WEB OF SCIENTIST: INTERNATIONAL
SCIENTIFIC RESEARCH JOURNAL
ISSN: 2776-0979, Volume 5, Issue 4, April - 2024

INFLUENCE OF IONIZING RADIATION ON SEMICONDUCTORS AND SEMICONDUCTOR FILMS

Muzaffarova N. M.
Kipchakova G. M.
Uzbekistan. Fergana Polytechnic Institute

Abstract

This article provides information about the effect of ionizing radiation on semiconductors and semiconductor films, which lists the most important experimentally established positions that underlie solid state radiation physics, discusses general issues related to the effect of penetrating radiation on semiconductors, direct energy transfer to matter atoms, and analyzes the types of radiation.

Keywords: ionizing radiation, films, physics, solid body, radiation, silicon, germanium, gamma radiation, neutrons.

Introduction

The influence of penetrating radiation on the properties of semiconductor materials and devices has been intensively studied over the past three decades in order to determine the causes of failures of semiconductor devices operating in the radiation zone [1, 2].

Methods

Let us list the most important experimentally established principles underlying solid state radiation physics [1].

1. All types of ionizing radiation with particle energies exceeding the threshold for a given material lead to the appearance of radiation defects in the crystal lattice. Primary radiation defects when irradiated by particles with moderate energy (up to several megaelectron volts) are Frenkel pairs.

At high particle energies, in addition to Frenkel pairs, displacement cascades, disordered regions, thermal flashes, dislocation loops and other defects are formed.

2. The interaction of primary radiation defects with each other and other structural defects leads to the appearance of more complex secondary defects. The process of complex formation occurs especially intensively at the initial stages of irradiation, until the sinks for vacancies and interstitial atoms are saturated.

3. Most of the point radiation defects can be eliminated by annealing. The required annealing temperature depends on the type of defects, the binding energy of atoms in the lattice, and the migration energy of intrinsic point defects.
4. The nature of secondary radiation defects depends on the properties of the irradiated substance, the type of radiation and particles, as well as the irradiation conditions that determine the interaction processes of primary defects.

When interacting with semiconductors, part of the energy of high-energy radiation and particles is lost. to excite bound electrons. Calculating the magnitude of ionization losses and particle paths is an important task for studying many processes during the passage of radiation through matter. The influence of ionization losses directly on those electrons of the substance to which this energy is transferred is taken into account by introducing the so-called "average electron excitation energy" into the formulas for calculating specific energy losses ($-\frac{dE}{dX}$).

In some cases, it is important to know the spatial distribution of ionization and the nature of the path of particles. During the passage of heavy particles, we can assume that the direction of motion of the particle remains almost unchanged as long as ionization losses predominate. In this case, take into account. transfer of energy to secondary electrons, which in turn can cause ionization relatively far from the trajectory region. In the case of the passage of monoenergetic electrons, the ionization distribution is mainly affected by the scattering of electrons by the atoms of the material, and the average value of the ionization loss along the original direction and silicon has a technique and calculated the ionization distribution for various energies. Experimental data for germanium agree quite well with theoretical calculations. Ionization effects can cause lattice defects. In addition to losses due to ionization, part of the energy goes into bremsstrahlung electromagnetic radiation, which begins to play a significant role, starting from a certain threshold value.

Results

Direct transfer of energy to atoms of a substance leads to structural disturbances in the lattice - radiation defects (RD). When considering the theory of radiation damage, it is assumed that the simplest type of defect are vacancies and atoms in the interstices of the crystal lattice (Frenkel point defects). The second assumption is the idea of the existence of a threshold energy for defect formation Ed. Calculating the value of Ed is an important task in many experimental and theoretical studies of the interaction of radiation with matter. The probable value of Ed for crystals with an atomic binding energy of about 10 eV is taken to be 25 eV.

In the case of bombardment by electrons, the probability of displacement of atoms is small. When bombarded by heavy particles, elastic collisions begin to play a significant role, starting from a certain value of the kinetic energy of particles, determined by the formula:

$$E_i = \frac{Eg}{8} * \frac{Ma}{m} \qquad (1)$$

where M_A- mass of an atom of a substance;
m- particle mass;
E_g- band gap.

Types of Radiation

1. Electrons. When electrons are scattered, the kinetic energy of an atom after a collision can be determined from the expression

$E_A=E_{Amax}\cos^2\Theta_A$ (2)

where Θ_A– the angle between the direction of electron motion and the direction after the collision;
E_{Amax} - the maximum energy transferred to the atoms of a substance. The angular distribution of atoms after scattering is determined as follows

$$\delta\ \Theta_A=4\delta_o\frac{\beta(cos\Theta A)}{cos3\Theta A} \qquad (3)$$

where $\delta\ (\Theta_A)$ – cross section characterizing the probability of melting electron motion.

