A Study of the effect of gamma radiation on some alloy materials for use as dosimetry systems and its applications.

A Thesis
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2013
Dedicated to my

- Father and mother
- Beloved husband and my daughter mariam.
- Dear professors Dr. Sayeda and Dr. Hatem
  and Dr. Seif and Dr. Karema
- Brothers and sister
- To every one helped me to finish this work
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Preface

The industrial application of radiation processing has a wide industrial field, the sterilization of medical products, food irradiation, pasteurization, water purification, radiation treatment of polymers and semiconductors. The quality control step is considered a very important part of the radiation processing to measure and control the absorbed radiation dose of any application, whatever the kind of treatment is. The quality control processes depend mainly on the dosimetric systems, such that for each radiation process there is the suitable type of dosimetry systems.

For dose monitoring in radiation processing, the polymeric dyed flexible films are considered to be the most commonly used as dosimeters, indicators and for monitoring the absorbed dose delivered by electron beams and gamma rays. Alloy polymer films prepared by a simple technique of casting aqueous solutions of poly (vinyl alcohol) containing different alloy concentrations have been investigated to be a useful dosimeter in the high dose range as good dosimeters. These films can be used as dosimeters and applied in food-irradiation, radiation processing, water purification, medical sterilization, for routine monitoring and dose mapping in radiation processing. They are easy to prepare in a laboratory and don’t require any toxic solvents in the preparation process. Also they are inexpensive materials.

The National Centre for Radiation Research and Technology (NCRRT) was provided with Egypt’s Mega Gamma I irradiation facility in 1979. This facility is used in sterilization of many medical products and food irradiation processes for the Egyptian market. Different dosimetry systems for dosimetric quality control are used, and which are imported at costly price. The search for Egyptian homemade dosimeters is one of the NCRRT goals.
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Cohesive energy versus Tellurium%
Abstract

Alloys are metallic materials consisting of two or more elements combined in such a way that they cannot be readily separated by physical means. More than 90% of metals used are in the form of alloys. Alloys can be divided into two types: ferrous and non-ferrous. In metallurgy, a non-ferrous metal is any metal that is not ferrous, including alloys, that does not contain iron in appreciable amounts. Groups of inorganic glassy materials which always contain one or more of the chalcogen elements S, Se or Te, in conjunction with more electropositive elements as As, Sb and Bi, are recognized as chalcogenide glasses but Ferroalloy refers to various alloys of iron with a high proportion of one or more other elements, for example ferrotitanium alloy.

Chalcogenide glasses are generally less robust, more weakly bonded materials than oxide glasses. Glasses were prepared from Ge, Se, As and Te elements with purity 99.999%. These glasses are reactive at high temperature with oxygen. Therefore, synthesis was accomplished in evacuated clean silica tubes. The tubes were washed by distilled water, and then dried in a furnace whose temperature was about 100°C.

The weighted materials were introduced into the cleaned silica tubes and then evacuated to about $10^{-4}$ torr and sealed. The sealed tubes were placed inside the furnace and the temperature of the furnace was raised gradually up to 900°C within 1 hour and kept constant for 10 hours. Moreover, shaking of the constituent materials inside the tube in the furnace was necessary for realizing the homogeneity of the composition. After synthesis, the tube was quenched into ice water. The glassy ingots could be
obtained by drastic quenching. Then materials were removed from the tubes and kept in dry atmosphere. Thin films of the selected compositions were prepared by thermal evaporation technique under vacuum $10^{-4}$ torr with constant thickness 100 nm.

Ferrotitanium alloy is prepared by the reduction of rutile and ilmenite ores. One of the most used methods of extracting metals from their ores (usually oxides) is the chemical reduction of these oxides by means of a reducing agent, often carbon or another metal. Among these pyrometallurgical reductions, as they are known in chemical metallurgy are reductions with aluminum, referred to as aluminothermy. Ferrotitanium alloy prepared by the reaction of iron oxide and titanium oxide with aluminum powder during which liquid iron and liquid alumina (aluminum oxide) are formed. Then fluxes (fluorspar) and nitrates were added as initiator reaction agent. Mg was added as heat generator for full smelting process. Sudden reaction then gives two layers of product: Upper layer containing slag (low density) and Lower layer containing metal (high density). After cooling bulk sample of metal was taken and converted to powder by grinding process for XRD and EDX analysis. Finally the samples were converted from powder to liquid by dissolution in concentrated HCl.

The structural properties of $\text{Te}_x\text{Ge}_{20}\text{Se}_{(60-x)}\text{As}_{20}$ amorphous semiconductor in the powder and thermally evaporated thin films have been investigated. Differential Thermal Analysis, DTA, for $\text{Te}_x\text{Ge}_{20}\text{Se}_{(60-x)}\text{As}_{20}$ in the powder form showed that an endothermic peak in the DTA curve results from an increase in specific heat at the glass transition temperature $T_g$. The absence of any sharp exothermic peak in the DTA curve is a good indicator for absence of the structural changes. The analysis of X-Rays Diffraction
Patterns (XRD) of $\text{Te}_x\text{Ge}_{20}\text{Se}_{(60-x)}\text{As}_{20}$ in the powder form confirmed its amorphous state.

The density of the as prepared glasses of the system $\text{Te}_x\text{Ge}_{20}\text{Se}_{(60-x)}\text{As}_{20}$ films has been determined by the hydrostatic method with an accuracy of ± 0.05 %. It has been noticed that the density increases by increasing Te from 4.93 gm/cm$^3$ for the composition $\text{Te}_x\text{Ge}_{20}\text{Se}_{(60-x)}\text{As}_{20}$ at $x=0\%$ to 5.53 gm/cm$^3$ for composition $\text{Te}_x\text{Ge}_{20}\text{Se}_{(60-x)}\text{As}_{20}$ at $x=20\%$.

The optical properties have been investigated by the measurements of the absorbance in the wave length 200 – 1100 nm for the deposited films. The type of the electronic transition responsible for optical properties is indirect allowed transition with transport and onset energy gap in the range 1.61-1.53 eV. The values of the optical energy gap $E_{\text{opt}}$ were found to decrease with increasing Te content which could be due to the fact that Te has a metallic behavior.

The absorption spectra of $\text{Te}_x\text{Ge}_{20}\text{Se}_{(60-x)}\text{As}_{20}$ is recorded in the UV region. Some important parameters such as coordination number $N_{c-o}$, and the number of constraints ($N_S$) were studied. Finally, the study of effect of gamma rays on the $\text{Te}_x\text{Ge}_{20}\text{Se}_{(60-x)}\text{As}_{20}$ showed that the gamma radiation didn’t have a noticeable effect, for a dose of 200KGY showed a constant value in the absorbance upon the addition of Te.

Ferrotitanium alloy polymer films, prepared by a simple technique of casting aqueous solutions of poly (vinyl alcohol) PVA containing Ferrotitanium alloy with different concentration0.4, 0.8, 1.2phr of alloy on a horizontal glass plate, are useful as routine high-dose dosimeters, since the dose range depends on the concentration of alloy. These flexible plastic film dosimeters have yellow color, and are bleached when exposed to gamma rays. The chemical composition of alloy was determined by EDX. This
technique indicates the elemental analysis of ferrotitanium alloy which contain Fe, Ti, Al, Si with 39, 41, 14, 6% percent respectively, and structure of alloy was determined by XRD. The X-ray diffraction technique indicates that Ferrotitanium alloy samples are amorphous. The response of these dosimeters depends on the concentration of alloy. Theoretical density was calculated and its value decreased from 4.58 to 4.305 (gm/cm³). The energy band gap \( E_g \) was calculated and the effect of gamma radiation on its value was determined. It was found that \( E_g \) decreases from 3.4 to 3.11(ev) for the first state and for second decreases from 2.43 to 1.97(ev). The optical absorption spectra showed that the absorption mechanism is an indirect allowed transition which found that energy band gap \( E_g \) decreases after irradiation. The decrease in the energy gap with increasing absorbed dose may be attributed to an increase in structural disorder of the irradiated Ferrotitanium/PVA film. These films have negligible humidity effect in the range from 0-100%. Also it exhibits good pre-and post-irradiation stability in dark and light.
Aim of the work

The aim of the present thesis is the investigation of new film dosimeter for high dose so we dealing with preparation of two different types of alloy (Ferrotitanium and Chalcogenide alloy), studying their physical, optical properties and the effect of gamma radiation.

Moreover, it is aimed at finding practical labeling film dosimeter for high doses. The study is extended to investigate in detail the variation of response of these films under environmental conditions (e.g. light and relative humidity) both during irradiation and during storage.

An investigation of a gamma dosimeter is carried out to be used as high dose dosimeter.
I. Introduction

Radiation processing, a relatively young industry dating from the mid-1950, has progressed and continues to grow rapidly.

Radiation processing, today offers various advantages in the field of sterilization of medical and pharmaceutical products, food preservation, treatment of chemical materials, polymers and variety of other products widely used in modern society, all of which are of direct relevance to human health and welfare.

Reliable dosimetry is a key parameter for all these processes, from the point of view of quality assurance of radiation processing.

This chapter highlights some important aspects of alloys properties and their types, dosimetry and optical properties and it deals with radiation sources, effect of gamma radiation on matter, radiation dosimetry, dosimetry systems, and role of dosimetry systems in quality control. These headings cover most of the aspects, which are relevant to the subject of the present work. The last part of this chapter is a literature review on chalcogenide glasses alloy, metal oxide and dosimetry and high dose range.
I.1 Alloys; definition and properties

Alloys are metallic materials consisting of two or more elements combined in such a way that they cannot be readily separated by physical means. More than 90% of metals used are in the form of alloys. They represent an enormous family of engineering materials that provide a wide range of products with useful properties [1].

Each alloy is distinct from its components, and the properties of each alloy are distinct. Indeed, the purpose of forming an alloy is to provide a metallic substance with physical, mechanical and/or chemical properties and characteristics that are different from those of its components. Moreover, these properties are influenced by the manner in which the alloy is formed and treated. The physical and chemical properties of an alloy can be modified by heat treatment and mechanical working. In most cases, the alloy is chemically more stable than the component elements, so that alloys are designed for specific resistance to actions such as corrosion, wear, fatigue and temperature. Other alloys are made to impart magnetic or electrical properties, strength, formability, etc. [1].

Examples of the properties of alloys:

- Steel is an alloy of iron with carbon and, usually, small amounts of a number of other elements, each of which imparts some unique characteristic to steel;
- Stainless steel alloys are a combination of iron, chromium and nickel frequently modified by the presence of other elements. This family of alloys is particularly resistant to corrosion, in contrast to the rusting phenomenon that consumes ordinary steel;
- beryllium-copper alloys are stronger and have higher electrical conductivity than other copper alloys;
• gallium arsenide is a superconducting alloy used in laser-beam technology;
• superalloys of nickel and cobalt are used in aircraft engines due to their corrosion- and heat-resistance;
• aluminum with small amounts of silicon, iron, copper, manganese, magnesium and zinc provides an alloy specifically designed for the manufacture of beverage cans;
• pewter is an alloy of tin with minor amounts of antimony and copper;
• Copper with some zinc makes brass for a variety of fittings, and copper with tin forms bronze for plumbing fixtures; 18-carat gold is 75% gold, with the balance made up of nickel, copper and zinc.

Alloying a metal is done by combining it with one or more other metals or non-metals that often enhance its properties. For example, steel is stronger than iron, its primary element. The physical properties, such as density, reactivity, Young's modulus, and electrical and thermal conductivity, of an alloy may not differ greatly from those of its elements, but engineering properties such as tensile strength [1] and shear strength may be substantially different from those of the constituent materials. This is sometimes a result of the sizes of the atoms in the alloy, because larger atoms exert a compressive force on neighboring atoms, and smaller atoms exert a tensile force on their neighbors, helping the alloy resist deformation. Sometimes alloys may exhibit marked differences in behavior even when small amounts of one element are present. For example, impurities in semiconducting ferromagnetic alloys lead to different properties, as first predicted by White, Hogan, Suhl, Tian Abrie and Nakamura [2, 3]. Some alloys are made by melting and mixing two or more metals. The term alloy is used to describe a mixture of atoms in which the primary constituent is a metal. The primary metal is called the
base, the matrix, or the solvent. The secondary constituents are often called solutes. If there is a mixture of only two types of atoms, not counting impurities, such as a copper-nickel alloy, then it is called a binary alloy. If there are three types of atoms forming the mixture, such as iron, nickel and chromium, then it is called a ternary alloy. An alloy with four constituents is a quaternary alloy, while a five-part alloy is termed a quinary alloy. Because the percentage of each constituent can be varied, with any mixture the entire range of possible variations is called a system. In practice, some alloys are used so predominantly with respect to their base metals that the name of the primary constituent is also used as the name of the substitutional and interstitial alloys.

