STUDY OF DEGRADATION PROCESSES OF PEROVSKITE SOLAR CELLS

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Abstract: The degradation processes of perovskite solar cells with a p-i-n structure based on PEDOT: PSS were studied, and their current-voltage characteristics were measured. It is shown that the general form of the current-voltage characteristic weakly depends or does not depend on the voltage scanning direction. The most significant changes in characteristics and a significant decrease in *Isc* and *Voc* are observed 12 days after sample production, and the magnitude of the decrease in performance characteristics depends on the conditions of preparation of the absorber.

Keywords: solar cell, perovskite absorber degradation, current-voltage characteristic.

Currently, despite the achieved fairly high conversion rates of perovskite-based solar cells of more than 22%, one of the main key problems hindering the practical use of these devices is the problem of degradation of the perovskite absorber [1-2]. In accordance with the Work Schedule, we studied the degradation processes of perovskite solar cells created within the framework of the methods we are developing.

A set of cells with a p-i-n structure on PEDOT: PSS was chosen as the objects of study. The samples were prepared according to the following procedure [3-4].

1) Application of a hole-conducting layer of PEDOT: PSS.

A solution with a volume of 50 μl was applied to glasses measuring 11x11 mm, 1 cell per glass. Spinning was carried out for 45 s at a speed of 6200 rpm. Next, the PEDOT: PSS layer was annealed at 1500C for 10 minutes.

2) Layer of iodide perovskite CH3NH3PbI3.

The formation of a perovskite absorber was carried out using a one-step method from a solution of MAI:PbI2 (1:1). Spinning of 50 μL of solution was carried out for 40 s at 2500 rpm. During the spinning process, 100 μl of toluene was added dropwise at different times for different series of samples, at the 6th and 4th seconds, respectively. The resulting samples were then annealed for 10 minutes at 1000C.

3) Deposition of a PCBM layer with electronic conductivity.

The volume of the applied solution was 250 μl. Spinning mode – 40 s at 1500 rpm. Annealing was carried out for 5 minutes at 1000C.

After applying the PCBM, a strip of carbon nanotubes was applied to the cell in air. A PCBM layer (~50 μL) was then deposited on top of the nanotubes. The samples were dried by slow spinning for 2-3 minutes at a speed of 500 rpm (3B), and then the structure was annealed at 1000C for 5 minutes. After obtaining a layered structure, all layers were removed mechanically, with the exception of the region under the nanotubes and directly near them. The areas of the working cells were approximately 2x2 mm (the area of intersection of the remaining ITO strip and the nanotube strip).

Before measuring the current-voltage characteristics, a “direct” voltage of 3 V was applied to the freshly prepared samples for 30 s.

The measurements carried out show that the current-voltage characteristics of “fresh” samples, measured immediately after their preparation, have pronounced diode characteristics. As a typical example, Fig. 1a, b, c and below show the current-voltage characteristics of a sample in which a

