Chapter I

Introduction

1.1 Introduction:

It is well known that semiconductors are a group of materials having conductivities between metals and insulators. Generally, the semiconductors are classified into two major groups, namely: elemental semiconductors found in group IV of the periodic table and compound semiconductors formed by the combination of group III and groups II & VI elements. Prior to the invention of transistors, the semiconductors were mainly used as two terminal devices such as photodiodes and rectifiers. In the early 1950's, Germanium was the major semiconductor material [1] but exhibited high leakage current in diodes at moderately high temperatures and thus proved unsuitable for device applications and hence silicon became a practical substitute for semiconductor devices. Silicon, in the form of silicates and silica, is abundantly available on the earth and forms 25% of the earth's crust. The invention of transistors boosted the semiconductor technology and silicon was the major semiconductor material used in MOS and CMOS technologies, which are important for IC design and development. Today the IC technology has become so sophisticated that microprocessors are developed which have the capability of storing billions of informations in one square centimeter of the semiconductor chip. Recently, the amorphous semiconductors have gained importance due to their cost effective manufacturing technology and flexible properties especially after W.E Spear and P.G. Lecomber [2] prepared doped amorphous silicon material. Doping of the material opened the gateway for the fabrication of thin film devices and devices like p-n junctions [3,4], solar cells [5], Schottky barriers [3,6] and electroluminescent diodes [7] were made from doped a-Si layers. These exciting developments led to intense experimental and theoretical work on hydrogenated amorphous silicon. Hydrogenated amorphous silicon is an exciting material with properties attractive for various types of optoelectronic devices [8-10] including photovoltaic cells [11]. The incorporation of hydrogen atoms in the a-Si network has reduced the number of dangling bonds in the material significantly and has modified the electronic and optical properties of the semiconductor material significantly. This material is widely used in making devices like solar cells, photoreceptors [12,13], flat panel displays [14], page wide document scanners [15,16], printer heads [17] and a lot more devices. The study of the electrical and optical properties of crystalline and amorphous semiconductors is basic to determine their application potentialities. In a defect free crystalline semiconductor, the optical absorption spectrum terminates abruptly at the energy gap. In contrast, in an amorphous semiconductor, a tail in the absorption spectrum extends even into the gap region [18]. In this work, first the single crystal silicon and germanium are studied to lay a strong foundation for the understanding of the amorphous structure. Annealing is a process, which controls the hydrogen content in hydrogenated amorphous silicon material. The process of annealing is used as a tool to understand the role of hydrogen atoms incorporated in amorphous silicon network and thereby to determine the optimum hydrogen content in it.

Chapter II gives a theoretical background of crystalline and amorphous semiconductors. Section 2.1 briefly introduces crystalline, amorphous and a polycrystalline material while section 2.2-2.5 discusses the band structure, electrical transport properties and optical properties of crystalline semiconductors. Various band models, electrical transport properties and optical properties of amorphous semiconductors are discussed in sections 2.6-2.9. Section 2.10 discusses the role of hydrogen in hydrogenated amorphous silicon.

Chapter III deals with the experimental techniques and calculations employed in the characterization of crystal silicon, crystal germanium and hydrogenated amorphous silicon studied in this work. Sections 3.2-3.5 discuss the X-ray diffraction technique, conductivity measurement of crystal germanium using the four-point probe technique, preparation of hydrogenated amorphous silicon and the electrical characterization of a-Si:H respectively. The experimental details of infrared spectroscopic technique are presented in section 3.6. While sections 3.7 and 3.8 deal with the optical characterization of crystal and hydrogenated amorphous silicons respectively. Section 3.9 discusses the annealing process carried out in this work.

The experimental results are discussed in chapter IV. In section 4.2 the X-ray diffraction results of crystalline and amorphous semiconductors are presented. The DC electrical characterization of crystal silicon and crystal germanium are presented in section 4.3 while in section 4.3.1 the DC electrical characterization results of hydrogenated amorphous silicon are reported. A detailed examination and discussions on the infrared spectra of crystal silicon, crystal germanium and hydrogenated amorphous silicon are given in section 4.4. This section mainly determines the various constituents of the sample and their bonding configurations.

Section 4.5 gives the optical transmission spectroscopic results of crystal silicon while section 4.5.1 gives the optical results on hydrogenated amorphous silicon.

Chapter V analyses the various experimental results obtained as a result of different measurements. Section 5.2 analyses the X-ray diffractograms, optical and electrical results of crystal silicon and crystal germanium. The optical characterization result of the hydrogenated amorphous silicon film is studied in detail and is presented in section 5.3. The DC electrical characterization results of hydrogenated amorphous silicon are given in section 5.4. This section also studies the effect of annealing on the conductivity, activation energy, hydrogen content and the density of states at the Fermi level of hydrogenated amorphous silicon.

Finally chapter VI concludes this work and suggests proposal for further research in this area of work.

Source of Research Material

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