**Fig (1)** Different atomic mechanisms of alloy formation, showing pure metal, substitutional, interstitial, and a combination of the two [2],

When a molten metal is mixed with another substance, there are two mechanisms that can cause an alloy to form, called atom exchange and the interstitial mechanism. The relative size of each atom in the mix plays a primary role in determining which mechanism will occur. When the atoms are relatively similar in size, the atom exchange method usually happens, where some of the atoms composing the metallic crystals are
substituted with atoms of the other constituent. This is called a substitutional alloy. Examples of substitutional alloys include bronze and brass, in which some of the copper atoms are substituted with either tin or zinc atoms. With the interstitial mechanism, one atom is usually much smaller than the other, so cannot successfully replace an atom in the crystals of the base metal. The smaller atoms become trapped in the spaces between the atoms in the crystal matrix, called the interstices. This is referred to as an interstitial alloy. Steel is an example of an interstitial alloy, because the very small carbon atoms fit into interstices of the iron matrix. Stainless steel is an example of a combination of interstitial and substitutional alloys, because the carbon atoms fit into the interstices, but some of the iron atoms are replaced with nickel and chromium atoms [4].

Alloys are produced through a staggering variety of methods, from ancient steelmaking techniques to electric induction furnaces. They can be produced by both hot and cold processes (provided sufficient pressure is applied), depending on the materials involved and the complexity of the alloy. Uses of alloys are limitless, and include an extensive range of marine, medical, military, commercial, industrial, residential and manufacturing applications. Even brass and bronze, two of the earliest alloys produced, still have extensive uses, and remain in high demand.

I.2 Types of alloys

I.2.1 Non-ferrous alloy (Chalcogenide glasses)

In metallurgy, a non-ferrous metal is any metal that is not ferrous, including alloys, that does not contain iron in appreciable amounts. Generally more expensive than ferrous metals, non-ferrous metals are used because of desirable properties such as low weight (e.g., aluminum), higher conductivity (e.g., copper) [5] non-magnetic property or resistance to corrosion (e.g., zinc)[6]. Some non-ferrous materials are also used in
the iron and steel industries. For example, bauxite is used as flux for blast furnaces, while others such as wolframite, pyrolusite and chromite are used in making ferrous alloys[7].

Important non-ferrous metals include aluminum, copper, lead, nickel, tin, titanium and zinc, and alloys such as brass. Precious metals such as gold, silver and platinum and exotic or rare metals such as cobalt, tungsten, arsenic, beryllium, bismuth, cerium, cadmium, niobium, indium, gallium, germanium, lithium, selenium, tantalum, tellurium, vanadium, and zirconium are also non-ferrous[8]. They are usually obtained through minerals such as sulfides, carbonates, and silicates [9]. Non-ferrous metals are usually refined through electrolysis [10].

Group of inorganic glassy materials which always contain one or more of the chalcogen elements S, Se or Te, in conjunction with more electropositive elements as As, Sb and Bi, are recognized as chalcogenide glasses.

Many amorphous materials can be called Semiconductor in the sense that they are neither good conductors nor good insulators, but instead they are poor conductors. Many are also similar to their crystalline counterparts in that they possess an optical gap. Amorphous Semiconductors are characterized by:
1. Their electrical properties are similar to intrinsic semiconductor or perfectly compensated S.C.
2. They are partially transparent in the infrared region.
3. Their room temperature conductivities are lower than $10^3 - 10^4 \, \Omega^{-1} \, \text{cm}^{-1}$.

A major category of a-S.C. is the chalcogenide glasses. The first chalcogenide glass to be commercially developed in 1950s was As$_2$S$_3$, produced for passive bulk optical component for the mid-IR. During the next two decades, other sulphide and selenide-telluride glasses have been used as optical components for the far infrared which have since then
been exploited commercially [11,12]. Applications of infrared optics include energy management, thermal fault detection, and electronic circuit detection, temperature monitoring and night vision [13, 14].

Chalcogenide glasses are a recognized group of inorganic glassy materials which always contain one or more of the chalcogen elements S, Se or Te, in conjunction with more electropositive elements as As, Sb and Bi [15]. These glasses are band gap S.C. and they are generally less robust, more weakly bonded materials than oxide glasses. Chalcogenide glasses S.C. have several useful properties that can be employed in various solid state devices. They show a continuous change in physical properties with change in chemical composition [16].

Chalcogenide a-S.C. materials exhibit a number of interesting changes when exposed to light having photon energy comparable to the band gap. Such changes can be structural, mechanical, chemical or optical (photo-darkening and photo-bleaching). The light induced changes can in general be either irreversible, i.e. the changes are permanent after irradiation, or reversible, in which case the changes can be removed by annealing to the glass transition temperature (T_g). These changes are favored in chalcogenide glasses due to their structural flexibility and also due to their high-lying lone pair (L_P) p states in their valence bands [17].

Amorphous Semiconductors are present in three types [18] elemental, covalent alloys and ionic. The first category contains elements such as S and Se which can be obtained in the amorphous state. The S and Se are characterized by chain and ring structure, and a short-range order which extends over a distance, depending on temperature and thermal history of the material. The second category contains covalent bonded alloy glasses. These alloys possess compositional and translational disorders; therefore, all atoms locally satisfy their valence
bond requirements. The third category contains ionic materials such as silicate glasses, which contain at least one element of the chalcogens (S, Se and Te) [19].

Ag-doped chalcogenide glasses and their films have many current and potential applications in optics, optoelectronics, chemistry and biology (optical elements, gratings, memories, micro lenses, waveguides, bio- and chemical-sensors, solid electrolytes, batteries…etc.) [20] The Ag-doped glasses can be used as optical memory materials and materials for holography. The sensitivity can be increased by the simultaneous application of an electrical field with light. The Ag-doped binary and ternary tellurides are becoming important because some of them are used as materials for phase-change optical storage (DVD disks …etc). They exhibit single glass transition and single crystallization temperatures, which is important for rewritable disks.

1.1.2 Ferrous alloy

At present, ferrous metallurgy is mostly aimed to increase products quality without rapid expansion of facilities but not to grow material output as the situation has been for several years. It requires producing structural material consuming less metal, but having higher mechanical properties due to adding alloying elements to the melt. Sometimes such elements can be added in pure form, but as a rule, in the form of ferroalloys, i.e. iron alloys with alloying elements. Ferrotitanium is one of the most widespread and effective ferroalloys.

a. Ferroalloy refers to various alloys of iron with a high proportion of one or more other elements.

b. Alloys of iron

- Ferroalloys (Category:Ferroalloys)
  - Ferroboron
  - Ferrochrome
  - Ferrocerium
  - Ferrovanadium
Chapter I

- Ferromagnesium
- Ferromolybdenum
- Ferrophosphorus
- Ferrosilicon

Introduction & Literature Review

**c. Ferrotitanium**

Ferrotitanium is a ferroalloy, an alloy of iron and titanium with between 10-20...45-75 % titanium and sometimes a small amount of carbon. It is used in steelmaking as a cleansing agent for iron and steel; the titanium is highly reactive with sulfur, carbon, oxygen, and nitrogen, forming insoluble compounds and sequestering them in slag, and is therefore used for deoxidizing, and sometimes for desulfurization and gentrification. In steelmaking the addition of titanium yields metal with finer grain structure. Ferrotitanium powder can be also used as a fuel in some pyrotechnic compositions. Manganese alloyed ferrotitanium is investigated as a material for hydrogen storage.

I.3 Radiation Sources

The sources of radiation, which are used in radiation studies and applications, can be divided into two groups, those employing natural and artificial radioactive isotopes, and those that employ some form of particle accelerator. The first group consists of the classical radiation sources, radium and radon, and such artificial radioisotopes as cobalt-60 cesium-137, and of various types, and accelerators such as van de Graaff accelerator and cyclotron used to generate beams of positive ions. Nuclear reactors currently have the most widely used radiation sources as cobalt-60 (γ-radiation) and electron accelerators (electron beam).

Choice of a particular radiation source is generally dependent on the nature and size of the object to be irradiated. Gaseous materials can be
irradiated successfully using any type of ionizing radiation, but irradiation of bulk liquid or solid samples requires one of the more penetrating and ionizing radiations such as (γ-radiation) or a beam of energetic electrons in MeV range. Less penetrating radiations such as α or β radiation or lower-energy electrons can be used if irradiation is to be restricted to the surface layers of the sample.

I.3.1 Gamma radiation

Gamma rays are electromagnetic radiation of nuclear origin with wave lengths in the region of $3 \times 10^{-11}$ m to $3 \times 10^{-13}$ m. It is more convenient to describe the radiation in terms of energy than in terms of wavelength since the energy absorbed from the radiation is basically of interest. The relationship between wavelength and energy is

$$E = \frac{hc}{\lambda}$$

(1)

Where h is Plank's constant, c is the velocity of light, and λ is the wave length. Substituting for the constants gives

$$E(eV) = (1.24 \times 10^{-6})/\lambda(m)$$

(2)

In terms of energy the wave length range $3 \times 10^{-11}$ m to $3 \times 10^{-13}$ m becomes approximately 40KeV to 4 MeV. The γ-rays emitted by radioactive isotopes are either mono-energetic or have a small number of discrete energies. Cobalt-60, for example, gives equal numbers of gamma photons of energy 1.332 and 1.173 MeV.

I.3.2 Interaction of gamma radiation with matter

In passing through matter, γ-radiation interacts with matter in a variety of processes. The three main processes are the photo electric effect, Compton scattering and pair production. The probability of each of these interactions depends on the energy of the incident photon. At low energies, the Compton Effect dominates, and at high energies pair production dominates as shown in Fig (2) and Fig (3).
I.3.2.1 Photo electric effect

When $\gamma$-rays are incident on a solid, a single electron absorbs the incident photon and becomes excited to the conduction band or ejected from the atom. This ejected electron will collide with other electrons, sharing the electron. This will result in many electrons excited to the conduction band, each with roughly the same energy. Eventually, these electrons will fall back to the more stable ground state. When this occurs, each will emit a photon with energy approximately equal to the band gap. Because this process happens so quickly, all the electrons will fall back to the ground state at roughly the same time. The photoelectric effect is the dominant energy transfer mechanism for X and $\gamma$-ray photons with energies below 50 Kev.

I.3.2.2 Compton scattering

When a $\gamma$-ray collides elastically with an electron, the electron absorbs some of the energy, and the photon continues in a new direction with less energy and a longer wavelength. The amount of energy absorbed by the electron is dependent on the scattering angle of the $\gamma$-photon after collision takes place. When maximum energy is transferred to the electron, the rebound photon has maximum wavelength and minimum energy. Compton scattering is thought to be the principal mechanism for $\gamma$-rays in the intermediate energy range from 100 keV to 10MeV.

I.3.2.3 Pair production

A gamma ray may spontaneously change into an electron and positron pair, in the vicinity of the nucleus. A positron is the anti-matter equivalent of an electron. It has the same mass as an electron, but it has a positive charge equal in strength to the negative charge of an electron. Energy in excess of the equivalent rest mass of the two particles(1.02
MeV) appears as the kinetic energy of the pair and the recoil nucleus. The positron has a very short lifetime (if immersed in matter) (about 10-8 seconds). At the end of its range, it combines with a free electron. The entire mass of these two particles is then converted into two gamma photons of 0.51 MeV, energy each. The secondary electrons (or positrons) produced in any of these three processes frequently have enough energy to produce many ionization up to the end of range.

I.3.3 Defect Production by Gamma – Rays

Gamma rays, like fast electrons produce point defects. The probability of an atom being displaced by a direct interaction between gamma – rays and atomic nuclei in crystal is very small.

Most defects are formed by the secondary fast electrons produced as a result of the photo electric effect, the gamma rays Compton scattering or/and the electrons – positions pairs creation pairs creation formed at high gamma–ray energies. The total absorption cross–section of gamma – rays is determined as a result of the above three processes. Evans and some others could calculate the probabilities of occurrence for each of these events. Frenkel defects are produced uniformly through the lattice.

At finite temperature, particularly above -173 °C, the vacancies are mobile in the solid, and they unite with themselves or with impurities in the solid, and from defect complex in order to obtain lower energy levels in the forbidden gap. Theoretical analysis of the problem is difficult especially due to the lack of data concerning the exact values of the capture cross–sections. The number of defects produced by hard radiation and the energy levels of such defects can be studied by measuring the electrical conductivity and the Hall Effect.
Two aspects for the interaction of radiation with matter are recognized. A large fraction of the energy of an incident energetic goes in electronic processes (excitation and ionization), and this produces temporary or transient disturbance in the material which disappear shortly after the removal of radiation source. The remainder of the incident optical energy goes into atomic processes and produces displacement of atoms within the solid lattice. The fraction of these displacements which remain for a long time, \((10^3)\) seconds at room temperature, will be called damage.
There are many factors influencing the amount and type of damage produced by radiation. Some of these factors can change the results by a factor of 2 or 3, and some others change the results by more than an order of magnitude for a given radiation. The amount of permanent radiation damage is given by:

\[ \text{Damage} = f(A,B,C,D,E) \]

Where A, B, C…etc. are all parameters, each depending on:

i. The temperature of sample during irradiation.
ii. Inactive dissolved impurity concentration.
iii. P-Type or n–type.
iv. History after irradiation.
v. Rate of irradiation.