ISSN 2277-3630 (online), Published by International journal of Social Sciences & Interdisciplinary Research., under Volume: 13 Issue: 04 in April-2024
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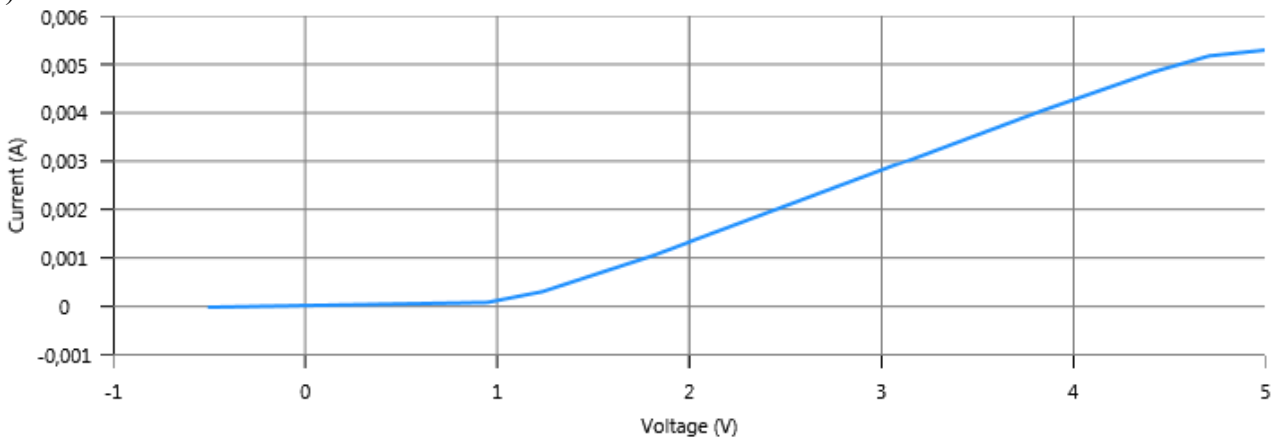
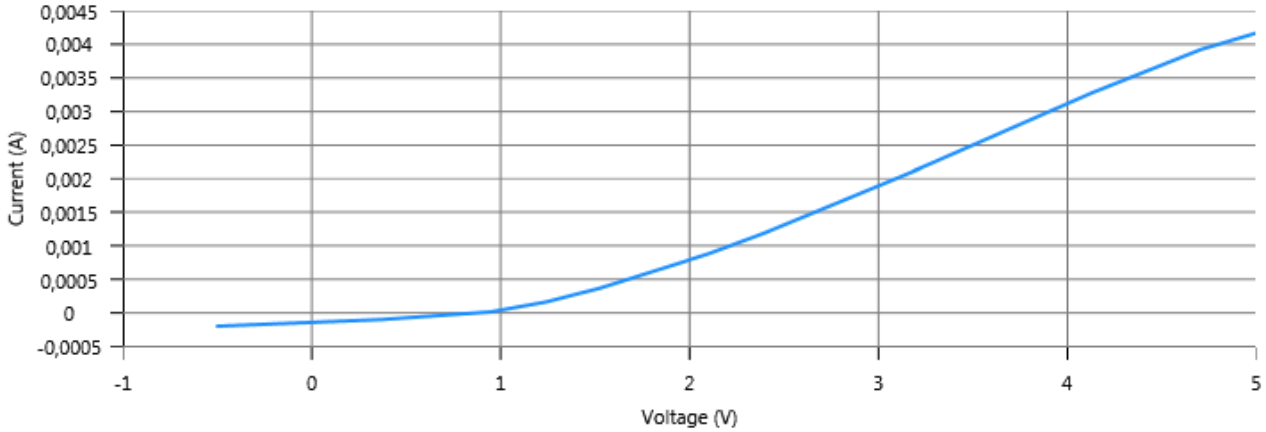
perovskite absorber was obtained by dropping toluene at the 4th second during the spinning process. When lighting is applied, the current values on the forward branch of the current-voltage characteristic practically do not change, but the reverse current increases slightly (Fig. 1b). The open circuit voltage V_{oc}=0.75 V, short circuit current I_{sc}=10-4 A (Fig. 1c), i.e. its density j_{sc}≈2.5 mA*cm-2. When measuring current-voltage characteristics in different modes of voltage scanning direction (i.e. from –U to +U or vice versa), both the general appearance of the current-voltage characteristics themselves and the values of V_{oc} and I_{sc} practically do not change.

a)



b)



c)

