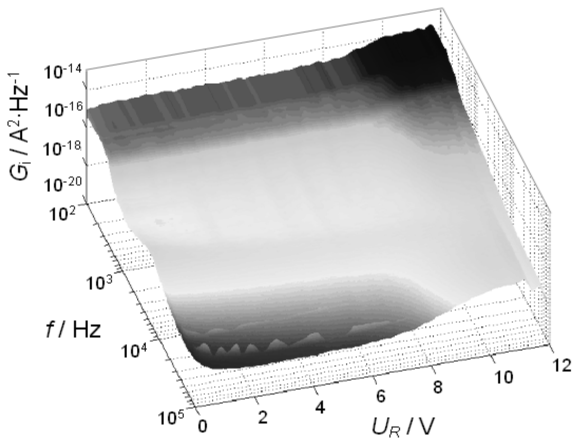

Fig. 7 Spectral power density for various reverse voltages, sample 30_3

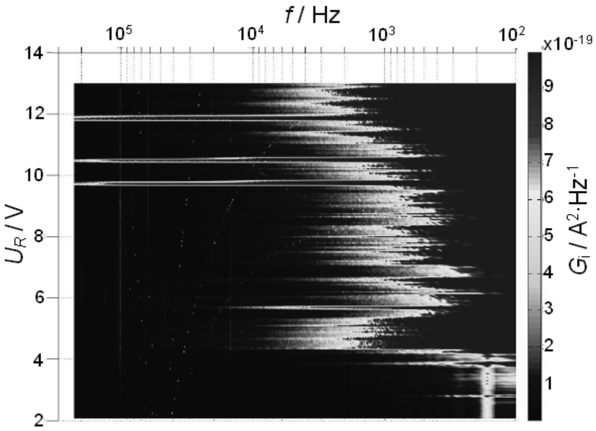

Fig. 8 Spectral power density for various reverse voltages, sample K2

The increase of power is good apparent in the low frequency region (the spectrum shape monotonously decreases approximately with the $1 / f^{1}$, see Figure 7). In the time domain the amplitude of current noise hardly increases.

In contrast to Figure 7, Figure 8 shows other phenomenon. It is possible view also the power increase at low frequencies, which is probably the same B-type noise incidence as mentioned above but interesting are three horizontal fringes. It represents mentioned microplasma (A-type) noise, and its generation-recombination spectrum. This image is profitable because it makes possible to differentiate various processes with various characteristics in spectrum.

4. CONCLUSION

The two noise types can be observed by the solar cell that is A-type (microplasma noise) and B-type noise. The microplasma noise is very important and we can use it in non-destructive diagnostics for quality classification. We can obtain much useful information from spectral power density and we can investigate the physical principle of origin. It is possible to perform description more complicated B-type noise, too. The spectral density shape and thermal properties evinces that this type of noise is result of the thermal breakdowns in PN junction. This hypothesis is supported by the $G_i = f(U_R)$ characteristics measurement and it is important for non-destructive solar cell testing improve.

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