So, in studying the damage produced by radiation, these parameters must be known, or at least they must be kept constant. Electrons, gamma – rays, neutrons and heavy particles, are most interesting types of radiation commonly used in solid state studies.

I.4 Optical Properties of Amorphous Materials

The distribution in energy of the electron states in an amorphous material has gross features that resemble those of the material in its crystalline form. Optical techniques such as U.V. absorption and photoemission can be used to probe the spectrum of electron levels in non – crystalline systems. One of the most important properties of glass is its transparency in IR region. The implication of this as far as the energy spectrum of electron states is concerned is that they are empty, just as crystalline semiconductors and insulators. So, in ordinary window glass this gap must be larger than the energy of quanta, whereas in Te–As–Se–Ge, which is opaque the transparency is in the infra-red. The origin of the gap in semiconducting or insulating amorphous materials cannot be considered from the viewpoint of scattering of Block waves by periodic
lattice potential, which is the normal approach for crystals. In glasses there is no translational symmetry. The gross features of the energy spectra of electron states in many solids (particularly the density of valence band states) is now known to depend on the nearest neighbor environment of a particular atom, with long-range interactions affect details only, since in most amorphous materials the forces that bind atoms together are virtually the same as in the crystalline state. One frequently finds nearest-neighbor bond length and angles similar to those in the corresponding crystals and thus a similar density of states distribution.

I.4.1 Optical Absorption Mechanisms

Optical absorption in solids can occur by several mechanisms all of which involve coupling of the electric vector of the incident radiation to dipole moments in the material and a consequent of energy.

Semiconductors show all the optical properties of insulators and metals though not of course to the same degree. The main features are as follows to figure (4) [21].

![Figure (4) Absorption spectrum of thin film](image)

In the ultraviolet, and sometimes extends into the visible and infra-red, intense absorption due to electronic transitions between valence and
conduction bands can be observed. Such transitions generate mobile electrons and holes resulting in photo-conductivity. The absorption coefficient is typically in the range $10^5$ to $10^6$ cm$^{-1}$ on the high energy side of this band (typically around 2eV). There is often a smooth fall in absorption over a range of several electrons volts. On the low energy side, the absorption coefficient falls more rapidly and may fall as much as six orders of magnitude within a few tenth of eV. In semiconductors, this low energy boundary of the fundamental absorption is often the most striking feature of the spectrum and is referred to as the “absorption edge”.

- The limit of the absorption edge corresponds to the photon energy required to promote electrons across the minimum energy gap $E_g$. The edge region often shows some structure in particular that are due to exactions. An exaction is formed when an electron, having been excited insufficiently to escape from the influence of the hole it leaves behind, is able to exist in a stable state in which it does not recombine with the hole. The electron and hole pair are held together as hydrogen atom by their mutual Coulomb attraction and the separated charges can exist in one of a series of quantized energy states. Exaction absorption is more pronounced in insulators particularly ionic crystals than in semiconductors and can lead to strong narrow – line absorption as in ionic spectra.

- As the wave length is increased beyond the absorption edge, the absorption starts to rise slowly again. This increase is due to electronic transitions within the conduction or intraband transitions and is referred to as "free carrier absorption" or "intraband transition". It extends throughout the infrared and microwave region of the spectrum.

- At photon energies between 0.02 and 0.05 eV (50 to 20 μm wave length) a new set of absorption peaks appears. These are due to interaction between the incident photons and the vibrational modes of the
lattice. If the crystal is ionic the absorption coefficient may reach $10^5$ cm$^{-1}$ and strong reflection occurs.

- Impurities give rise to additional absorption but only at low temperatures such that thermal energy is less than the ionization energies of the impurity atoms.
- Absorption may occur in solids due to electron spin reversal. Solid containing paramagnetic impurities will show absorption line spectra in the presence of external magnetic field.

**I.4.2 Absorption Edge**

Electronic transition between the valence and conduction bands shown in figure (5) in the crystal start at the absorption edge which corresponds to the minimum energy difference $E_g$ between the lowest minimum of the conduction and highest maximum of the valence band. If these extremes lie at the same point of the K- space, the transitions are called direct. If this is not the case, the transitions are possible only when phonon–assisted and are called indirect transitions.

**Figure (5)** Optical inter-band transitions in (a) Direct (b) Indirect band gap semiconductor
The rule governing these transitions is the observation of quasi momentum during transitions either of the electron alone in direct transitions or the sum of the electron and phonon quasi momenta in indirect transitions. The value of the gap $E_{\text{opt}}$ depends in a rather subtle way on the structure and actual values of the pseudo potential in the crystal. When the semiconductor becomes amorphous one observes a shift of the absorption edge either towards lower or higher energies the shape of the absorption curve appears to be similar for many amorphous semiconductors. In many amorphous semiconductors the absorption edge has the shape shown in figure (6).

It can be distinguished by the high absorption region A ($\alpha > 10^4$ cm$^{-1}$). The exponential part B extends over 4 orders of magnitude of $\alpha$ and the weak absorption tail C. The high absorption region A probably corresponds to normal one–electron transitions and carries information on the energy dependence of the density of states at the band edges. In general the high absorption region is often observed in semiconducting glasses that at high enough absorption levels ($\alpha \geq 10^4$ cm$^{-1}$) the absorption constant $\alpha$ has the following frequency dependence:

![Figure (6) parts A, B, C of the absorption edge](image)

*Figure (6) parts A, B, C of the absorption edge*
\[ n_0 \hbar \gamma \alpha(\gamma) = (\hbar \gamma - E_{g\text{opt}})^n \]  

(3)

Where \( n \) is a constant that depends on the type of transition and \( n_0 \) is the refractive index. For direct transitions the constant \( n \) in the above equation can take either the value 1/2 or 3/2 depending on whether the transition is allowed or forbidden in the quantum mechanical sense. For amorphous chalcogenides the spectral dependence of \( \alpha \) is given by the following relation:

\[ \alpha = B(\hbar - E_{g\text{opt}})^2 / \hbar \omega \]  

(4)

Where \( B \) is a constant for indirect transition:

\[ \alpha n_0 \hbar \gamma = \frac{(\hbar \omega - E_{g\text{opt}} + h\gamma_{\text{ph}})^n}{\exp\left(\frac{h\gamma}{kT}\right)} + \frac{(\hbar \omega - E_{g\text{opt}} + h\gamma_{\text{ph}})^n}{1 - \exp\left(\frac{h\gamma}{kT}\right)} \]  

(5)

Rom transitions involving phonon absorption and emission respectively. For allowed transitions \( n=2 \) and for forbidden transitions \( n=3 \). The exponential region of the absorption edge (part B), i.e. in the absorption constant range from 1 cm\(^{-1}\) to about 10\(^4\) cm\(^{-1}\), the absorption constant \( \alpha(\omega) \) is described by the formula:

\[ \alpha(\omega) = \alpha_0 \exp(h\omega/E_0) \]  

(6)

Where \( E_0 \) is the width of the band tail. The energy \( E_0 \) characterizing the slope is almost temperature independent at low temperatures. It is interesting to note that \( E_0 \) values between 0.05 eV and 0.08 eV.

1.5 Radiation Dosimetry

Dosimetry is the science of radiation dose measurement. There are several reasons why one would like to measure the dose. Dose is a parameter or a physical quantity that can be measured and compared against biological or chemical change in a material. Also it is a useful quantity when one needs to transfer the information or experience gained
in a laboratory to another laboratory or to a commercial radiation facility. Dosimetry is needed for the following objectives [22-24].
- Determination of the process dose limits along with microbiology.
- Materials testing laboratories.
- Operational qualification of the irradiation facility on regular basis.
- Performance qualification for each product/process.
- Process control during routine production.
- Research facilities.

1.5.1 Dosimetry systems

Since the IAEA Symposium on High – Dose Dosimetry for Radiation Processing was held in Vienna [23]; notable progress has been made in several key areas. Many involve the development of numerous standard guides and practices developed by the American Society for Testing and Materials (ASTM) [22]. A number of new advances are featured in the present symposium, and lead us to the future of dosimetry for industry, agriculture, and medicine on an international scale.

A number of these novel dosimetry systems constitute significant advances in practical radiation processing, providing more efficient and accurate means of assuring that a given process is meeting specifications. A sampling of new dosimetry developments is listed as follows: Free-radical systems – polyolefin or silicone as binders for EPR analysis of alanine in the form of pellets or thin films. Radio-chromic films or solutions – Tetra-zolium salts for liquid or film systems for broad dose range applications [25], [26] and Gaf-Chromic film systems for relatively low doses (radiotherapy, blood irradiation, insect population control, food irradiation) [27] as measured spectrophotometrically. Dye solutions and films – aqueous alcohol or polyvinyl alcohol solutions of methylene blue, methyl orange, or Congo red, which bleach upon irradiation and are measured with a spectrophotometer or densitometer. These may be used
for either large-scale liquid-phase dosimetry or for expensive routine processing dosimetry [28].

Photo-luminescent systems – Sunna dosimeter films for single-point or 2D imaging, readout by spectrofluorimetry, phosphor imaging systems or semiconductor micro-diode arrays [29]. Opaque radiochromic labels – Diffuse reflection spectrophotometric readout of color changing labels and opalescent media (e.g. dyed paper or coated films) [30]. Optical waveguides – Radio-chromic fiber optics for food irradiation dosimetry or for real-time dose monitoring. Polymers – polyethylene film readout by ultraviolet (UV) or Fourier transform infrared (FTIR) spectrophotometry, semiconductor or solid-state chips – bipolar, p-FET, or MOFET transistors, diamond detectors, or pure Li-F crystals, as active or passive dosimeters for broad dose and dose-rate ranges. Conductometric systems – Liquid solutions or solid matrices which can be readout by high-frequency (oscillometric) or steady-state conductometry, fluorimetry can be applied for dosimetry purposes due to its significant sensitivity which facilitates the methods for absorbed dose measurements in radiation therapy, environmental protection and radiation processing. The method is based on the measurement of the fluorescent light; when a molecule, excited by UV or visible light or radiation, emits part of its energy in the form of light. This phenomenon can be utilized for dosimetry purposes, when there is suitable shift between the excitation and emission wavelengths. The intensity of the fluorescent light, which is related to the concentration of the fluorescent compound e.g. formed due to ionizing radiation, can be a measure of absorbed dose.

I.5.2 Absorbed dose

Absorbed dose is a statement of the amount of energy absorbed per unit mass of an irradiated material. Its formal definition is the quotient.
\[ D = \frac{d \varepsilon}{dm} \]  

(7)

Where \(d \varepsilon\) is the mean energy imparted by ionizing radiation to matter of mass \(dm\). Absorbed dose is therefore a point function and is continuous and differentiable and one may refer to its gradient and its rate.

The unit by which absorbed dose is specified is J.kg\(^{-1}\) and the special name for this is gray (Gy).

\[ 1 \text{ Gy} = 1 \text{ J.kg}^{-1} \]  

(8)

The absorbed dose rate: is the absorbed dose per unit time:

\[ \dot{D} = \frac{dD}{dt} \text{ Gys}^{-1} \]  

(9)

Table 1 summarizes some of the successful and established dosimetry systems for reference and/or routine radiation processing applications.

Table 2 presents some newer dosimeters, detectors, and dose monitoring systems that show promise for the future. The latest developments of many from both groups are included in these proceedings.

Table 3 shows different levels of radiation dose that are relevant for various applications. The commercial applications (shown at the last three part of the table) are generally referred to as ‘radiation processing’ and the relevant dose range may be referred to as ‘radiation-processing dose’. Sometimes this is also referred to as ‘high dose’.