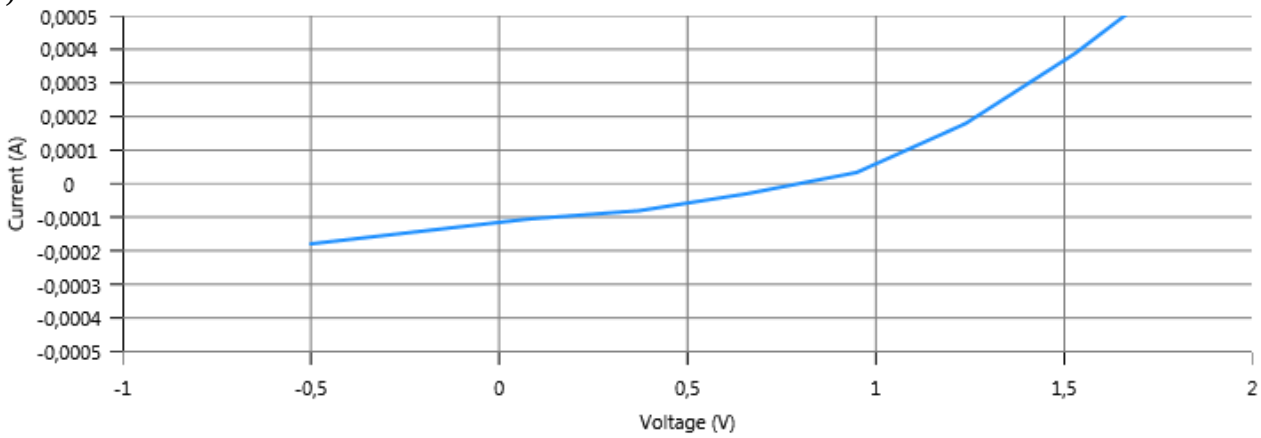


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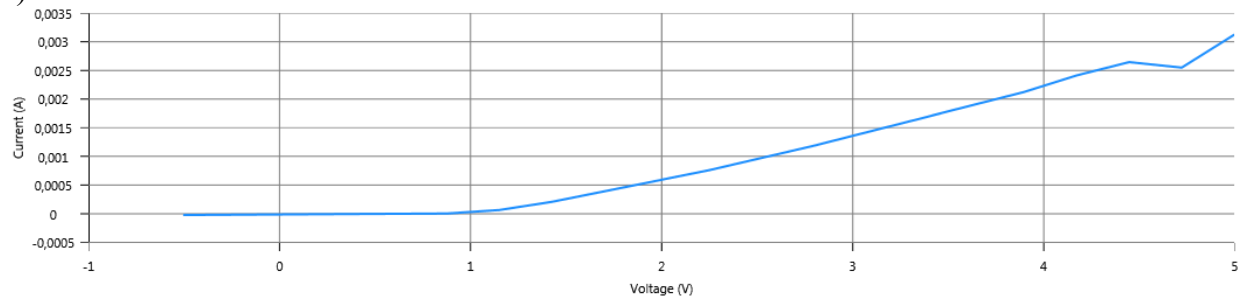
Fig.1. Typical current-voltage characteristics of the sample, taken immediately after its preparation: a) – dark current-voltage characteristic, b) – current-voltage characteristic under illumination, c) – fragment of the current-voltage characteristic in figure b).

When measuring the current-voltage characteristics on all samples after a day, their general appearance, both in the dark and under illumination, practically does not differ from those obtained previously (Fig. 2). The numerical values of the open circuit voltage V_{oc} and the short circuit current I_{sc} also remain unchanged within the limits of measurement accuracy.

a)



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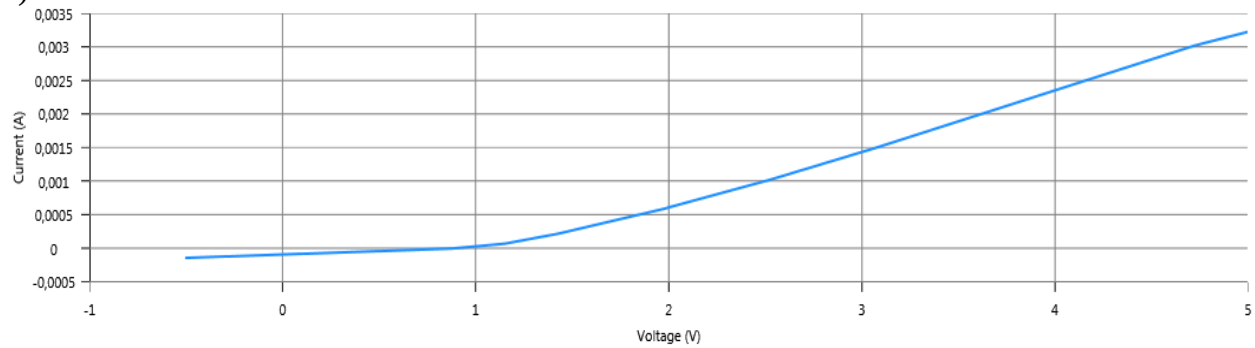

c)

