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Introduction

1.1 General Aspects of Amorphous Semiconductors

Amorphous solids are typical disordered systems. Two classes of disorder can be defined, namely, compositional disorder as seen in crystalline binary alloys and topological disorder as seen in liquids. Amorphous solids have topological disorder. However, short-range order, that is, chemical bonding of constituent atoms, exists in amorphous covalent semiconductors. Spatial fluctuations in the bond lengths, bond angles, and dihedral angles (Figure 1.1) give rise to tail states in the band gap region, that is, below the edge of the conduction band and above the edge of the valence band. The edges of the conduction and valence bands are called mobility edges and the band gap is called a mobility gap. These edges are the boundaries between delocalized and localized states. This is illustrated in Figure 1.2. Such boundaries are caused by disorder; this is called Anderson localization. In an amorphous network, translational order does not exist, so the Bloch theory of crystalline solids is not applicable, but the tight-binding model, the Hartree–Fock approximation or the density functional method can be applied for understanding the electronic properties of amorphous semiconductors, as shown in Chapter 4.

Although the above considerations are based on a continuous random network, actual samples have a structure deviating from an ideal random network, that is, the coordination of the constituent atoms deviates from the normal coordination following the $8 - N$ rule [1], where N denotes the relevant column number in the periodic table. Here, we consider elements only in columns IV–VI of the periodic table. An additional rule can be given as follows: Z (the valency) = N if $N < 4$. For instance, the normal coordination of amorphous silicon is fourfold, but threefold-coordinated silicon atoms are also present. These are called structural defects. For amorphous selenium, since the normal coordination is twofold, the structural defects are onefold- and threefold-coordinated selenium atoms. The band tails and structural defects affect the optical and

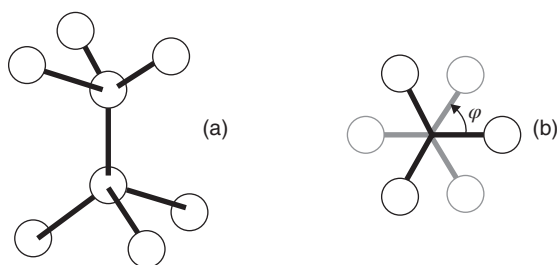


Figure 1.1 Short-range order structure and dihedral angle φ in amorphous silicon.

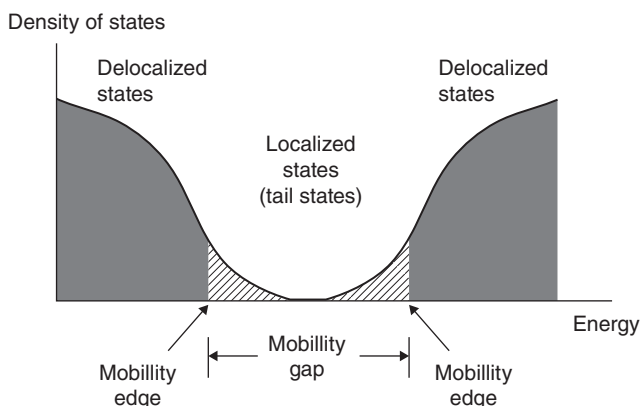


Figure 1.2 Schematic illustration of density of states in an amorphous semiconductor. See text for details.

electronic properties of amorphous semiconductors. Thus it is very important to elucidate the electronic structures of these states in order to understand these properties. An important experimental means of doing this is magnetic resonance. For instance, the electronic structures of these localized states can be elucidated from electron spin resonance (ESR); that is, their symmetry can be determined from a g -value measurement. However, the principal axes of symmetry are randomly oriented in an amorphous network, and that it makes more difficult to identify defects in amorphous semiconductors than in crystals. This identification is normally performed by comparison between observed ESR spectra and computer-simulated spectra. In addition, electron–nuclear double resonance (ENDOR) provides us with a powerful means for identification of defects, as shown in Chapter 5, in which pulsed electron magnetic resonance measurements in particular are presented in detail.

In this book, we consider two types of material as examples of amorphous semiconductors, namely, amorphous silicon and other column IV elemental semiconductors, and amorphous chalcogenides, including amorphous metal chalcogenides. Their preparation, structure, and optical and electronic

properties are presented in Chapters 2, 3, 5, 6, and 7. In Chapter 3, definitions of crystalline and noncrystalline structures are given, and the structures of amorphous silicon, hydrogenated amorphous silicon (a-Si:H), and amorphous selenium are treated theoretically and experimentally in more detail.

1.2 Chalcogenide Glasses

Amorphous chalcogenides are also known as chalcogenide glasses, because they exhibit a glass transition. The details of the glass transition and the structural, optical, and electronic properties of these material are dealt with in Chapter 6.

1.3 Applications of Amorphous Semiconductors

Amorphous semiconductors are widely today used as device materials. Devices using a-Si:H include, for example, solar cells and thin-film transistors. Devices using amorphous chalcogenides include, for example, phase-change memories, direct x-ray image sensors for medical use, high-gain avalanche rushing amorphous semiconductor vidicons, and optical fibers and waveguides. These are treated in Chapter 8.

There are several comprehensive books about amorphous semiconductors [1–5], as well as books about hydrogenated amorphous silicon [6] and amorphous chalcogenides [7].

References

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