I.5.3 Role of dosimetry in quality control

For those processes that are regulated, namely health related, dosimetry can be used to show that the process is correctly applied. Sterilization of medical products and food irradiation fall in this category. Regulation in a country generally specifies the minimum dose and quite
often the maximum dose depending upon the application. Dosimetry is used to provide this important starting point by measuring the relation between absorbed dose and the key parameters and by measuring the dose distribution in a reference product. Before radiation sterilization of a specific product can begin, it must be ensured that the legally required minimum dose is exceeded in all parts of the product, and that the maximum dose occurring will not impair the functionality of the product. For some other processes, where human safety is not of concern, for example, polymerization or cross-linking, the facility operator in this case does not have to satisfy the regulators, however, his customers demand a reliable and consistent product and again radiation dose can be used as a normalizing factor to which the process can be anchored.
Table (1): Dosimetry Systems for Radiation Processing

<table>
<thead>
<tr>
<th>System</th>
<th>Method of Analysis</th>
<th>Useful Dose Range, kGy</th>
<th>ASTM practice No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calorimeters</td>
<td>Heat meas. By thermistor or thermocouple</td>
<td>0.001- 50</td>
<td>E 1631</td>
</tr>
<tr>
<td>Fricke solution</td>
<td>UV spectrophotometry</td>
<td>0.02 -.40</td>
<td>E 1026</td>
</tr>
<tr>
<td>Dichromate sol.</td>
<td>UV or vis-spectrophotometry</td>
<td>2.0 - 50</td>
<td>E 1401</td>
</tr>
<tr>
<td>Ceric– cerous sol.</td>
<td>UV or vis-Spectrophotometry Electrochem. Potentiometry</td>
<td>0.5 -50</td>
<td>E 1205</td>
</tr>
<tr>
<td>Radiochromic sol.</td>
<td>Vis. Spectrophotometry</td>
<td>0.01 - 40</td>
<td>E 1540</td>
</tr>
<tr>
<td>Ethanol chlorobenzene sol.</td>
<td>Vis. Spectrophotometry or HF conductimetry</td>
<td>0.02 - 2000</td>
<td>E 1538</td>
</tr>
<tr>
<td>Alanine pellets or film</td>
<td>EPR spectrometry</td>
<td>0.001 - 100</td>
<td>E 1607</td>
</tr>
<tr>
<td>Polymethyl - methacrylate</td>
<td>Vis. Spectrophotometry</td>
<td>0.1 - 100</td>
<td>E 1276</td>
</tr>
<tr>
<td>Radiochromic film</td>
<td>Vis. Spectrophotometry or densitometry</td>
<td>0.1 - 100</td>
<td>E 1276</td>
</tr>
<tr>
<td>Cellulose triacetate film</td>
<td>UV or vis. spectrophotometry</td>
<td>5 - 1000</td>
<td>E 1650</td>
</tr>
<tr>
<td>Lithium fluoride crystal</td>
<td>UV or vis. spectrophotometry</td>
<td>0.5– 20,000</td>
<td>------</td>
</tr>
<tr>
<td>Radiochromic optical waveguide</td>
<td>Vis. Spectrophotometry or densitometry or photometry</td>
<td>0.01 - 10</td>
<td>E 1310</td>
</tr>
</tbody>
</table>
Table (2): Novel Approaches To dosimetry And Dose Monitoring

<table>
<thead>
<tr>
<th>System</th>
<th>Sensor Components</th>
<th>Method of Analysis</th>
<th>Useful Dose Range, kGy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiochromic polydiacytelene film</td>
<td>Substitution Polydiacytelene coating on film</td>
<td>Vis. Spectrophotometry</td>
<td>0.001 – 50</td>
</tr>
<tr>
<td>Tetrazolium salt in polymer</td>
<td>Tetrazolium chloride in polyvinyl alcohol</td>
<td>Vis. Spectrophotometry or densitometry</td>
<td>1 – 50</td>
</tr>
<tr>
<td>Tetrazolium salt solution</td>
<td>Tetrazolium chloride in aqueous alcohol</td>
<td>Vis. Spectrophotometry</td>
<td>1 – 100</td>
</tr>
<tr>
<td>Bleachable dye solution</td>
<td>Methylene blue, Congo red, etc. in aqueous alcohol</td>
<td>Vis. Spectrophotometry or densitometry</td>
<td>0.05 – 30</td>
</tr>
<tr>
<td>Optically stimulated luminescent film</td>
<td>Inorganic salts in polymer</td>
<td>Vis. Spectrofluorimetry</td>
<td>0.01 – 100</td>
</tr>
<tr>
<td>Polyethylene film</td>
<td>Low- or high-density polyethylene</td>
<td>Fourier– transform-IRspectrophotometry</td>
<td>0.01 – 1000</td>
</tr>
<tr>
<td>Inorganic crystals</td>
<td>SiO₂, Al₂O₃, or CaSO₄:Dy in polymer</td>
<td>EPR spectrometry</td>
<td>0.01 - 10,000</td>
</tr>
<tr>
<td>Bipolar; MOSFET; or p-FET transistors</td>
<td>Silicon- or rare-earth-base devices</td>
<td>Electrical load (voltage) signal</td>
<td>0.001 – 100</td>
</tr>
<tr>
<td>Diamond probe, film or disk</td>
<td>Diamond (carbon) crystal or sintered film</td>
<td>Electrical load (current) signals</td>
<td>Dose –rate meas. Up to 10³Gy/min</td>
</tr>
</tbody>
</table>

Table (3): levels of radiation dose relevant for various applications [31],

<table>
<thead>
<tr>
<th>application</th>
<th>Dose range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental</td>
<td>1 – 100 μGy</td>
</tr>
<tr>
<td>Diagnostic (medical)</td>
<td>10 – 100 mGy</td>
</tr>
<tr>
<td>Therapy (medical)</td>
<td>1 – 10 Gy</td>
</tr>
<tr>
<td>Food and agriculture</td>
<td>0.1 – 10 kGy</td>
</tr>
<tr>
<td>Sterilization</td>
<td>10 – 30 kGy</td>
</tr>
<tr>
<td>Material modification</td>
<td>50 – 100 or more kGy</td>
</tr>
</tbody>
</table>
I.5.4 Dosimeter classes and application

Dosimeters may be divided into four basic classes according to their relative quality and areas of application. There are four classes of dosimeters [31], [32]:

- Primary standard dosimeters,
- Reference standard dosimeters,
- Transfer standard dosimeters, and
- Routine dosimeters.

These four classes of dosimeters are defined below and some examples of these dosimeters and typical uncertainties in the dose values measured by them are given in Table 5.

I.5.4.1 Primary standard dosimeters

Primary standard dosimeters are generally of the highest meteorological quality in the field of radiation dosimetry. They are established and maintained by national standards laboratories for calibration of radiation fields. The two most commonly used primary standard dosimeters are ionization chambers and calorimeter.

I.5.4.2 Reference standard dosimeters

Reference standard dosimeter is defined as a dosimeter of high meteorological quality available at a given location, that has been calibrated against a reference standard (e.g. calorimeters or ionization chambers), and to be of use, it must satisfy well-established criteria. It must have a radiation signal that is accurately measurable, and this signal must have a well-defined functional relationship with absorbed dose. For example, calorimeters, alanine, and the ferrous sulfate dosimeter may serve as reference dosimeters if irradiated at conditions where the response of these dosimeters is not influenced by the dose rate. Examples of reference dosimeters are listed in Table 5.
Table (4): Classes of dosimeters [31, 32]

<table>
<thead>
<tr>
<th>Class</th>
<th>Calibration necessary?</th>
<th>Uncertainty (k=1)</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>No</td>
<td>1 %</td>
<td>Calorimeter, ionization chamber</td>
</tr>
<tr>
<td>Reference</td>
<td>Yes</td>
<td>1 – 2%</td>
<td>Calorimeter, alanine, dichromate, ceric-cerous, ECB, Fricke</td>
</tr>
<tr>
<td>Transfer</td>
<td>Yes</td>
<td>1 – 2%</td>
<td>Alanine, dichromate, ceric-cerous, ECB, Fricke</td>
</tr>
<tr>
<td>Routine</td>
<td>Yes</td>
<td>3 – 5%</td>
<td>PMMA, radiochromic and CTA films, ceric-ceric-cerous sulphate, ECB cerrous sulphate, ECBPMMA, radiochromic and CTA films,</td>
</tr>
</tbody>
</table>

I.5.4.3 Transfer dosimeters

Transfer dosimeters are specially selected dosimeters for transferring dose information from an accredited or national standards laboratory to a local irradiation facility in order to establish traceability for the local calibration facility. These dosimeters should be sufficiently precise and stable so that they can be transported for irradiation at an irradiation facility for dose evaluation, or for calibration of routine dosimeter [31]. The alanine, dichromate solution, ceric-cerous sulfate solution and ethanol chlorobenzene dosimeters are examples of transfer dosimeters. Characteristics of transfer standard dosimeters are summarized as follows:

- Long pre-irradiation stability
- Long post-irradiation stability
- Easily calibrated
- Portable
- Mailable and stable
- Broad absorbed dose range
- Produced in reproducible lots
- Radiation absorption properties similar to those of irradiated product
- Relatively insensitive to extremes of environmental conditions
- Correctable systematic errors (e.g. temperature, humidity, etc.)

I.5.4.4 Routine dosimeter

Routine dosimeter is generally a working standard that is used routinely in the processing facility, but it must itself be frequently calibrated against reference or transfer dosimeters, as it may not be stable enough to serve as a transfer dosimeter.

Table (5): Examples of Reference Standard Dosimeters [32].

<table>
<thead>
<tr>
<th>Dosimeter</th>
<th>Readout system</th>
<th>Absorbed dose range, Gy</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calorimeter</td>
<td>Thermometer</td>
<td>$10^2$ to $10^5$</td>
<td>[Miller and Kovaces, 1985]</td>
</tr>
<tr>
<td>Alanine</td>
<td>EPR</td>
<td>$1$ to $10^5$</td>
<td>[Regulla and Deffiner, 1985]</td>
</tr>
<tr>
<td>Ceric-cerous sulfate solution</td>
<td>UV spectrophotometer or electrochemical potentiometer</td>
<td>$10^3$ to $10^5$</td>
<td>[Matthews, 1982; Bjergbakke, 1970]</td>
</tr>
<tr>
<td>Ethanol-Chlorobenzene</td>
<td>Colorimetric titration</td>
<td>$10^2$ to $10^5$</td>
<td>[Kovács et. al., 1985]</td>
</tr>
<tr>
<td>Ferrous-sulfate solution</td>
<td>UV spectrophotometer</td>
<td>$10$ to $4 \times 10^2$</td>
<td>[Ellis, 1977]</td>
</tr>
<tr>
<td>Potassium/silver dichromate</td>
<td>UV spectrophotometer</td>
<td>$10^3$ to $10^5$</td>
<td>[Sharp, 1985]</td>
</tr>
</tbody>
</table>
I.5.5 Characterization of dosimetry systems

Basically a dosimeter is any material that’s at least one property changes systematically when exposed to radiation, such that this change is measurable and that it can be uniquely corrected to the absorbed dose. Thus, a dosimetry system consists of: dosimeters, equipment to measure the dosimeter response (spectrophotometer, thermometer, EPR spectrometer, electro-chemical cell and spectrofluorometer) and a documented procedure for its use.

Before using a routine dosimetry system for dose measurement, it should be carefully characterized. These characterizations consist of:
- determining lot homogeneity,
- calibration of the dosimetry system,
- establishing traceability, and
- determining uncertainty in the measured dose value.

I.5.5.1 Lot homogeneity

This involves understanding the behavior of the dosimetry system under various conditions. This includes intra-batch variability and influence of various parameters on its response.

A few dosimeters are generally used from the entire lot of dosimeters for establishing the calibration relationship for the dosimetry system; it is assumed that the relationship is valid for the entire lot. Also, when a dose is measured at a point, generally only 1 or 2 dosimeters which have been selected randomly from the lot are used. It is assumed that all the dosimeters are the “same” - that is they all behave the same way. Therefore, it is necessary to ascertain the extent to which these dosimeters are the same or behave the same [31].
I.5.5.2 Influence quantities

There are many external factors that can influence the signal (radiation-induced response) of the dosimeter. Most common are temperature, humidity, oxygen content, light, radiation type, dose rate, energy of radiation and geometrical factors. These effects should be carefully studied and the impact minimized or corrected for. For example, if the dosimetry system is used for dose measurement at a temperature different than the one for which it was calibrated, some correction is necessary [31].

I.5.5.3 Calibration

Calibration is always of a dosimetry system not a dosimeter. A dosimetry system consists of dosimeters and analysis equipment. Thus, if the equipment has been repaired or changed, the dosimetry system should be recalibrated or a few points may be checked. Also, calibration established with equipment is not valid for equipment. Calibration is the relationship between the absorbed dose and the response of the dosimeters measured using the analysis equipment. Such a calibration must be traceable to a National Laboratory. This means that the measurements are certified by a National Laboratory.

There are three different ways to calibrate a routine dosimetry system. All these methods provide traceability of the dose measurements [31].

1- Irradiation of routine dosimeters at a Calibration Laboratory to very accurate dose levels. The response of these dosimeters is then measured at the processing plant laboratory using their equipment. This calibration procedure involves mailing the dosimeters back and forth.

2- Irradiation of the dosimeters in an in-house calibration facility whose dose rate has been measured using a reference or transfer standard
dosimeter by the National Laboratory or Calibration Laboratory. The advantage is that the post- and pre-storage conditions of routine dosimeters are controlled to similar to those during actual use.

3- Routine dosimeters are irradiated in the production facility along with the transfer dosimeters provided by a Calibration Laboratory. These transfer dosimeters are then returned to the Calibration Laboratory for analysis. The advantage is that the environmental conditions are similar to those in production irradiation. However, special care should be taken to assure that both dosimeters receive the same dose.

I.5.5.4 Traceability

It is essential that all measurements are traceable to a National Laboratory or a Standard Laboratory. Traceability may be defined as the ability to show that a measurement is consistent with the appropriate national or international standards through an unbroken chain of comparisons. For a measurement to be traceable to a national standard, the measurement value must be linked through an unbroken chain of calibrations to that national standard. Every aspect of the dosimetry system should be traceable. Any equipment that is used, for example, should be calibrated and compared against a standard supplied by a national laboratory or a standard laboratory. This exercise should be done regularly.