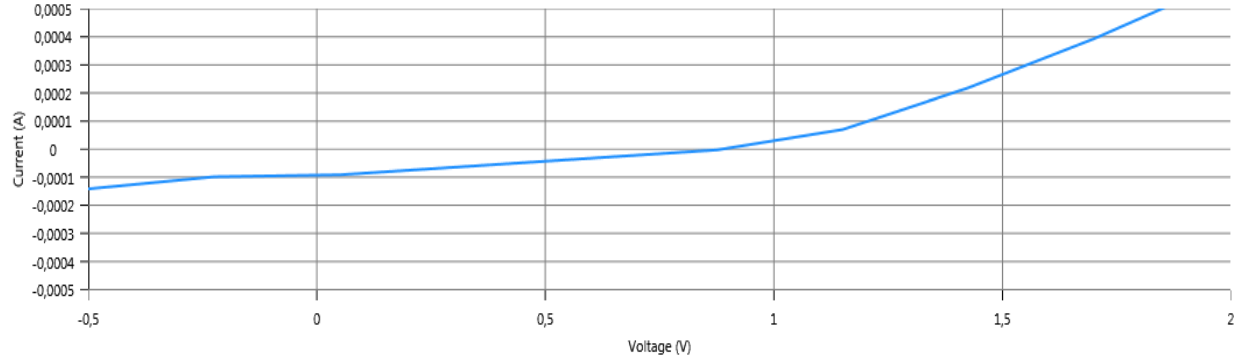

Fig. 2. Current-voltage characteristics of the sample, taken a day after its preparation: a) – dark current-voltage characteristic, b) – current-voltage characteristic under illumination, c) – fragment of the current-voltage characteristic in figure b).

Measurements after 6 days show a slight difference in the general appearance of the current-voltage characteristics from those measured earlier (Fig. 3.). There are also no significant differences in the current-voltage characteristics measured in darkness and illumination, as well as for different voltage scanning directions. At the same time, on all samples there is a decrease in the short-circuit current (to I_{sc}=3*10-5 A, j_{sc}≈0.8 mA*cm-2 in our example, Fig. 3.c) and open circuit voltage (up to V_{oc}=0.6 V).

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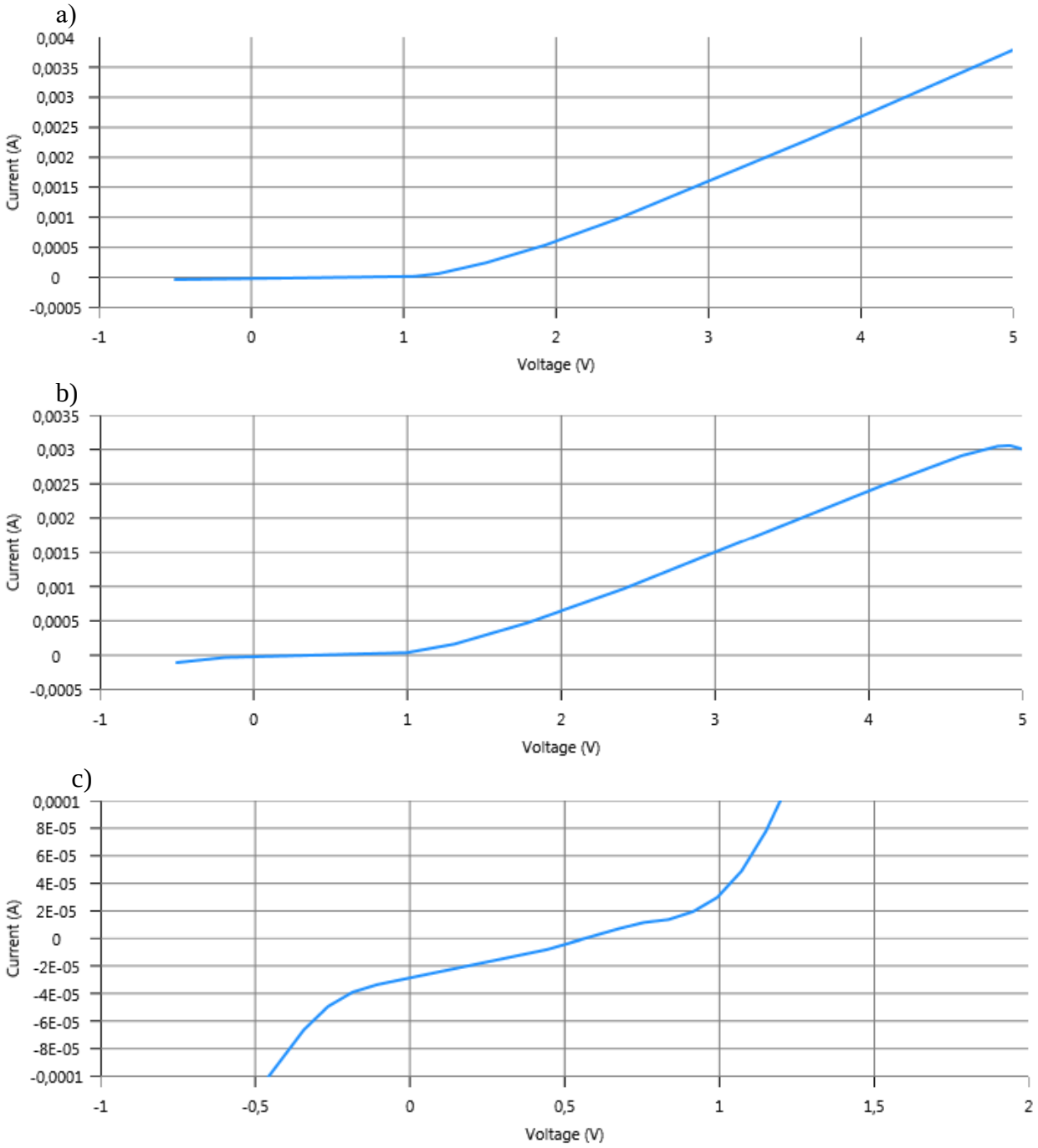

