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Evaluating of the Quality of New Solar Cells Designed for Concentrator Systems Application by Noise Spectroscopy

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Abstract – **The paper presents an experimental study of silicon solar cells of dimensions 80 x 80 mm, designed for concentrator systems. Transport and noise characteristics of these cells have been analyzed and PN junction and contact quality have been assessed.**

Keywords – **solar cell, concentrator system, noise**

I. INTRODUCTION

The need for increasing the solar cell efficiency implies the application of selective processes within the framework of their structure preparation technology. Under the term selective processes, we understand such processes, in the course of which the solar cell structure is formed within an exactly predefined region. This process includes, as a rule, the formation of two different structure regions at the front and rear side, or, within one of the sides.

The starting point in the solar cell optimization process consists in defining a process structure, which is as simple as possible, containing as few process steps as possible. The input-stage substrate is a single-crystal silicon wafer of a thickness of about 300 µm, which has been made from an ingot by means of a wire cutter. A damaged sub-surface layer containing a number of defects, is given rise during the wire cutting process, which is assisted by a cutting emulsion supply. The defective layer is to be removed by etching in an alkali solution. The double-sided-etched silicon wafer with a nearly defect-less surface has to be subjected to another etching process in order to minimize the reflected light intensity. Randomly localized pyramids of various sizes (as a rule up to 15 µm at the pyramid base) arise during the etching process.

The above described initial technology makes a limiting factor for the resulting solar cell efficiency, mainly due to a large area of the cell rear side additionally increased by a textured surface and to an inappropriate floating N^+ layer structure of the of the thick-film contacts at the rear side. What matters is the rear side face properties, from the minority charge carrier surface recombination point of view. Present technologies use silicon wafers, whose thickness is being reduced permanently, so that the effect of the wafer surface on the resulting solar cell parameters is more pronounced.

Diagnostic methods have been applied to examine the process steps intended to eliminate or at lest reduce the above mentioned structure imperfections. They include the following: acid-etch-based surface structuring and single-side etching of the rear side, aimed at removing the excessive N^+ layer and finishing the surface. In addition, the effect of the silicon oxide thin film located under the silicon nitride cover layer, particularly at the single side etched rear side, have been investigated.

This paper is intended to present the results of our studies of 3 silicon solar cells designed for concentrator systems, of dimensions 80 x 80 mm. These specimens feature a main conductor bar located at the specimen side and auxiliary conductor bars buried in the substrate in order to carry much higher current densities than in ordinary cells.

Noise and transport characteristics have been measured in the framework of this study. An analysis of U-I characteristics is presented in this paper. The spectral power density versus frequency function allowed us to evaluate the different types of noise. On the basis of the behaviour of particular spectral power densities versus forward voltage plots the quality of the different specimens can be evaluated [1-3].

II. EXPERIMENT RESULTS AND THEIR ASSESSMENT

Three silicon solar cells of dimensions 80 x 80 mm labelled S1-25, S1-26 and S2-26 have been studied.

Fig. 1 shows a semilog chart of the U-I characteristics of these cells. All of the three specimens feature a marked excess current component I_e in the forward voltage region near 0.2 V. The slope β ranges from 16.2 V^{-1} for specimen No S1-26 up to $\beta = 16.4\ V^{-1}$ for specimen No S2-26.

A voltage drop across the specimen contacts is observed at voltages over 0.7 V. The least voltage drop is exhibited by specimen No S2-26 – the best contacts of the specimen set – and the highest voltage drop is observed in specimen No S1-25. The S2-26 specimen contact series resistance is 0.6 Ω, the S1-25 contact series resistance, about 3 Ω.

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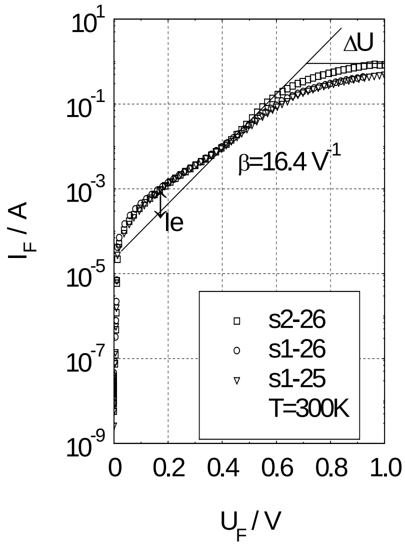

Fig.1 I-V characteristic for solar cells No S1-25, S1 -26 and S2-26 in forward bias direction

As is seen in Fig. 2, showing the log-log scale U-I characteristic, a straight-line section occurs in the characteristic at forward voltages of up to 0.1 V, giving evidence of a parallel resistance effectively shunting the PN junction. The shunt resistence is about 500 Ω and 200 Ω for S1-26 and S1-25 specimens, respectively.