I.5.5.5 Uncertainty in dose measurement

The objective of a measurement is to determine the value of the measured, that is, the value of the specific quantity to be measured. A measurement therefore begins with an appropriate specification of the measured, the method of measurement, and the measurement procedure. Thus, uncertainty of the result of a measurement indicates the lack of
exact knowledge of the value of the measured, or in other words it reflects the degree of accuracy in the measured value.

In practice there are many possible sources of uncertainty in a measurement, including:

- incomplete definition of the measured,
- sampling, the sample measured may not represent the defined measured,
- inadequate knowledge of the effects of environmental conditions,
- personal bias in reading analog instruments,
- instrument resolution or discrimination threshold,
- values assigned to measurement standard,
- approximations and assumptions incorporated in the measurement method and procedure,
- Variation in repeated observation.
I.6.1 Chalcogenide glasses

Chalcogenide glasses have been recognized as promising materials for infrared optical elements [33] and for the transfer of information [34]. They have also found applications in Xerography [35] switching memory devices [36] in the fabrication of extensive solar cells [37] and more recently, for reversible phase change optical records [38]. Thus, it is important to have an insight into their electronic properties. It has been reported that for any chalcogenide glassy system, increasing the relative atomic mass of the chalcogen or its proportion in glass diminishes the average bond strength and hence decreases the glass transition temperature [39]. The additions of chalcogen which act as chains or network terminators tend to decrease the glass transition temperature and increase the thermal expansion coefficient [40].

Thin films of Se$_{1-x}$ Te$_x$ (x=0.2, 0.4, & 0.6) deposited on a glass substrate were studied and investigated by H.ELZahed et al [41]. Optical band gap $E_g$ were determined from the absorbance and transmittance measurements in the visible and near IR spectral range (500-1100nm). Optical band gap $E_g$ was found to be decreased with increasing tellurium concentration.

M.A.Abdel-Rahim [42] reported and discussed the results of differential thermal analyses (DTA) under non isothermal conditions for three compositions of the Se$_{85-x}$ Te$_{15}$Sb$_x$ (x=0, 3 and 9). The onset crystallization temperatures ($T_c$), and the peak temperature of crystallization ($T_p$) were found to be dependent on the compositions and the heating rates. From the dependence on heating rates of ($T_g$) and ($T_p$) the activation energy for glass transition($E_t$) and the activation energy for crystallization($E_c$) were calculated and their composition dependence
were discussed. The crystalline phases resulting from DTA have been identified using X-ray diffraction and Scanning electron microscope (SEM).

**A.Dahshan et al.** reported the effect of replacement of selenium by antimony on the optical gap and some other physical parameters of new quaternary chalcogenide \( \text{As}_{14} \text{Ge}_{14} \text{Se}_{72-x} \text{Sb}_x \) (where \( x=3.6.9 \) and 15 at %) thin films. Thin films with thickness 200-220 nm of \( \text{As}_{14} \text{Ge}_{14} \text{Se}_{72-x} \text{Sb}_x \) were prepared by thermal evaporation of bulk samples, increasing antimony content was found to affect the average of atomization, the average coordination number, number of constraints and cohesive energy of \( \text{As}_{14} \text{Ge}_{14} \text{Se}_{72-x} \text{Sb}_x \) alloys. Optical absorption measurements showed that fundamental absorption edge is a function of composition. Optical absorption is due to allowed non direct transition and the energy gap decreases with increasing antimony content. The chemical bond approach has been applied successfully to interpret the decrease in the optical gap with increasing antimony content [43].

Thin films were thermally evaporated from ingot pieces of the \( \text{As}_{30} \text{Se}_{70-x} \text{Sb}_x \) (with 2.5<\( x <17.5 \) at.%) glasses under vacuum of \( \sim 10^{-5} \text{Torr.} \) by **A.H. Moharram et al.** Increasing Sb content was found to affect the thermal and optical properties of these films. Non-direct electronic transition was found to be responsible for the photon absorption successfully to interpret the decrease of the glass optical gap with increasing Sb content [44].

**P.Sharma et al.** studied the optical properties of Se substituted by Bi in \( \text{Ge}_{20} \text{Se}_{80-x} \) thin films. Optical reflection and transmission spectra, at normal incidence of \( \text{Ge}_{20} \text{Se}_{80-x} \text{Bi}_x \) thin films (\( x=0, 4, 6.8, 10, 12 \)) were obtained in the range 200nm-840nm. The optical energy gap was estimated from the absorption coefficient values using Tauc’s procedure.
It is found that, the optical band gap decreases with increasing bismuth content [45].

Glasses, based on selenium and tellurium, were carefully characterized to establish the interdependence between chemical composition and the magnitudes of the physical parameters. Optical measurements were performed on thin amorphous chalcogenide films from the system of pure (Se\(_{0.8}\)Te\(_{0.2}\)) and metal doped (Se\(_{0.8}\)Te\(_{0.2}\))\(\cdot\)M\(_{0.1}\) (M= Cu, Ag and Sn) by A. F. Maged et al. Parameters considered are density, molar volume, the concentrations of metal atoms per unit volume, and optical energy gap. Bulk Se\(_8\)Te\(_2\) alloy was prepared by the standard melt quenching technique and the different metals were added to the binary system using the same technique. Thin films of the prepared compositions was grown using thermal evaporation method. The effects of different metallic additions and annealing at a temperature below the glass transition temperature \(T_g\) on the optical characteristics were explored. The bulk and thin films of the samples were tested by x-ray diffraction, which reveals that they are amorphous. The optical energy gap \(E_0\) was found to decrease with the addition of metal, the amount of decrease depends on the chemical character of added metal. Annealing leads to a decrease of the optical energy gap with annealing time. The gamma irradiation (up to 100 KGY) has no detectable effect on the optical energy gap [46].

Amorphous Se\(_{90}\)In\(_{10-x}\)Sn\(_x\) (\(x=2, 4, 6, \) and 8) thin films of thickness 1000 Å were prepared on glass substrates by the thermal evaporation technique. Optical parameters of the films were investigated, in the wavelength range 400–700 nm, before and after irradiation by 4, 8, and 12 KGY doses of \(\gamma\)-ray. The optical absorption coefficient \(\alpha\) for as-deposited and gamma irradiated films was calculated from the reflectance \(R\) and transmittance \(T\) measurements, which were recorded at room
temperature. From the knowledge of $a$, at different wavelengths, the optical band gap $E_g$ was calculated for all compositions of Se–In–Sn thin films before and after gamma irradiation. Results indicate that allowed indirect optical transition is predominated in as-deposited and irradiated films. Besides, it is found that the band gap decreases with increasing Sn concentration and this is attributed to the corresponding decrease in the average single bond energy of the films. The band gap, after irradiation at different doses of $\gamma$-ray, was found to decrease for all compositions of the studied films. This post-irradiation decrease in the band gap was interpreted in terms of a bond distribution model [47].

Gamma radiation is known to induce changes in physical, optical, and structural properties in chalcogenide glasses, but previous research has focused on As$_2$S$_3$ and families of glasses containing Ge. For the first time, we present composition and dose dependent data on the As–S binary glass series. Binary As$_x$S$_{100-x}$ ($x = 30, 33, 36, 40, \text{ and } 42$) glasses were irradiated with gamma radiation using a $^{60}$Co source at 2.8 Gy/s to accumulated doses of 1, 2, 3, and 4 MGy. The irradiated samples were characterized at each dose level for density, refractive index, X-ray diffraction (XRD), and Raman spectrum. We report an initial increase in density followed by a decrease as a function of dose that contradicts the expected compositional dependence of molar volume of these glasses. This unusual behavior is explained based on micro-void formation and Nano-scale phase-separation induced by the irradiation. XRD, Raman, and electron spin resonance data provide supporting evidence, underscoring the importance of optimally- or overly constrained structures for stability under irradiation [48].

A.F.Maged et al. have studied the effects of addition of tellurium on transition temperature, density, molar volume and optical properties for Ge-As-Se system and the effect of $\gamma$-irradiation on IR transmission for
the system \( x=0 \) and \( x=40 \). Oxygen impurities, which are increased after \( \gamma \)-irradiation, produce an absorption between 12 and 16 \( \mu \)m due to Ge-O, As-O and Se-O [49].

Chalcogenide glasses are interesting materials due to their infrared transmitting properties and photo induced effects exhibited by them. Thin films of the glasses \( \text{Sn}_{10}\text{Sb}_{20-x}\text{Bi}_x\text{Se}_{70} \) prepared by melt quenching technique were evaporated in a vacuum better than \( 10^{-5} \) mbar. Optical transmissions spectra of all the deposited films were obtained in a range 400–2500 nm. The optical band gap and the absorption coefficient were calculated from the transmission data. The optical band gap initially increases with increase in Bi content (for \( x = 2 \)) and then decreases sharply for higher Bi concentrations. The refractive index as well as absorption coefficient decrease with increase in wavelength. The dark activation energy initially increases with increase in Bi content and then decreases with further addition [50].

Chalcogenide alloys of \( \text{Sn}_{10}\text{Sb}_{20-x}\text{Bi}_x\text{Se}_{70} \) system were prepared by the melt quenching technique. Thin films were prepared on well-cleaned glass substrates by the thermal evaporation technique. The glass transition, crystallization, melting temperatures and glass forming tendency of the amorphous samples were determined from differential scanning calorimetric measurements. The glass transition activation energies and the crystallization activation energies were determined using the Kissinger method. Optical transmission and reflection spectra of thin films were obtained in the range 400-2500nm. The conductivity activation energy and optical gap initially increase with increasing Bi concentration and then decrease sharply for higher Bi content. The values of the band tailing parameter and the pre-exponential factor are also reported and discussed [51].
V.S. Shiryaev et al. [52] have studied the Calorimetric characteristic temperatures and crystallization behavior in Ge–As–Se–Te glass system. Results of differential scanning calorimetry of high purity Ge\textsubscript{x}As\textsubscript{40-x}Se\textsubscript{40}Te\textsubscript{20} (X = 0–40) chalcogenide glasses are reported. The glass transition temperatures and crystallization behavior were studied under non-isothermal conditions at different heating rates (2.5–35 K/min). The glass transition temperature changes from 140 °C up to 320 °C with increasing the Ge content in Ge\textsubscript{x}As\textsubscript{40-x}Se\textsubscript{40}Te\textsubscript{20} glass. The studied glasses with x ≤ 35 have no exothermal peaks of crystallization, indicating their high glass-forming ability. The glass of Ge\textsubscript{40}Se\textsubscript{40}Te\textsubscript{20} composition has one-stage glass transition and double-stage crystallization process during phase change. The activation energy of the glass transition (E\textsubscript{g}), the activation energy of crystallization (E\textsubscript{c}), the Avrami exponent (n), the frequency factor (K\textsubscript{0}) and the crystallization criteria of Ge\textsubscript{40}Se\textsubscript{40}Te\textsubscript{20} glass were determined.

C. Vigreux-Bercovici et al. [53] have reported Te-rich Ge–As–Se–Te bulk glasses and films for future IR-integrated optics. Ge\textsubscript{15}As\textsubscript{15}Se\textsubscript{70-x}Te\textsubscript{x} materials with x = 56, 60 and 63, of potential use in IR-integrated optics, were prepared by the classical melt quenching method. A macroscopic phase separation was observed with a crystalline phase on the top and an amorphous one at the bottom. The glasses from the bottom were transparent from 1.9 to 16 µm without any purification of the elemental precursors Ge, As, Te and Se. The higher the Te/Se content in the glasses the lower their glass transition temperature and thermal stability. Films 7–12 µm thick of the above stated compositions were deposited by thermal evaporation. The higher the tellurium content, the larger the optical band gap shifts of the films in the infra-red and the higher the refractive index.
Chapter I

Introduction & Literature Review

H.H. Amer et al. [54] have studied the electrical conductivity of amorphous semiconducting films of system (Ge_{20}As_{30}Se_{50-x}Te_x). The substitution effect of Te, with different concentrations, on the electrical and thermal properties of the quaternary chalcogenide semiconducting films Ge_{20}As_{30}Se_{50-x}Te_x, x = 0, 20, 30 and 40, have been studied. Dependence of d.c. conductivity on composition has been reported. It was found that the activation energy decreases with increasing Te content. The obtained results have been interpreted in the frame of the model proposed by Mott and Davis (1979). It has also been observed that the increase of Te was followed by a decrease in the glass transition temperature. In other words, the addition of Te decreases the stability of the formed glass.

A.F. Maged et al. [55] have studied the optical absorption of amorphous semiconductors Ge_{20}As_{30}Se_{50-x}Te_x and the effect of γ-irradiation. The Ge-As-Se system has been selected as the basic Glass system for studying the effects of addition of tellurium on transition temperature, density, molar volume and optical properties. The effect of γ-irradiation on IR transmission for the system x= 0 and x = 40 has been studied. Oxygen impurities which are increased after gamma-irradiation produce an absorption between12 and 16µm due to Ge-O, As-O and Se-O.

