МОДЕЛИРОВАНИЕ ОДНОКАСКАДНОГО СОЛНЕЧНОГО ЭЛЕМЕНТА НА ОСНОВЕ АМОРФНОГО КРЕМНИЯ

Аннотация: В данной статье представлено моделирование однокаскадного солнечного элемента на основе аморфного кремния посредством программы AFORS-HET v2.5, которая предназначена для моделирования фотоэлектрических преобразователей. В статье представлена зависимость КПД солнечного элемента от степени легирования и толщины фронтального слоя. Было определено, что с увеличение степени легирования с \( N_d=1\cdot10^{16} \text{ см}^{-3} \) до \( N_d=1\cdot10^{20} \text{ см}^{-3} \) происходит снижение КПД солнечного элемента с 5,34 % до 4,929 %, а при уменьшении толщины фронтального слоя с 750 нм до 250 нм происходит увеличения КПД с 1,022 % до 5,34 %.

Ключевые слова: аморфный кремниевый солнечный элемент, толщина, степень легирования, КПД.
MODELING OF THE SINGLE-JUNCTION SOLAR CELL BASED ON AMORPHOUS SILICON

Abstract: This article presents a modeling of the single-junction solar cell based on amorphous silicon by means of the AFORS-HET v2.5 program, which is designed for modeling photoelectric converters. The article presents the dependence of the efficiency of the solar cell on the degree of doping and the thickness of the frontal layer. It was determined that with increasing the degree of doping with $N_d = 1 \cdot 10^{16} \text{ cm}^{-3}$ to $N_d = 1 \cdot 10^{20} \text{ cm}^{-3}$, the efficiency of the solar cell decreased from 5.34% to 4.929%, and with a decrease in the thickness of the front layer from 750 nm to 250 nm there is an increase in efficiency from 1.022% to 5.34%.

Key words: amorphous silicon solar cell, thickness, degree of alloying, efficiency.

Recently, solar cells based on amorphous silicon in connection with the improvement of methods for their production are becoming increasingly in demand. Amorphous silicon (a-Si) is a non-crystalline allotropic form of semiconductor silicon and has a high absorptivity and can be used to fabricate thin-film solar cells (thickness is usually less than 100 times that of crystalline silicon). Thus, the savings in material costs compensate for performance deficiencies in comparison with solar cells made of crystalline silicon (c-Si) [1].

Films of amorphous silicon can be deposited at very low temperatures (250-400 °C) and on various structures, not only on glass, but also on plastic, which makes it possible to use inexpensive substrates; this production is also waste-free, which allows reducing the price of products. Since amorphous silicon does not have a large sequential structure and its atoms are randomly ordered and some atoms have broken bonds, this leads to anomalous electric power behavior, then, to reduce this, passivation of the material with hydrogen is used, resulting in the formation of hydrogenated amorphous silicon (a-Si: H) [1,2]. The band gap $E_g$ for amorphous silicon (a-Si: H) is 1.72 eV at temperature 300 K.
Improving the methods of production of amorphous silicon led to a wider range of applications of solar cells based on it. This paper presents a simulation of the dependence of the efficiency of the single-junction solar cell based on (a-Si: H) through a freely distributed AFORS-HET v2.5 program on the thickness and degree of doping of the frontal layer [3]. Figure 1 shows the structure of an amorphous silicon solar cell implemented in the AFORS-HET v2.5 program.

![Structure of the single-junction solar cell based on amorphous silicon (a-Si: H)](image)

In the course of modeling, the thickness of the front layer was changed from 750 nm to 250 nm, as well as the degree of its doping, while the thickness of the back layer and the degree of its doping remained constant and amounted to 2 µm and \( N_a = 1 \cdot 10^{16} \text{ cm}^{-3} \), respectively. As a result of a reduction in the thickness of the front layer of amorphous silicon from 750 nm to 250 nm, the efficiency of the device increased from 1,041% to 5,408% Figure 2. An increase in the efficiency with decreasing thickness of the frontal layer is due to the fact that the front layer generates the bulk of the electrons that need to travel a certain distance to the p-layer of amorphous silicon, and with a decrease in this distance the probability
Figure 2. Dependence of the efficiency of the solar cell on the thickness of the frontal layer a) The efficiency is 5.408% at the thickness of 250 nm b) The efficiency is 1.041% at the thickness of 750 nm

of this increases (the diffusion length of the charge carriers is the average distance from the moment of photogeneration to recombination). This is the reason for the low depth of the p-n junction.

Further, a study was made of the influence of the degree of doping of the frontal layer on the efficiency of the solar cell. The concentration of the front layer was changed from \( N_d = 1 \cdot 10^{16} \text{ cm}^{-3} \) to \( N_d = 1 \cdot 10^{20} \text{ cm}^{-3} \), which resulted in a decrease in the efficiency of the solar cell from 5.408% to 4.996%, which is related to the change in the potential barrier with increasing doping 3.

Figure 3. Dependence of the efficiency of the solar cell on the degree of doping of the frontal layer a) At a doping level \( N_d = 1 \cdot 10^{16} \), the efficiency is 5.408% b) With an alloying degree \( N_d = 1 \cdot 10^{20} \text{ cm}^{-3} \), the efficiency is 4.996%

Further, the spectral response of this solar cell was analyzed, it follows from Fig. 4 that the spectral response of this solar cell is rather narrow, which makes it
impossible to absorb solar radiation in a wide spectrum, which is a drawback of the single-junction solar cells from amorphous silicon [4].

Figure 4. Dependence of the spectral response of the solar cell based on amorphous silicon in the AFORS-HET v2.5 program

Based on the simulation of the amorphous silicon solar cell in the AFORS-HET v2.5 program, it can be concluded that a change in the thickness and degree of doping of the frontal layer has a significant effect on the efficiency of the solar cell. The obtained dependences can be used at the stage of technological production of amorphous silicon solar cells.

References