Fig.3. The current-voltage characteristics of the sample, taken 6 days after its preparation: a) – dark current-voltage characteristic, b) – current-voltage characteristic under illumination, c) – fragment of the current-voltage characteristic in figure b).

Measurements after 12 days show different patterns of changes in the current-voltage characteristics on different samples. Thus, the characteristics of the cells in which, during spinning, toluene was added dropwise at the 6th second change most significantly. In these samples, either the diode structure of the current-voltage characteristic completely disappears, or with relatively small changes in the general form of the characteristics, a drop in the short-circuit current I_{sc} and the open circuit voltage up to V_{oc} is observed to critically low values. As for the current-voltage characteristics

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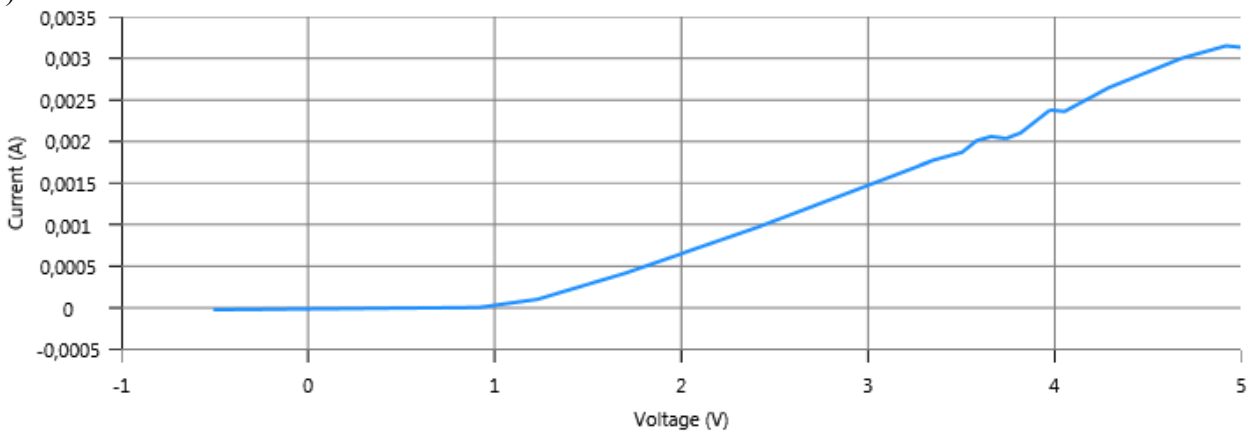
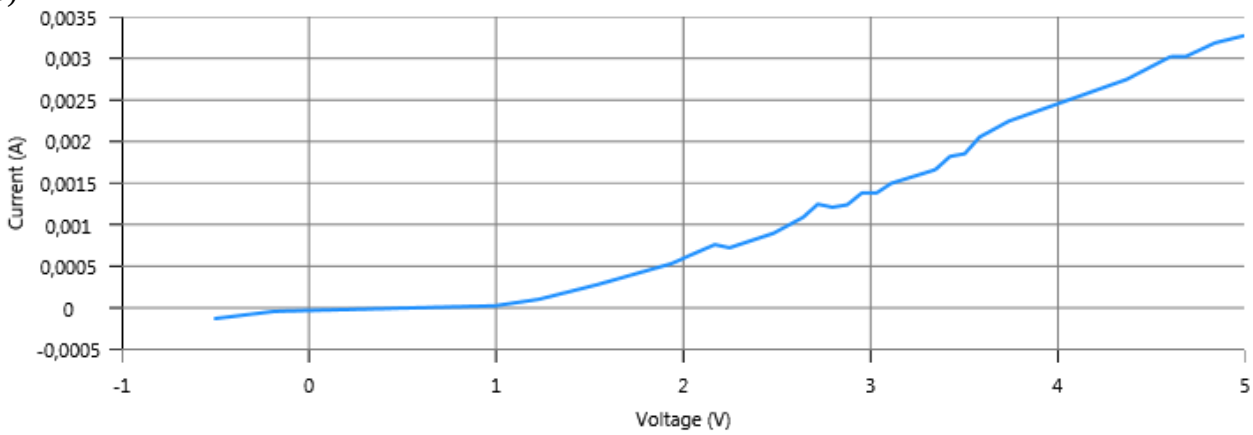
of the samples with toluene added at the 4th second, they are almost identical when measured in the dark and under light, as well as in the forward and reverse scanning directions, and differ slightly from the initial ones (Fig. 4a, b).