I.6.2 Metal oxide and dosimetry

Metal oxides are widely used in many technological applications, such as coating, catalysis, electrochemistry, optical fibers, sensors, etc. [56, 57]. Metal oxide sensors have been utilized for several decades for their low-cost and simplicity. However, issues with sensitivity, selectivity and stability have limited their use, often in favor of more expensive approaches [58, 59]. The recent availability of various metal oxide materials in high-surface-area nano-powder form, as well as
implementation of newly developed nanofabrication techniques, offer tremendous opportunities for sensor manufacturers.

**K. Arshak and O. Korostynska** [60] studied the response of metal oxide thin film structures to radiation. The properties of the materials undergo changes by the influence of gamma-rays. The degree of these changes could serve as a measure of the received radiation dose. Deep understanding of physical properties of the materials under the influence of radiation is vital for the effective design of devices for radiation-sensing applications. Mixing oxides in various proportions was found to control the radiation-sensing properties of the semiconductor films in terms of their sensitivity to γ-radiation exposure and working dose region.

Metal oxides thin films are highly affected by the influence of radiation. The changes caused their electrical or optical properties to be correlated with radiation dose for dosimetry applications. It was noticed that material mixing as well as thickness variations could be employed to control the sensitivity to radiation and working dose range.

**K. Arshak and O. Korostynska** [61] prepared Thick film oxide diode structures for personal dosimetry application. The aim of work is to develop a novel sensor for γ-ray radiation with instantaneous dosage readouts. Metal oxides, such as NiO, CeO$_2$ and In$_2$O$_3$ are the key sensing elements in the proposed approach. The physical principles of radiation detection by oxide materials are connected with the radiation-induced formation of specific structural defects called color centers. The density of these defects is dependent on the absorbed radiation dose.

**K. Arshak and O. Korostynska** [62] prepared thin film pn-junctions based on oxide materials as γ-radiation sensors. Thin films of TeO$_2$, In$_2$O$_3$ and SiO and their mixtures were used in this study for the fabrication of pn-junctions. The detection of radiation is based on the fact
that properties of the materials undergo changes by the influence of γ-rays. A number of various pn-junctions that differ in their materials composition were made. All the devices were exposed to $^{60}$Co or $^{137}$Cs radiation sources and their current–voltage ($I$–$V$) characteristics were examined. The influence of radiation depends on both the dose and the parameters of the films including their thickness: the degradation is more severe for the higher dose and the thinner films [63]. Deep understanding of the physical properties of the materials under the influence of radiation exposure is vital for the effective design of dosimeter devices.

J. Huang et al. [64] have studied the application of concentrated TiO$_2$ sols for γ-ray radiation dosimetry. Upon exposure to γ-radiation, a concentrated TiO$_2$ sol changes from colorless to deep blue with an absorption maximum at 540 nm. The absorption has been assigned to trapped electrons or Ti$^{3+}$ states in the solid matrix based on its spectroscopic similarity to the samples irradiated with UV light. Unlike the conduction-band electrons generated from direct excitation by UV radiation, the origin of the trapped electrons during gamma-ray irradiation may be traced to a series of reducing species produced by the high energy electrons, which in turn, are the direct result of γ-irradiation. As the absorption intensity is linearly related to the duration of exposure to γ-radiation, it may have an application in γ-ray dosimetry. The sensitivity of its dosage response has been found to be influenced by the semiconductor particle concentration and the dispersing solvent.

K. Arshak et al. [65] have studied the gamma radiation sensing properties of TiO$_2$, ZnO, CuO and CdO thick film pn-junctions. The aim of work is to investigate the feasibility of the use of titanium dioxide (TiO$_2$), zinc oxide (ZnO), copper oxide (CuO) and Cadmium oxide (CdO) in the development of thick film gamma radiation sensors with instantaneous dosage readouts. A number of pn-heterojunctions with
various compositions of sensitive layers were formed by screen printing the thick film pastes on silicon wafers. All these devices were exposed to a disc-type $^{137}$Cs source with an activity of 370 kBq. It was found that for all samples the values of leakage current increased with increasing radiation dose.

Metal oxides were considered as suitable materials for gamma radiation sensing layers due to high sensitivity of their optical, electrical and structural properties to ionizing radiation [66–68]. Gamma rays produce a change in the density of charge carriers in semiconducting material, which alters the material properties in measurable way. This change provides information about the dose absorbed by the material. The influence of radiation depends on both the dose and the parameters of the films including their thickness. The degradation is more severe for higher doses and thinner films [69, 70].

I.6.3 Dosimetry and high dose

**M. El-Kelany et al.** [71] studied the development of a plastic dosimeter for industrial use with high doses. These films contain a mixture of two dyes namely bromothymol blue (BTB) and methyl orange (MO) indicator with different concentration of alanine in poly (vinyl alcohol). The color of this film changes from green to pale yellow. The response of these films can be modified by changing the alanine concentration and the ratio of the two dyes. As a result, these films can be used as a dosimeter in high dose range. The dosimetric parameters, e.g. dose response, effect of relative humidity, pre- and post-irradiation stability of these films are investigated.

**S. Ebraheem et al.** [72] investigated a new dyed poly (vinyl alcohol) film for high-dose applications. These films contain a mixture of two dyes, namely 2,6 dichloro phenol indophenol sodium salt (DCP) and cresol red (CR) indicator with different concentrations of chloral hydrate
in poly (vinyl alcohol). The color of this film changes in two steps from green to yellow and finally to red color. Due to irradiation, first the bleaching reaction for DCP takes place in the absorbed dose range up to about 17 kGy, followed by the transformation of CR to its acidic form due to the presence of chloral hydrate in the dose range up to 50 kGy. The response of these films can be modified by changing the chloral hydrate concentration and the ratio of the two dyes. As a result, these films can be used as a dosimeter in the two dose ranges. The dosimetric parameters, e.g. dose response, effect of relative humidity and temperature during irradiation on response as well as pre- and post-irradiation stability of these films are investigated.

W. B. Beshir and S. Eid [73] studied the investigation of dyed film based on quinaldine red dyed poly (vinyl alcohol) and poly (vinyl butyral) for high dose dosimetry applications. The dyed polymer films, prepared by a simple technique of casting aqueous solutions of poly (vinyl alcohol) PVA or poly (vinyl butyral) PVB containing quinaldine red (QR) on a horizontal glass plate, are useful as routine high-dose dosimeters. These flexible plastic film dosimeters are bleached when exposed to gamma rays. The response of these dosimeters depends on the concentration of QR and the polymer material. The radiation chemical yield (G-value) of both PVA and PVB dyed films was calculated and was found to increase with increasing dye concentration.

A.A. Abdel-Fattah et al. [74] studied the use of bromophenol blue or xylenol orange dyed polyvinyl alcohol for high-dose film dosimeters. Dyed poly (vinyl alcohol) (PVA) films, prepared by a simple technique of casting aqueous solutions of PVA containing bromophenol blue (BPB) or xylenol orange (XYO) on a horizontal glass plate, are useful as routine high-dose dosimeters. These flexible plastic film dosimeters are bleached
when exposed to γ-ray photons. Absorbed doses should not exceed 20 kGy for BPB/PVA film and 90 kGy for XYO/PVA film.

S.Ebraheem et al. [75] investigated dyed poly (vinyl alcohol) films containing 4-nitrophenol dye for high-dose dosimetry applications. These flexible plastic films investigated to be dosimeters, have been studied in case of addition achlorine containing substance; trichloroacetamide or chloral hydrate as well as L-alanine. These films were bleached when exposed to gamma rays.

S.Ebraheem et al. [76] investigated dyed acrylic-acid grafted polypropylene films for high-dose radiation dosimetry. Gamma radiation-induced polymerization of acrylic acid (AAc) onto polypropylene (PP) film has been carried out under nitrogen atmosphere. The grafted film of PP-g-PAAc was allowed to react with solutions of two ionic dyes, namely malachite green (MALG) or methylene green (METG). The investigations show that these new dosimeter films of PPMALG and PPMETG may be useful for high-dose gamma radiation applications. The useful absorbed dose range of the dyed films extends up to about 400 kGy, with a minimum useful dose of about 5 kGy. The radiation-induced colour bleaching has been analyzed with visible spectrophotometry.
II. Experimental Techniques

II.1. Preparation of chalcogenide glass

There are at least a dozen of different techniques that can be used to prepare materials in the amorphous phase. Of these, two normal ways are commonly used in one form or another to produce most non-crystalline materials; by cooling from a melt or by condensation from the vapor. The first method forms bulk materials, while the second yields thin films as in thermal evaporation, sputtering or glow discharge techniques. During the preparation of the amorphous material, the faster the rate of cooling or deposition, the farther the amorphous solid lies from equilibrium. These glasses were prepared from As, Se, Ge and Te elements with purity 99.999 %. These glasses are reactive at high temperature with oxygen. Therefore, synthesis was accomplished in evacuated clean silica tubes. The tubes were washed with distilled water, and then dried in a furnace whose temperature was about 100°C. For each composition the proper amounts of materials were weighted using an electrical balance type (Sartorius) with accuracy ± 10^{-4} gm. The weighted materials were introduced into the cleaned silica tubes and then evacuated to about 10^{-4} torr and sealed. The sealed tubes were placed inside the furnace and the temperature of the furnace was raised gradually up to 900°C within 1 hour and kept constant for 10 hours. Moreover, shaking of the constituent materials inside the tube in the furnace was necessary for realizing the homogeneity of the composition [77].

After synthesis, the tube was quenched into ice water. The glassy ingots could be obtained by drastic quenching. Then materials were removed from the tubes and kept in dry atmosphere. The ingot materials were identified as glass due to their bright features. The proper ingots were confirmed to be completely amorphous using x-ray diffraction and
differential thermal analysis. Homogeneity of the prepared samples was proved by determination of density of different parts. Silica tubes used for bulk amorphous are illustrated in fig (7). Figure (8) shows the design flow chart for preparation of bulk amorphous Ge$_{20}$As$_{20}$Se$_{(60-x)}$Te$_x$ [78].

**Figure (7)** Silica tubes used for bulk amorphous semiconductors preparation

**II.2. Preparation of Ferrotitanium alloy**

Ferrotitanium alloy is prepared by the reduction of rutile and ilmenite ores. One of the most used methods of extracting metals from their ores (usually oxides) is the chemical reduction of these oxides by means of a reducing agent, often carbon or another metal. This principle has been put to industrial use basically since the Bronze Age. Among these pyrometallurgical reductions, as they are known in chemical metallurgy, reductions with aluminum, referred to as aluminothermy, Ferrotitanium alloy prepared by the reaction of iron oxide and titanium oxide with aluminum powder during which liquid iron and liquid alumina (aluminum oxide) are formed [79].
Washing silica tubes with distilled water and dried in a furnace whose temperature about 100 °C.

**Weighting of each component in composition**

**Weighted materials introduced into the cleaned silica tubes.**

**Cleaned silica tubes evacuated to about 10^{-4} torr and sealed.**

The sealed tubes placed inside the furnace and the temperature of the furnace was raised gradually up to 900°C within 1 hour and kept constant for 10 hours.

**Shaking the constituent materials inside the tube in the furnace is necessary for realizing the homogeneity of the composition.**

**After synthesis the tube was quenched into ice water.**

**Materials removed from the tubes and kept in dry atmosphere.**

**Figure (8)** Design flow chart for Preparation of bulk amorphous \( \text{Ge}_{20}\text{As}_{20}\text{Se}_{(60-x)}\text{Te}_x \)

*Iron oxide + Aluminium ---\> liquid Iron + liquid Aluminium Oxide*

The convenient fact that both reaction products are generated in the molten state is due to the fact that the reaction is accompanied by massive heat generation, sufficient to heat the reaction products to well
above their respective melting points (3,730 °F for alumina and 2,800°F for iron). In the case of aluminothermy, most usually a heat booster reaction is chosen that involves the oxidation of extra amounts of added aluminum powder with a powerful oxidizer. The worded reaction of the heat booster reaction is simply:

Oxidizer + Aluminum $\rightarrow$ Alumina + by-product

Oxidizers capable of oxidizing aluminum with great generation of heat are plenty (in fact, all the metal oxides suitable for thermite reductions are great oxidizers, it just so happens that titanium dioxide isn't very good on its own). Commercially used heat booster oxidizers include chlorates, per chlorates, nitrates and sulphates. By combining the main reduction reaction (titanium and iron dioxide + aluminum) with the booster reaction in the correct ratios, the required reaction temperature can be increased to almost any level, including that all three reaction products (titanium metal, iron metal calcium sulphide and alumina) are produced above their melting points. From the post-reaction, hot, molten metal/slag mixture. After cooling, the metal (the densest component of the mix) is then found at the bottom of the crucible, nicely protected by the slag from oxidation by air during the cooling step. The ignition mix itself requires quite a bit of heat input to get going (which is why it's safe to store indefinitely) and the best way of doing this, is by means of magnesium ribbon. Finally, bulk sample of ferrotitanium alloy is formed by aluminothermy process, after that this bulk sample is converted into powder by grinding process [79], shown in figure (9). Then the sample is converted from powder to liquid by dissolution in concentrated HCl [80].
II.2.1. Preparation of alloy stock solution

Three different concentrations of alloy were by prepared dissolving 0.04, 0.08, and 0.12 gm in 15ml HCl and then the volume was completed to 100ml with double distilled water.