C-U characteristics have been measured, too. S2-26 specimen features a capacitance of 3.4 μF. Fig. 3 shows the function C = (U^n) resulting from our measurements. The function appears to be almost of the $U^{1/3}$ type, which would suggest a linear type junction by Shockley.

Fig 4 shows a noise power spectral density versus DC forward voltage plots as picked up across a load resistance of R_L = 100 Ω and R_L = 1 kΩ for specimen No S1-25, at a mean frequency of 1 kHz and a bandwidth of 20 Hz.

A curve showing two peaks is observed. The first peak occurs at a voltage of U_{max1} = 0.15 V, whereas the second, at U_{max2} = 0.35 V.

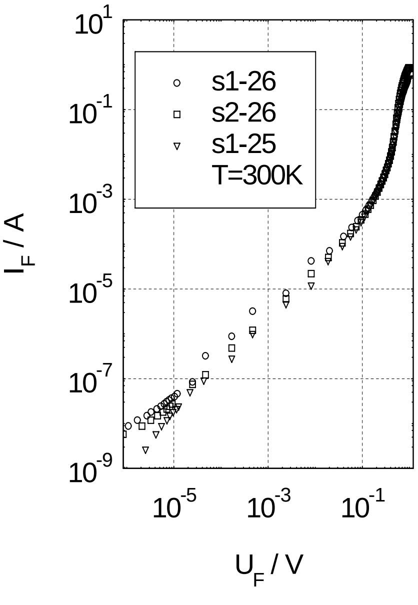

Fig.2 Plot of log I versus log U for solar cells No S1-25, S1-26 and S2-26 in forward bias direction

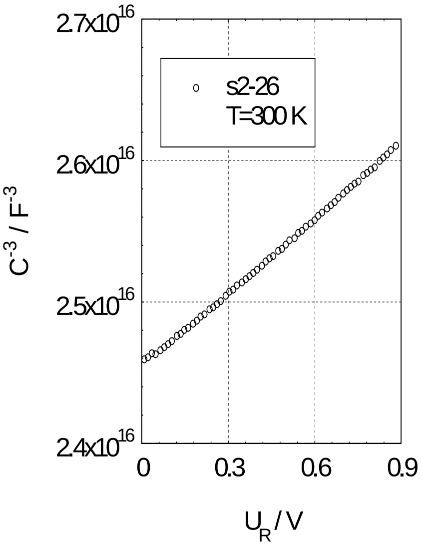

Fig.3 C-V characteristic for solar cells No.S2-26

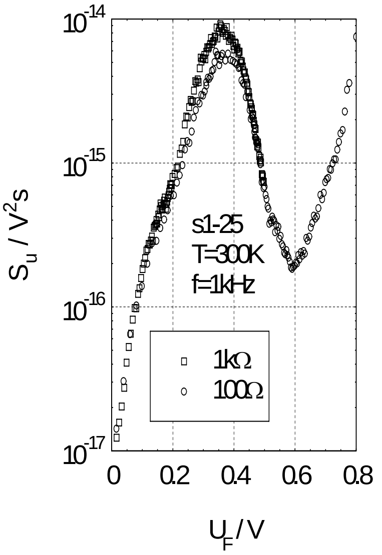

Fig.4 The noise spectral density as a function of forward voltage for solar cells No.S1-25