a)



b)



c)

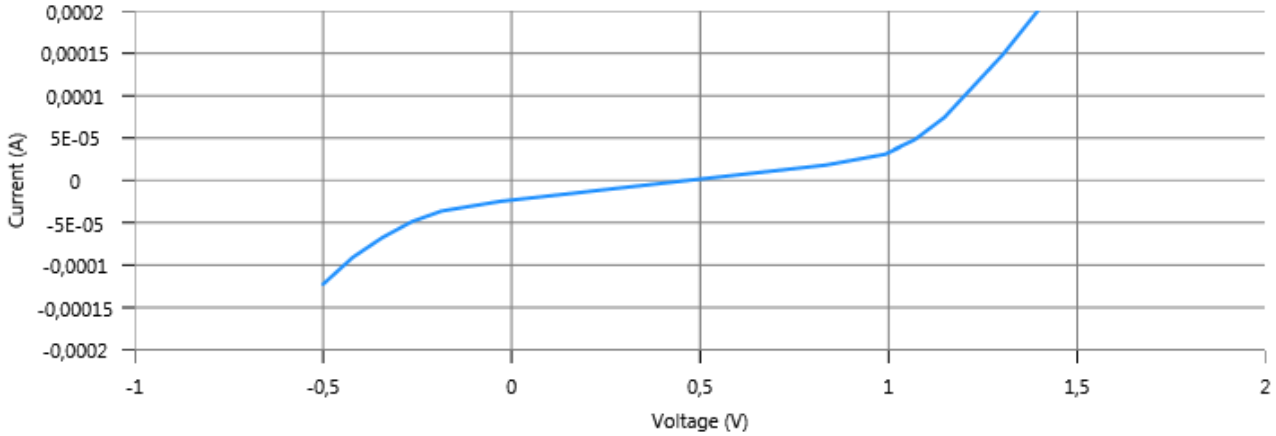


Fig.4. The current-voltage characteristics of the sample, taken 12 days after its preparation: a) – dark current-voltage characteristic, b) – current-voltage characteristic under illumination, c) – fragment of the current-voltage characteristic in figure b).

At the same time, there is a drop in the short circuit current to I_{sc}=3*10-5 A (Fig. 4c), and a slight decrease in the open circuit voltage to V_{oc}=0.5 V.

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Thus, based on the totality of studies performed on the degradation processes of perovskite solar cells with a p-i-n structure on PEDOT: PSS and measurements of their current-voltage characteristics, the following main conclusions can be drawn. Measurements of the current-voltage characteristics of all samples showed that their general appearance weakly depends or does not depend on illumination (except for the appearance of a small reverse current), as well as on the voltage scanning direction. The change in the type of current-voltage characteristic practically does not occur the next day after the cells are manufactured. After 6 days, all samples show a decrease in the short-circuit current I_{sc} and the open circuit voltage Voc. The most significant changes in characteristics and a significant decrease in I_{sc} and V_{oc} are observed 12 days after sample production, and the magnitude of the decrease in performance characteristics depends on the conditions of preparation of the absorber.

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