II.2.2. Preparation of film dosimeter

Films were prepared by dissolving 3.75 gm of PVA (Average mo.wt 25.000 fully hydrolyzed 99-100%) product of J.T baker chemical/Co. USA), in 75 ml double distilled water. Complete dissolution
was obtained by stirring 3 hours at 60 °C followed by continuous stirring for 24 hours at room temperature then left to cool. The polymer solution was divided into 3 parts each of 25 ml. Films were prepared by adding 12.5 ml of stock alloy solution to each part of polymer. The solutions were kept well stirred at room temperature for about 3 h in order to obtain uniformly mixed solution. Each solution was poured into a 15x15cm horizontal glass plate and dried at room temperature for about 48 h. After stripping the films were cut into 1x1cm pieces and were stored in the dark at (RH) of 33%, the film thickness was measured using digitrix-mark II gauge. Three polymer films were obtained, containing 0.4, 0.8, 1.2 phr (phr = part per hundred parts by weight of resin).

II.3. Irradiation procedure

The irradiation of the film dosimeters has been carried out at the central position of the sample chamber in the Gamma chamber 4000A using specially designed polymethylmethacrylate (Perspex) holder. This holder maintains the center of the sample chamber. This place is the most uniform iso-dose in the chamber, and it is accurately calibrated using the standard Fricke dosimeter. Irradiation was carried out with the ⁶⁰Co Gamma chamber 4000A irradiation facility (product of, India). The absorbed dose rate in water was measured to be 3.75 kGy/h using reference alanine dosimeters. The temperature during gamma-ray irradiations was maintained at 37°C ± 2°C.

The films were numbered, measured spectrophotometrically at characteristic λ_max and then placed between two polystyrene slabs of the same thickness (3mm) to ensure that irradiations were performed under conditions of electronic equilibrium. After that, the film samples were subjected for irradiation with various doses through removing sequentially 4 films at each dose, one after another until the highest dose was reached. The irradiated films were then readout
spectrophotometrically at characteristic $\lambda_{\text{max}}$, and the results were subjected to different calculation methods. The average value of each 4 films corresponding to an absorbed dose was plotted against absorbed dose producing response curves.

For ultraviolet irradiation, the film dosimeters were irradiated at different irradiation wavelengths using the ultraviolet source and different filters. For irradiating the sample at the required wavelength, the sample was covered by the filter and then fixed at a certain distance (using special holder) in the path of UV lamp irradiation. The change in optical density before and after irradiation ($\Delta A$) was measured at the characteristic peak of different dosimeters as function of exposure energy of ultraviolet radiation. The variation of ($\Delta A$) as function of ultraviolet incident energy was recorded as response curve for each dosimeter system.

II.4. Absorption spectra measurements

The absorption spectra of unirradiated and irradiated films were measured on Uvikon 860 or UV4 spectrophotometers. These films were placed into the holder designed specially for reproducible fitting into the sample beam of the instrument. The absorbance spectra were scanned to determine the wavelengths (nm) of the maximum absorbance ($\lambda_{\text{max}}$) and the change in absorbance for UV/VIS spectra was recorded.

The spectral UV/VIS measurements were undertaken at selected $\lambda_{\text{max}}$ wavelength (nm) for each tested film before and after irradiation. For establishment of the response functions, different calculation techniques were used, e.g. calculating the change in $(\Delta \text{Amm}^{-1})_{\lambda}$, or $(\Delta A/A_0)_{\lambda}$, where $\Delta A=A_0-A_i$ and $A_0$ and $A_i$ are the absorbance before and after irradiation, respectively. The average response value of each three films corresponding to an absorbed dose were plotted against absorbed dose (in K Gy) producing response curves.
II.5. Relative humidity during irradiation procedure

The effect of relative humidity (RH) during irradiation on the gamma ray response of different film dosimeters was investigated by the following procedure: Each dosimeter piece was held by a plastic clip in air in enclosed 100-ml glass tubes during irradiation. Each tube contained 25-ml of a saturated salt solution [81]. The salt solutions are listed in table (6) along with the different values of relative humidity in air in the enclosed tubes at the temperature of irradiation (25± 2°C). The dosimeters were subjected to the various relative humidity for about 48 hours before irradiation and then irradiated with gamma rays at these values of relative humidity. Immediately after irradiation the dosimeters were removed from the tubes and then measured spectrophotometrically. Table (6) Saturated aqueous salt solutions for producing different relative humidity in an enclosure.

<table>
<thead>
<tr>
<th>Salt</th>
<th>Relative Humidity at 25°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica Gel</td>
<td>0%</td>
</tr>
<tr>
<td>LiCl</td>
<td>11%</td>
</tr>
<tr>
<td>MgCl2.6H2O</td>
<td>33%</td>
</tr>
<tr>
<td>NaCl</td>
<td>76%</td>
</tr>
<tr>
<td>KNO3</td>
<td>92%</td>
</tr>
<tr>
<td>H2O</td>
<td>100%</td>
</tr>
</tbody>
</table>

II.6. Structure measurements

The structure characteristics of the investigated alloys in both powder and thin film forms have been investigated. A brief description of these methods will be given below.

II.6.1. X-Ray analysis (XRD)

X-ray analysis for both bulk and thin films include two analyses for getting compositional and structural information about prepared samples.
Chapter II

Experimental Techniques

X-Ray diffraction has been used to investigate and characterize the structure of the as prepared samples. This has been done with the aid of “Shimadzu XRD-6000”X as shown in fig (10) diffractometer which consists of αpw1400/90 stabilized X-ray generator, αpw1050/70 vertical goniometer, αpw1995/60 proportional counter and αpw1930 electronic panel. Nickel–filtered copper radiation with λ=1.542 Å was used in the present investigation.

The choice of a particular X-ray radiation source of a certain wavelength depends on the fact that if the radiation wave length λ is less than that of the absorption edge of the examined sample, large absorption will cause a faint reflection. The filter was located between the scatter slit and the count tube. The X-ray has been operated at 50 kv and 25 mA throughout the measurements.

A sample of the considered material was ground to fine powder flat rectangular specimen holders, made of aluminum, and is used, each with an aperture of 2 x 1 x 0.2 cm³. The rear of aperture was closed with metal plates. A smooth specimen surface was prepared by backing with a glass slide. By an appropriate choice of the slit system, at least half of the specimen surface area was examined in each angular range from 10 to 90 degrees (2θ) X–ray diffraction pattern was recorded automatically by the diffract meter, is essentially a plot of intensities as a function of the angle of reflection given by the material.

The resulting diffraction pattern of crystal comprises both positions and intensities of the diffraction effects.

Analysis of the position of the diffraction effects leads immediately to a knowledge of the size, shape, and orientation of the unit cell, while the position of the individual atoms in the cell may be found from the peak intensity measurements. The measured angle (2θ) of the crystalline samples and inter planar (d′) are related through Bragg’s law.
$$n\lambda = 2d'_{hkI}\sin\theta_{hkI}$$  \hspace{1cm} (10)

Where $\lambda$ is the wave length of the X–ray source, $\theta$ is the Bragg’s angle (angle of the incidence or reflection), $d'_{hkI}$ refers to the orientation of the plane, and $n$ is an integer equal to 1, 2, 3…etc.

**Figure (10)** X-ray diffractometer, “Shimadzu XRD-6000”- 6

### II.6.2. Energy Dispersive X-ray:

The elemental analysis of the prepared samples in the bulk and thin film form was performed by a technique known as *Energy Dispersive X-ray (EDX)* analysis. In this analysis the specimen is subjected to an energetic electron beam (20Kev) resulting in production of characteristic X-rays from the specimen surface. The emitted X-ray spectrum used to determine qualitatively and quantitatively the composition of each sample and to ensure the sample homogeneity as well. The electron beam energy 20kev was selected for two reasons. The first is because; the maximum X-ray energy collected by the device is 20kev on the X-ray scale. The second reason is to prevent high penetration of the film, since energy greater than 20kev may occur.

### II.6.3 Differential Thermal Analysis (DTA)

Differential thermal analysis (DTA) is the technique of measuring the heat effects associated with physical or chemical changes that take
place as a substance is heated at a constant rate. The appearance of many papers in the last decades in which quantitative DTA results showed that under controlled conditions, fairly good quantitative results can be obtained. Also, the availability of better equipment has assisted in getting reproducible conditions. The basic principle of DTA is the measurement of the temperature difference between the sample and a reference material as they are heated simultaneously under uniform rate.

A solid state reaction causes an evolution of heat, which is shown as temperature difference $\Delta T$ between the sample and the reference material [82]. As this heat is dissipated to the surroundings, $\Delta T$ reduces to zero again. Measurements of the temperature $T$ and $\Delta T$ over a suitable range gives a thermo gram characteristic of the reaction occurred. Accordingly, the DTA curve of Fig (11) continues in an approximately rectilinear manner, until the test material undergoes some physical or chemical change.

![Figure (11) typical DTA thermo gram illustrating the definition of the different transition temperature](image)

The curve begins to deviate from the baseline; the first deviation is more representative of the start of a transition than the peak. V.G. Hill and Roy [83] stated that the nearest approach to transition temperature is the point at which the curve leaves the baseline. This point is difficult to be determined, so the intersection of the baseline and the extrapolation of
the straight part of the adjacent side of the peak is the glass transition temperature \( T_g \), then the curve begins to deviate from the base line forming the crystallization peak at temperature \( T_c \). After that, the curve returns to the new baseline. The onset of an endothermic reaction is indicated by the downwards deflection of the baseline giving rise to endothermic peak, melting temperature \( T_m \).

Micro–DTA apparatus, shimadzu DTA-50 model, was used for the measurement of DTA. Figure (12) and Fig (13) showed the captured photo of Differential and a block diagram illustrating the main units of the used DTA.

**Figure (12)** Captured photo of Differential thermal analysis

![Differential thermal analysis](image)

**Figure (13)** Principle Block diagram of Differential thermal analysis

It is mainly a combination of a sample holder, DA-30 amplifier, control unit and two pen recorder R–22T. The control unit permits temperature control for the sample holder. Also it permits the temperature
to be displayed digitally either in °C or K. The pen of the recorder provides a mark at every 1 degree or 10 degree on the chart to ensure more precise temperature measurement.

Also, the temperature is simultaneously recorded as a solid line on the chart. The heating rate can be adjusted to ten different rates ranging from 1 degree/min up to 100 degree/min. The experimental conditions adopted were in accordance with the recommendations of Mackenzie [84].

**II.7. Density Determination**

Density is an important physical parameter which is related to other physical properties of the material and also is used to examine the homogeneity of the as-prepared materials. The density of the considered samples was determined using the method of hydrostatic weight using toluene. A single crystal of germanium was used as a reference material for determining the toluene density. The latter has been determined from the formula:

$$d_{toluene} = \frac{W_{toluene} - W_{air}}{W_{air}} \times d_{Ge}$$  \hspace{1cm} (11)

Where, \(w'\) is the weight of single Ge crystal. Then, the sample density was calculated from the formula:

$$d_{sample} = \frac{W_{air}}{W_{air} - W_{toluene}} \times d_{toluene}$$  \hspace{1cm} (12)

Where \(w\) is the weight of the sample.

While the density \(d_{th}\) of the prepared compositions was also calculated theoretically using Muller's formula, [85]

$$d_{th} = [\sum \frac{p_i}{d_i}]^{-1}$$  \hspace{1cm} (13)

Where \(P_i\) is the fraction of weight of the \(i_{th}\) element and \(d_i\) is its density.
III Results & Discussion

The industrial application of radiation processing has a wide industrial field, such as the sterilization of medical products, food irradiation, pasteurization, water purification, radiation treatment of polymer and semiconductors. The quality control step is considered to be a very important part of the radiation processing to measure and control the radiation absorbed dose for any application, whatever the kind of treatment is [86].

The National Center for Radiation Research and Technology “NCRRT”, was provided with Egypt’s Mega-Gamma I radiation facility in 1979. This facility is used in sterilization of many medical products for the Egyptian market as well as a lot of food irradiation processes. Different films for dosimetric quality control are used, and are imported at costly price. Search for Egyptian homemade dosimeters is one of NCRRT goals.