$\delta_o = (\frac{Z_g^2}{2mc^2})^2 * \frac{1-\beta}{\beta}$ (4)

Z- nuclear charge. $\beta=\frac{\gamma}{C}$

From the analysis of electron scattering, it can be concluded that there is a tendency for momentum to be transmitted at a large angle to the direction of incidence of the electron. As the electron energy increases, most of the collisions are grouped towards angle $\Theta_A= \frac{\pi}{2}$. Taking into account the energy distribution shows that the majority of defects arise in collisions with an energy of no more than 50-70 eV.

To calculate the concentration of defects Nd, the cross section $\sum d$ is calculated, which characterizes the probability of defects occurring. In this case, we proceed from the assumptions that the threshold energy of displacement of an atom E into the interstice does not depend on the direction of the atom's momentum, and that for each scattering event one Frenkel defect appears.

$N_d = \sum d\ (E) FN$
Φ- integral electron flux per 1 cm^2 ;
N- number of atoms in 1 cm^2 .

Theoretically, it can be shown that the function $\sum d\,(E)$ in the case of a crystal consisting of identical atoms is determined by the parameter E_d.

When calculating the total number of displaced N^+ atoms, it is necessary to take into account that in the case when the energy of the primary displaced atom $E>2Ed$, secondary and other defects arise. Then the total number of defects according to the cascade theory is $V = \frac{EA}{2Ed}$.

The electron scattering theory agrees well with the experimental results. The accuracy of the match exceeds 1%. Therefore, the mechanism of primary energy transfer by fast electrons to lattice atoms can be considered fully explored.

2. Gamma radiation. High-energy electromagnetic radiation, interacting with semiconductors, also causes the appearance of “point-type” structural defects. But the probability of a defect occurring under the direct action of a gamma quantum is negligible. Defects mainly arise as a result of the action of fast electrons on the crystal, resulting from the photoelectric effect and the Compton effect, as well as the formation of gamma quanta, pairs of electrons and positrons at high energies. As a result, the effects of gamma radiation can be described by the methods indicated above for fast electrons and light particles.

3. Fast neutrons. The main mechanism of interaction of fast neutrons and heavy particles with solids is elastic scattering. Taking into account the nature of scattering for neutrons, the average scattering energy can be determined from the expression

$$E_A = \frac{4}{A}\left(1 + \frac{1}{A}\right)^{-2}$$

where A – atomic weight.

Results and Discussions

It is assumed that neutrons are scattered isotropically. In fact, as energy increases, forward scattering becomes preferred. In this regard, a correction factor f is introduced [8]. In real processes, as a result of cascades of elastic collisions, secondary structural defects are formed, as a result of which the total number of atomic displacements significantly exceeds the number of scattering events. In addition to knocking out atoms at an interstitial site, it is possible for a defect to move within the bulk of the crystal. In addition, the act of primary energy transfer by an atom can be represented as the rapid heating of a limited volume to a high temperature.

References

1. Tyurik Yu.A., Khazan L.S. Plastic deformation and dislocation mismatches in heteroepitaxal systems. Kyiv: Naukova Dumka, 1993.
2. Coates R.,Mitchell E.W., J.Adv., Phys., 1975 y.v 90, p. 593.
3. Тожибоев А.К., Султонов Ш.Д. Измерение, регистрация и обработка результатов основных характеристик гелиотехнических установок // Universum: технические науки : электрон. научн. журн. 2021. 11(92).
4. Тожибоев А.К., Хошимжонов А.Т. Применение фотоэлектрического мобильного резервного источника электропитания в телекоммуникации // Universum: технические науки : электрон. научн. журн. 2021. 12(93).
5. Davlyatovich, S. S. & Kakhorovich, A. T. (2021). Recombination Processes of Multi-Charge Ions of a Laser Plasma. Middle European Scientific Bulletin, 18, 405-409.
6. Тожибоев, Аброр Кахорович, and Дилшод Махмудович Эргашев. "Физический метод очистки воды." Results of National Scientific Research International Journal 1.7 (2022): 317-325.
7. Тожибоев, Аброр Кахорович, and Насиба Дилшодовна Парпиева. "Подбор компонентов для систем слежения солнечной установки." Research Focus 1.2 (2022): 35-42.