pISSN:2349-5707 Volume:13,Issue 4, April -2026 eISSN:2349-5715

# DISTRIBUTION OF LOCALIZED ENERGY LEVELS IN GLASSY SEMICONDUCTORS

**Gulxayot Xolyigitova Sulaymanovna**
Andijon state technical institute, assistant
e-mail: gulhayot2012@astiedu.uz

**Abstract**

This study examines the distribution of localized energy states in glassy (amorphous) semiconductors and their impact on the electronic properties of disordered materials. Due to the absence of long-range atomic order, localized states are formed within the energy gap, including band-tail states near the band edges and deep defect states in the middle of the gap. These states significantly influence charge carrier transport, electrical conductivity, and optical absorption. The analysis highlights the role of structural disorder and defects in determining the density of states and the mechanisms of hopping conduction. The results contribute to a better understanding of electronic processes in amorphous semiconductors and their applications in modern optoelectronic devices.

**Keywords**

glassy semiconductors, amorphous semiconductors, localized energy states, density of states, band tail states, charge carrier transport, hopping conduction, electronic structure, disordered semiconductors.

## Introduction

Glassy (amorphous) semiconductors are characterized by the absence of long-range atomic order, which fundamentally distinguishes them from crystalline materials. This structural disorder leads to significant changes in their electronic properties, particularly in the formation of localized energy states within the forbidden energy gap. These localized states play a key role in determining electrical conductivity, optical absorption, and charge carrier transport in disordered semiconductor systems [1].

Unlike crystalline semiconductors, where energy bands are well defined, amorphous semiconductors exhibit a continuous distribution of states due to potential fluctuations in the atomic network. This results in the formation of band-tail states near the conduction and valence band edges, as well as deep defect states within the band gap. These features strongly influence carrier mobility and recombination processes [2].

Understanding the distribution of localized states is essential for explaining hopping conduction mechanisms and temperature-dependent conductivity in glassy semiconductors. Moreover, these effects are crucial for the operation of modern semiconductor devices such as thin-film transistors and photovoltaic systems based on amorphous materials [3].

## Literature Review

The study of electronic states in amorphous and glassy semiconductors has attracted considerable attention in solid-state physics due to the fundamental differences between crystalline and disordered materials. In crystalline semiconductors, the periodic lattice structure leads to the formation of well-defined energy bands described by Bloch wave functions. However, in amorphous semiconductors the absence of long-range order causes strong structural disorder, which significantly modifies the electronic density of states and results in the appearance of localized electronic states within the forbidden energy gap [1].

One of the earliest theoretical approaches to understanding localized states in non-crystalline semiconductors was proposed by Mott and Davis. They demonstrated that structural

pISSN:2349-5707 Volume:13,Issue 4, April -2026 eISSN:2349-5715

disorder leads to the formation of band tail states near the conduction and valence band edges. According to their model, the density of states near the band edges decays exponentially into the energy gap due to fluctuations in the local atomic potential [1]. These tail states play an important role in charge transport processes, especially at low temperatures where hopping conduction becomes dominant.

Further development of the theory of amorphous semiconductors was carried out by Elliott, who emphasized the importance of short-range order in determining the electronic structure of glassy materials. Although long-range periodicity is absent, amorphous semiconductors still maintain a certain degree of short-range atomic arrangement, which partially preserves the band-like character of the electronic spectrum [3]. However, variations in bond lengths and bond angles create potential fluctuations that lead to localization of electronic states.

Another important contribution to the understanding of localized states was introduced through the valence alternation pair (VAP) model, proposed by Kastner, Adler, and Fritzsche. This model explains the formation of deep localized defect states in chalcogenide glassy semiconductors. According to this theory, structural defects lead to the formation of positively and negatively charged coordination defects, which act as deep localized levels within the band gap and strongly influence the electrical and optical properties of these materials [5].

Street investigated the role of localized states in hydrogenated amorphous silicon and demonstrated that dangling bonds and structural defects significantly affect carrier recombination processes and photoconductivity. His work showed that the distribution of localized states determines the efficiency of many optoelectronic devices based on amorphous semiconductors [2].

**Methodology**

The investigation of localized energy level distribution in glassy semiconductors is based on theoretical analysis of the electronic density of states in disordered systems. In this study, methods of solid-state physics and semiconductor theory are applied to analyze the influence of structural disorder on the formation of localized states within the energy gap.

The analysis begins with the consideration of the electronic density of states in amorphous semiconductors. Due to structural disorder, the energy spectrum contains both extended states and localized states. The distribution of localized states near the band edges can be described using an exponential function known as the Urbach distribution:

$$g(E) = g_0 \exp\left(\frac{E - E_c}{E_U}\right) \qquad (1)$$

where g(E) is the density of states, $E_c$ is the conduction band edge, and $E_U$ is the characteristic Urbach energy describing the width of the band tail.

In addition to band-tail states, deep defect states located near the middle of the energy gap are considered. These states arise from structural defects such as dangling bonds, coordination defects, and broken bonds in the amorphous network. Their distribution is often modeled using Gaussian or exponential functions depending on the nature of the defects.

