Volume 3, Issue 1, January – 2025 **ISSN (E):** 2938-379X

MECHANISMS OF LIGHT ABSORPTION IN A SEMICONDUCTOR

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Abstract
The subject of the work is the influence of the technological parameters of the synthesis on the photoelectric characteristics of silicon thin-film solar cells.

Keywords. Solar cells, structure, strong radiation, doped hydrogen, vibrational bonds, microcrystal, single crystal, three-junction element.

Introduction

When interacting with a semiconductor crystal, optical radiation is partially absorbed, partially reflected from its surface, and partially passes through the crystal without absorption. The shares of transmitted, reflected and absorbed energy are estimated for semiconductor materials by corresponding coefficients. There are different transmittance coefficients:

$$T = \frac{P_{pr}}{P_{ric}}$$

reflection coefficient:

$$R = \frac{P_{rr}}{P_{ric}}$$

absorption coefficient:

$$R = \frac{P_{rpa}}{P_{ric}}$$

Where R_{rp} is the power of radiation passed through the crystal; R_{rr} is the power of radiation reflected from the surface of the crystal; P_{rpa} – radiation power absorbed by the crystal; R_{ric} is the power of radiation incident on the crystal.

The absorption coefficient α is numerically equal to the value of the inverse distance from the surface of the semiconductor, at which the initial power of the incident radiation is attenuated by a factor of e. At depth x:

$$P(x) = P_{ric}\, e^{-\alpha x}$$

$$\alpha = -\frac{1}{x} ln \frac{P(x)}{P_{ric}}$$

Where is P(x) is the radiation power at a depth x from the crystal surface.

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The dependence of the absorption coefficient on the wavelength of incident radiation α(λ) is called the absorption spectrum. A typical absorption spectrum is show in Fig. 1. Section 1 corresponds to its own absorption.

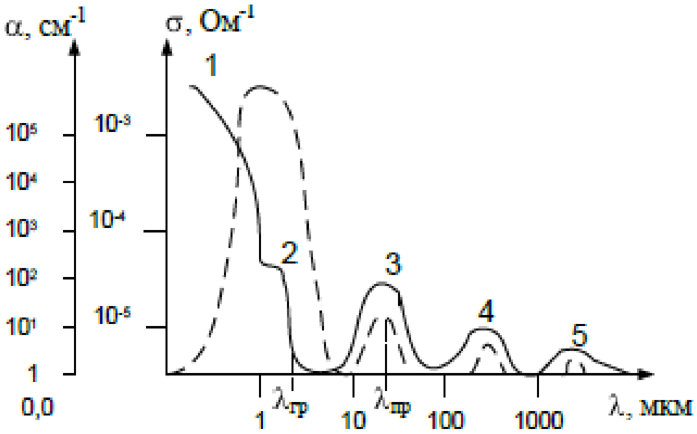
The energy absorbed in section 1 is spent on breaking the valence bond and the transition of an electron from the valence band of the semiconductor to the conduction band. This process is the reverse of interband recombination. To transfer an electron to the conduction band, it is necessary that the energy of the absorbed photon exceed is the band gap:

$$E_{ip} = h\nu \geq E_{bg}$$

where E_{ip} is the energy of the incident photon; E_g is the semiconductor band gap; h=6.63. 10-34 J*s – Planck's constant; ν is the frequency of electromagnetic oscillations of the incident light.

Therefore, the intrinsic absorption spectrum has a clearly defined boundary, called the red boundary of the photoelectric effect:

$$\lambda = \frac{c*h}{E_g}$$



The solid curve is a typical absorption spectrum, the dotted curve is the dependence of photoconductivity on the spectral composition of the incident light for a semiconductor: 1 – intrinsic absorption in the semiconductor; 2 – indirect transitions involving phonons and excitons; 3, 4 – impurity absorption; 5 – lattice absorption.

Figure 1– Typical absorption spectrum and dependence of the photoconductivity of the semiconductor on the spectral composition of the incident light.

As the radiation wavelength decreases, indirect transitions can be observed in the λgr region, in which phonons and excitons, which require less photon energy for ionization, participate in absorption (section 2 in Fig. 1). The value of λ can also be affected by temperature, external fields, and the degree of doping of the semiconductor with impurities. With increasing concentration of impurities, λ decreases, which is due to the filling of energy levels near the top of the valence band or the bottom of the conduction band. With increasing temperature, λ increases, which is due to a decrease in the band gap for most semiconductors with increasing temperature. In an electric field, λ shifts to the long-wave region (Keldysh-Franz effect), in a magnetic field - to the short-wave region (Landau splitting).

Sections 3 and 4 (Fig. 1.1) correspond to impurity absorption, when photon energy is spent on the ionization of impurity atoms. Since the ionization energy of impurity atoms σ E$\ll$ E_g, the impurity absorption spectrum is shifted to the infrared region. The electrons of impurity atoms can be in the ground and excited states, therefore, in the absorption spectrum we have several regions of impurity absorption (for example, 3 and 4 in Fig. 1.1).

Exciton absorption corresponds to the absorption of photon energy in which an electron in the valence band does not detach from the atom, but goes into an excited state, forming an electric dipole with a hole - an exciton. The exciton absorption spectrum consists of narrow lines in the λ region (it is not shown in Fig. 1.). Section 5 (Fig. 1.) corresponds to lattice absorption, in which light quanta lead to the generation of phonons and an increase in the thermal energy of the semiconductor. It is also possible that radiation can be absorbed by free charge carriers, associated with their transitions to other energy levels within the band. The absorption spectrum is practically continuous due to the small gap between the zone levels.

The generation of new charge carriers upon irradiation of a semiconductor leads to a change in its electrical conductivity – the photoresistive effect. The total conductivity of the semiconductor in this case can be given by the formula:

$$\sigma = \sigma_0 + \sigma_{ph}$$

Where is the $\sigma_0 = e(n_{0*}\ \mu_{n+}\ p_{0*}\ \mu_p)$ intrinsic dark conductivity of the semiconductor; σ_{ph}— photoconductivity of the semiconductor; μ_p and μ_n – mobility of holes and electrons; n_0 and p_0 are the equilibrium concentrations of electrons and holes; e=1,6* 10^{-19} C.

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