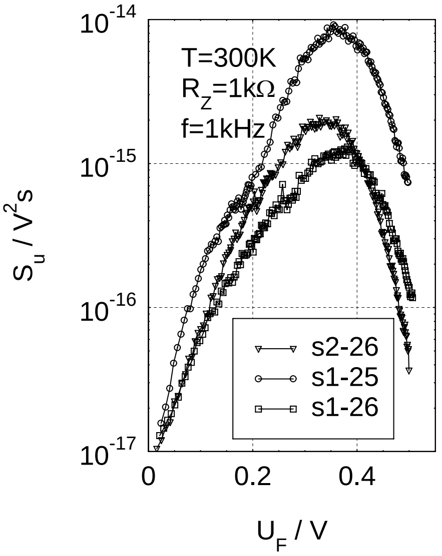

Fig.5 The noise spectral density as a function of forward voltage and load resistors R_L=100Ω, for solar cells Nos.S1-25, S1-26 and S2-26

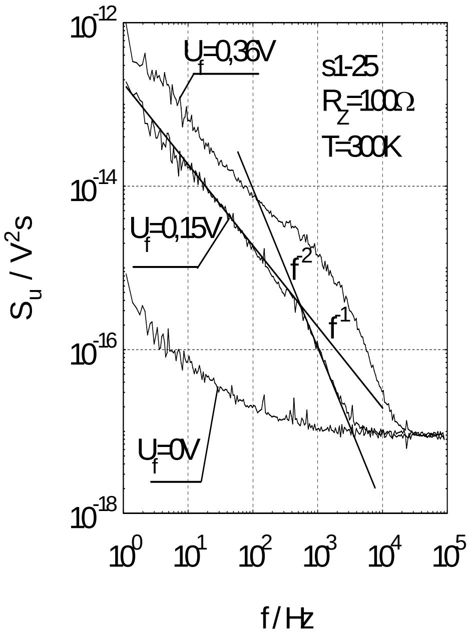

Fig.6 The noise spectral density versus frequency for solar cells No.S1-25, RL = 100 Ω, at $U_F = 0$ V, $U_F = 0.15$ V and $U_F = 0.36$ V

The maximum noise voltage is observed in the case of the PN junction dynamic resistance matching the load resistance value. This makes us to suppose two different defects in the PN junction regions being connected in parallel to each other.

The behavior of the characteristic over 0.6 provides us with indications concerning the contact quality. A fast growth of excess noise in this region leads us to a conclusion that the contact duality is poor.

Fig 5 shows the noise voltage power spectral density Su versus applied DC voltage plots for a load resistance $R_L = 1$ kΩ for all specimens under test. It is easily seen that the PN junction quality of S1-25 specimen is the poorest of the set, as $S_{umax} = 1.10^{-14}$ V^2s and two excess current sources), as well as the poorest contact quality.

At $U_F = 0.7$ V, the spectral density is = 7 x 10^{-16} V^2s.

S1-26 specimen features the best-quality PN junction, his noise power spectral density equaling
$S_{umax} = 1{,}05 \times 10^{-15}$ V^2s.

On the other hand, the best-quality contacts are shown by S2-26, as its noise spectral density Suk = 8.10^{-17} V^2s at $U_F = 0.7$ V.

Fig 6 shows the noise voltage spectral density versus frequency plot for specimen No S1-25. The load resistance was $R_L = 100$ Ω. The different characteristics have been measured at voltages: $U_{F1} = 0$ V characterizing the measuring setup background noise, $U_{F2} = 0.15$ V – the operating region of the first defect, and $U_{F3} = 0.36$ V – the operating region of the second defect. The excess noise appears to have two components. At frequencies below 1 kHz, noise of 1/f is predominating, whereas in the frequency range from 10^3 Hz to 10^4 Hz, noise of $1/f^2$ type is predominating. This behaviour gives evidence of the generation-recombination noise being present. Taking into account the frequency at which the g-r noise drops to one half, the charge carrier life time $\tau = \frac{1}{2\pi f}$ can be deduced, resulting in $\tau_1 = 1.10^{-3}$ s at $f_{01} = 1{,}5.10^2$ Hz for the first defect and $\tau_2 = 5.10^{-5}$ s at $f_{02} = 3.10^3$ Hz for the second defect.

III. CONCLUSION

Quality of three specimens of silicon solar cells of dimensions 80 x 80 mm designed for concentrator systems has been investigated.

Based on the above analysis of transport and noise characteristics, we can conclude that specimen No S1-26 features the best-quality PN junction, whereas specimen No S1-25, the worst.

The best-quality contacts were observed in specimen S2 - 26, the worst, in specimen No S1-25.

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