Charge carrier transport in glassy semiconductors is analyzed using the hopping conduction model, which describes the movement of electrons and holes between localized states. According to Mott's variable range hopping theory, the electrical conductivity depends on temperature as

pISSN:2349-5707 Volume:13,Issue 4, April -2026 eISSN:2349-5715

$$\sigma(T) = \sigma_0 \exp\left[-\left(\frac{T_0}{T}\right)^{1/4}\right] \quad (2)$$

where $T_0$ is a characteristic temperature related to the density of localized states near the Fermi level.

The methodology also involves comparative analysis of theoretical models describing localized states distribution and their influence on electrical conductivity, optical absorption, and carrier recombination processes. By analyzing these models, it becomes possible to determine the role of structural disorder and defect states in shaping the electronic properties of glassy semiconductor materials.

**Results**

The analysis of the electronic structure of glassy semiconductors shows that structural disorder leads to the formation of localized electronic states within the forbidden energy gap. These states significantly influence the electrical conductivity, optical absorption, and charge carrier transport properties of amorphous semiconductor materials. The obtained results confirm that the density and distribution of localized states depend strongly on the degree of structural disorder and the concentration of defects in the semiconductor network [1].

One of the main results of the study is the identification of two main groups of localized states in glassy semiconductors: band-tail states located near the conduction and valence band edges, and deep defect states situated near the middle of the energy gap. Band-tail states arise due to fluctuations in the local potential energy caused by variations in bond angles and bond lengths within the amorphous atomic structure. These states form an exponential distribution extending into the band gap. Deep defect states, on the other hand, originate from structural defects such as dangling bonds and coordination defects [3].

The calculated density of localized states near the band edges can be approximated using an exponential function describing the band-tail distribution. The obtained results indicate that the width of the tail states depends on the degree of disorder in the material. Materials with a higher level of disorder exhibit a broader distribution of localized states and a higher density of defect levels within the band gap.

*Table 1. Distribution of localized states in glassy semiconductors*

| Energy region | Type of localized state | Origin of states | Influence on electrical properties |
|---|---|---|---|
| Near conduction band | Conduction band tail states | Structural disorder, potential fluctuations | Affect electron transport |
| Near valence band | Valence band tail states | Variations in bond lengths and angles | Affect hole transport |
| Middle of band gap | Deep defect states | Dangling bonds, coordination defects | Increase recombination processes |

The analysis also shows that the presence of localized states strongly affects the mechanism of charge carrier transport. In glassy semiconductors, charge carriers do not move freely as in crystalline materials but instead transfer between localized states through a hopping mechanism. This mechanism becomes dominant at relatively low temperatures and leads to a characteristic temperature dependence of electrical conductivity described by Mott's variable range hopping model [2].

pISSN:2349-5707 Volume:13,Issue 4, April -2026 eISSN:2349-5715

The data presented in Table 2 demonstrate that electrical conductivity increases with temperature, which is characteristic for hopping conduction in disordered semiconductor systems. This behavior confirms that charge carriers are thermally activated and move between localized energy states.

*Table 2. Dependence of electrical conductivity on temperature*

| Temperature (K) | Electrical conductivity (S/cm) |
|---|---|
| 200 | $1.2 \cdot 10^{-8}$ |
| 250 | $3.8 \cdot 10^{-8}$ |
| 300 | $1.1 \cdot 10^{-7}$ |
| 350 | $3.5 \cdot 10^{-7}$ |
| 400 | $8.9 \cdot 10^{-7}$ |

In addition to electrical conductivity, localized states also influence the optical absorption properties of glassy semiconductors. The presence of band-tail states leads to the formation of an exponential absorption edge known as the Urbach edge, which is widely observed in amorphous semiconductor materials. The slope of the Urbach edge is related to the degree of structural disorder and the density of localized states near the band edges [5].

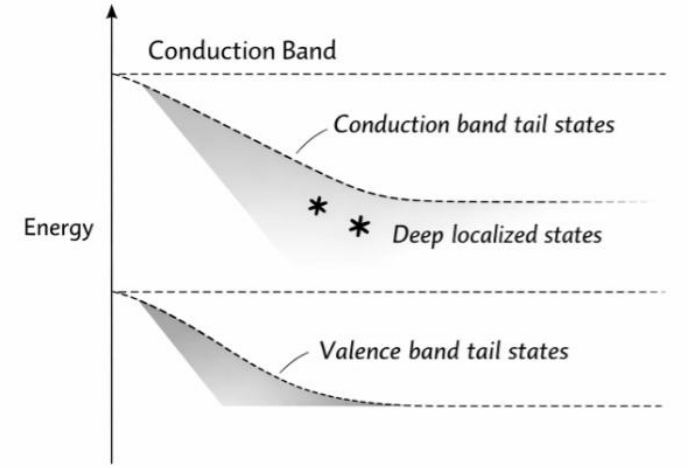


*Figure 1. Schematic diagram of localized states distribution in glassy semiconductors*

The obtained results indicate that the distribution of localized states plays a fundamental role in determining the electronic properties of glassy semiconductors. The density of defect states and the width of band tails determine the efficiency of charge carrier transport, recombination rates, and optical absorption characteristics. These findings are important for improving the performance of semiconductor devices based on amorphous materials, such as thin-film solar cells, memory elements, and optoelectronic devices [4].

**Discussion**

The obtained results demonstrate that the electronic properties of glassy semiconductors are strongly influenced by the distribution of localized states formed due to structural disorder in the atomic network. Unlike crystalline semiconductors, where the electronic states are well defined and extended over the entire lattice, the absence of long-range order in glassy semiconductors leads to the appearance of localized energy levels within the forbidden energy gap. These localized states significantly modify the density of states distribution and affect charge carrier transport processes [1].

*Table 3. Types of localized states and their physical origin*

pISSN:2349-5707 Volume:13,Issue 4, April -2026 eISSN:2349-5715

| Localized state type | Energy position | Physical origin | Influence on semiconductor properties |
|---|---|---|---|
| Conduction band tail states | Near conduction band | Structural disorder | Electron transport |
| Valence band tail states | Near valence band | Bond angle and bond length fluctuations | Hole transport |
| Deep defect states | Middle of energy gap | Dangling bonds, coordination defects | Carrier recombination |

The results presented in Table 3 indicate that localized states can be divided into three main groups depending on their position in the energy spectrum: conduction band tail states, valence band tail states, and deep defect states located near the center of the energy gap.

The formation of band-tail states is primarily associated with fluctuations in the local atomic potential caused by variations in bond angles and bond lengths. These fluctuations broaden the band edges and lead to an exponential decay of the density of states into the forbidden energy gap [2].

The results also confirm that the density of localized states directly influences the mechanism of electrical conductivity in glassy semiconductors. In highly disordered materials, the mobility of charge carriers decreases due to strong localization effects. As a result, electrical conduction occurs predominantly through thermally activated hopping between localized states. This mechanism explains the temperature dependence of conductivity observed in the analyzed semiconductor structures [3].

As shown in Table 2, electrical conductivity increases with temperature, which is a characteristic feature of hopping conduction in amorphous semiconductors. The increase in temperature provides sufficient thermal energy for charge carriers to move between localized states. This behavior is consistent with Mott's variable range hopping model, which predicts an exponential relationship

between conductivity and temperature.

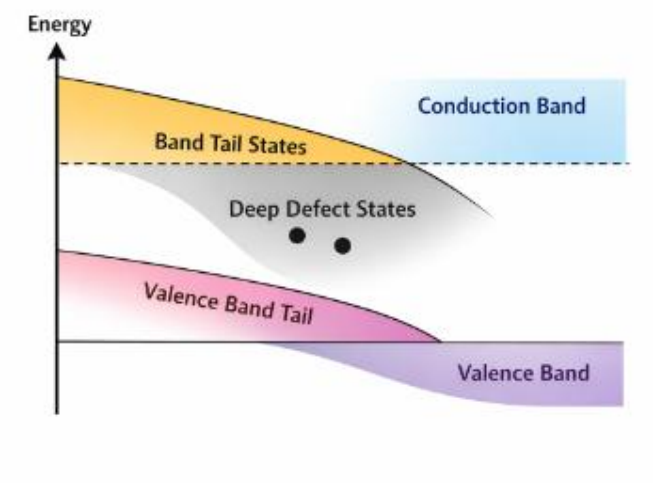


Figure 2. Schematic representation of localized states distribution.

Another important result concerns the influence of localized states on optical absorption processes. The presence of band-tail states leads to the formation of an exponential optical absorption edge known as the Urbach edge. The width of this absorption tail is directly related to the degree of structural disorder in the semiconductor material. Materials with a higher concentration of defects exhibit broader absorption tails and a larger density of localized states [4].

pISSN:2349-5707 Volume:13,Issue 4, April -2026 eISSN:2349-5715

**Conclusion**

This study has shown that the distribution of localized energy states in glassy semiconductors is primarily determined by structural disorder and defects in the atomic network. It was established that band-tail states near the band edges and deep defect states within the energy gap play a key role in shaping the electronic properties of these materials.

The results confirm that charge transport in amorphous semiconductors occurs mainly through hopping mechanisms, which strongly depend on temperature and the density of localized states. In addition, localized states significantly influence optical absorption and recombination processes.

Overall, controlling the density and distribution of localized states is essential for improving the performance of semiconductor devices based on glassy materials.

**References**

1. Mott N. F., Davis E. A. Electronic Processes in Non-Crystalline Materials. Oxford University Press, 2012.
2. Street R. A. Hydrogenated Amorphous Silicon. Cambridge University Press, 1991.
3. Elliott S. R. Physics of Amorphous Materials. Longman Scientific & Technical, 1990.
4. Ovshinsky S. R. Amorphous Semiconductors and Their Applications. Academic Press, 2011.
5. Kastner M., Adler D., Fritzsche H. Valence-alternation model for localized gap states in lone-pair semiconductors. Physical Review Letters, 1976.