The present work deals with the investigation and evaluation of results to conclude and discuss the dosimetric characteristics of both ferrotitanium and chalcogenide alloy. This chapter includes two parts; the first one is: Study the effect of gamma radiation on the optical energy gap of poly (vinyl alcohol) based Ferrotitanium alloy film; its possible use in radiation dosimetry, and the second part is: Study the physical properties of some chalcogenide alloy materials and effect of gamma radiation.
III.1. 1st Unit: Study the effect of gamma radiation on the optical energy gap of poly (vinyl alcohol) based Ferrotitanium alloy film and its possible use in radiation dosimetry.

In this part of work, thin PVA films colored with different concentrations of ferrotitanium alloy were investigated to be used as dosimeters for radiation processing. The effect of gamma radiation on optical band gap is studied, and also the effect of relative humidity, as well as pre- and post-irradiation stability of these films are examined. The chemical composition of alloy was determined by EDX, and structure of alloy was determined by XRD.

Many dyed films had been developed and investigated for possibility of their being used to measure absorbed doses in nuclear reactors and doses of X-rays, gamma rays and electron beam [87-92]. All these dyed PVA systems are bleached by irradiation the extent being to which the color change is used for determining the absorbed dose.

Radiation bleachable organic dyes were widely investigated [93]. For dose monitoring in radiation processing, the polymeric dyed flexible films are considered to be the most commonly used as dosimeters and indicators [94]. Based on the idea of mixing poly (vinyl alcohol) with two dyes having different sensitivities to radiation, a new label dosimetry system has been developed [95]. Dyed polymeric films containing organic dyes have been investigated to be a useful dosimeter in the high dose application [96]. Exposure of solid materials to ionizing radiation produces changes in the microstructural properties, which affects the optical, electrical and other physical properties of the solid materials [97]. The effect of gamma radiation on optical properties of thin films of tellurium dioxide have been studied. It was found that the optical band gap values decreased as the radiation dose was increased [98]. The effect
of gamma irradiation on the optical properties of polystyrene doped by methylene blue dye have been investigated, the optical band gap was determined and was found to decrease after irradiation [99]. The effect of $\gamma$-radiation on the optical and the electrical properties of manganese phthalocyanine thick film were investigated for dosimetry applications [100]. Optical properties of bismuth germinate (Bi$_4$Ge$_3$O$_{12}$-BGO) thin films under the influence of gamma radiation have been investigated [101].

III.1.1. Physical properties of ferrotitanium alloy

III.1.1.1. X-ray diffraction techniques (XRD):

X-Ray diffraction has been used to investigate and characterize the structure of the prepared samples. The X-ray diffraction technique indicates that Ferrotitanium alloy samples are amorphous, shown in Figure (14).

III.1.1.2 Energy Dispersive X-ray:

This technique indicates the elemental analysis of ferrotitanium alloy that containing Fe, Ti, Al, and Si with 39, 41, 14, 6% respectively, this is shown in Figure (15).
Chapter III

Results & Discussion

Fig (14) X-ray diffraction patterns of ferrotitanium alloy

Fig (15) EDX of Ferrotitanium Alloy
III.1.1.3. Differential Thermal Analysis of Ferrotitanium alloy

Differential Thermal Analysis, DTA, for ferrotitanium alloy in the powder form showed that an endothermic peak in the DTA curve results from an increase in specific heat at the glass transition temperature $T_g$. The absence of any sharp exothermic peak in the DTA curve is a good indicator for the absence of the structural changes, shown in figure (16).

![DTA measurements for ferrotitanium alloy](image)

**Fig (16)** DTA measurements for ferrotitanium alloy

III.1.2. Absorption spectra

The absorption spectra of pure PVA film and ferrotitanium alloy/PVA film containing alloy concentration (0.8 phr) are shown in Figure (17). From the figure the absorption band of pure PVA film appears at 285nm, where the ferrotitanium alloy/PVA film appears at 352nm.
The absorption spectrum of ferrotitanium alloy/PVA film with three different alloy concentrations (0.4, 0.8, and 1.2 phr) is shown in figure (18). From the figure all concentrations have the same wavelength but differ in their peak height. The peak height depends upon the alloy concentration where it increases with the increase in concentration.

![Absorption Spectra](image1)

**Figure (17)** absorption spectra of PVA film and alloy/PVA film with alloy concentration 0.8 phr.

![Absorption Spectra](image2)

**Figure (18)** absorption spectra of Alloy/PVA films unirradiated with different concentrations 0.4, 0.8, 1.2 phr.
The absorption spectra of Ferrotitanium alloy/PVA Film containing 1.2 phr was recorded before and after irradiation to different doses and are shown in Figure 19. The absorption spectrum of the unirradiated film shows a main absorption band in the visible region characteristic to yellow color peaking at 352 nm. The intensity of this absorption band decreases gradually with the increase of absorbed dose. Figure 20 and 21 represents the absorption spectra of ferrotitanium alloy/PVA film with (0.4 and 0.8 phr of alloy). Films were recorded before and after irradiation to different absorbed doses.

Figure (19) absorption spectra of Ferrotitanium Alloy/PVA films unirradiated and irradiated to different absorbed doses [Alloy]=0.12phr at $\lambda_{\text{max}}$=352nm
Figure (20) absorption spectra of Ferrotitanium Alloy/PVA films unirradiated and irradiated to different absorbed doses [Alloy]=0.4phr at $\lambda_{\text{max}}=352\text{nm}$

Figure (21) absorption spectra of Ferrotitanium Alloy/PVA films unirradiated and irradiated to different absorbed doses [Alloy]=0.8phr at $\lambda_{\text{max}}=352\text{nm}$
III.1.3. Response Curves

Figure 22 shows the response curves of ferrotitanium alloy/PVA containing different alloy concentrations 0.4, 0.8 and 1.2 phr respectively, the response curves were established in terms of change in absorbance per unit thickness, $\Delta A_{\text{mm}}^{-1}$ versus the absorbed dose $D$, where $\Delta A = A_o - A_i$, $A_o$ and $A_i$ are values of absorbance for the unirradiated and irradiated film respectively at 352nm. The curves show that the maximum dose range extends up to 200 kGy for Alloy/PVA films, it can be seen that all curves have the same trend but differ in their slopes depending on Alloy concentration.

**Figure (22)** change of $\Delta A_{\text{mm}}^{-1}$ as function of absorbed dose of Alloy/PVA films containing different concentrations of Alloy 0.4, 0.8, 1.2 phr
III.1.4. Effect of alloy concentration on response

The dose at saturation was found to increase with the increase of alloy concentration from 0.4 up to 1.2 phr as shown in figure (23).

Figure (23) variation of dose at saturation of Alloy/PVA films as function of concentration 0.4, 0.8, 1.2 phr.

III.1.5. Optical Energy gap

The optical energy gap holds the minimum of the conduction band and the maximum of the valence band. The relation between the optical energy gap, absorption coefficient and energy hν of the incident photon is given by [102, 103]:

\[ \alpha (h\nu) = B(h\nu - E_g)^r \]

(14)

Where \( E_g \) is the optical energy gap; \( \alpha \) is the absorption coefficient; \( B \) is a constant; and \( r \) is an index which can be assumed to have values of 1/2, 3/2, 2 and 3, depending on the nature of the electronic transition responsible for the absorption. \( r = 1/2 \) for allowed direct transition, \( r = 3/2 \) for forbidden direct transition and \( r = 3 \) for forbidden indirect transition,
and $r = 2$ refers to indirect allowed transitions. The absorption coefficient for direct transition takes the values from $10^4$ to $10^5$ cm$^{-1}$, while the absorption coefficient for indirect transition takes the values from 10 to $10^3$ cm$^{-1}$ [104]. The absorption coefficient $\alpha$ can be calculated according to urbach rule [102] as follows:

$$\alpha = \frac{1}{L} \ln \frac{I_o}{I_t}$$  \hspace{1cm} (15)

Where, $I_o$ and $I_t$ are the intensities of the incident and transmitted light, respectively, $L$ is the thickness of the sample (cm).

The optical energy gap can be evaluated from the linear plots of $(\alpha h\nu)^n$ as a function of energy at different doses, as shown in figure 24(a,b). Extrapolations of these plots to the point at which they cross the abscissa give the values of optical energy gap. The plots show $E_g$ decreases with increasing absorbed dose indicated in fig 25(a,b). Table 7(a,b) represents the value of $E_g$ for both direct and indirect transition (allowed and forbidden) for ferrotitanium alloy /PVA film with concentration 1.2 phr. From the table it can be seen that $E_g$ decreases with the increase of absorbed dose. Both calculated results from the table show that calculation of $E_{gap}$ can be detected from figure 24(a,b) from two different areas. The optical energy gap for the ferrotitanium alloy has the possibility to have two different values; this is because this alloy containing iron and titanium elements both have atomic structure with many valence states. The present results were found to obey equation (14) with $r=2$ for all films, which indicated indirect allowed transitions. Table 7 (a,b) shows the values of $E_g$ for direct and indirect transitions (allowed and forbidden).
Table 7 (a,b) shows the values of $E_g$ for direct and indirect transitions (allowed and forbidden).

### (a)

<table>
<thead>
<tr>
<th>Dose, KGy</th>
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### (b)

<table>
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<th>Dose, KGy</th>
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<th></th>
<th></th>
<th></th>
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<td>2.86</td>
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<td></td>
<td></td>
<td>1.97</td>
<td>2.43</td>
<td>3.21</td>
<td>1.96</td>
</tr>
</tbody>
</table>
Fig. 24(a, b) the relation between $(\alpha\nu)^{1/2}$ and photon energy for Ferrotitanium Alloy/PVA films irradiated with different doses.
The decrease in the energy gap with increasing absorbed dose may be attributed to an increase in structural disorder of the irradiated Ferrotitanium/PVA film. These contributed to the structural defects, which reduce the energy gap with increasing dose [105].

**Fig. 25(a,b)** change in the optical energy gap as function of irradiation dose of [ferrotitanium alloy/PVA] = 1.2 phr
III.1.6. Effect of titanium concentration on the density of ferrotitanium alloy

The density of the prepared alloy has been determined. The obtained results are given in table (8) where it is noticed that the density decreases by increasing Ti from 4.58 gm/cm$^3$ for the composition Fe$_{39}$Ti$_{41}$Al$_{14}$Si$_6$ up to 4.305gm/cm$^3$ for composition Fe$_{27}$Ti$_{33}$Al$_{14}$Si$_6$. Density decreases because atomic mass of Fe is greater than atomic mass of Ti which means that the molecular weight decreases by increasing Ti content. Table (8) the composition dependence of density.

<table>
<thead>
<tr>
<th>Ti at%</th>
<th>Composition</th>
<th>d$_{Th}$ gm/cm$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>41</td>
<td>Fe$<em>{39}$Ti$</em>{41}$Al$_{14}$Si$_6$</td>
<td>4.58</td>
</tr>
<tr>
<td>47</td>
<td>Fe$<em>{33}$Ti$</em>{47}$Al$_{14}$Si$_6$</td>
<td>4.46</td>
</tr>
<tr>
<td>53</td>
<td>Fe$<em>{27}$Ti$</em>{53}$Al$_{14}$Si$_6$</td>
<td>4.305</td>
</tr>
</tbody>
</table>

As it is known, the change of density is related to the change in the atomic weight of the elements constituting the system. The atomic weights of Fe, Ti, Al and Si are 55.845, 47.867, 26.98154 and 28.085 and respectively. Figure (26) represents the relation between the density and Ti content.

![Figure (26) Dependence of density on Ti content](image-url)
III.1.7. Coordination number

Ioffe and Regel [106] have suggested that the bonding Character in the nearest neighbor region, which is the coordination number, characterizes the electronic properties of the semiconducting materials. The coordination number obeys the so-called 8-N rule, where N is the valency of an atom; the number of the nearest-neighbor atoms for Ge, As, Se and Te are calculated and listed in table 9. The average coordination number in the quaternary compounds $A_\alpha B_\beta C_\gamma D_\lambda$ is as:

$$N_{co} = \frac{\alpha N_{co}(A) + \beta N_{co}(B) + \gamma N_{co}(C) + \lambda N_{co}(D)}{\alpha + \beta + \gamma + \lambda} \quad (16)$$

Where $\alpha$, $\beta$, $\gamma$, $\lambda$ are the valencies of the elements of compound. The calculated values of $N_{co}$ ferrotitanium alloy, using the elemental coordination number of Fe, Ti, Al and Si given in Table 9. Table (9) the average coordination number ($N_{co}$).

<table>
<thead>
<tr>
<th>Ti content at%</th>
<th>$N_{co}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>41</td>
<td>3.08</td>
</tr>
<tr>
<td>47</td>
<td>3.2</td>
</tr>
<tr>
<td>53</td>
<td>3.32</td>
</tr>
</tbody>
</table>

III.1.8. Stability

Stability measurements, before and after irradiation were made storing films in the dark and light, and reading the films spectrophotometrically at different times during the pre-irradiation storage period of 30 days.

III.1.8.1. Pre-Irradiation Stability

The color stability of ferrotitanium alloy/PVA films were examined before irradiation by storing the films at room temperature under laboratory fluorescent light. Figure 27 represents the change in $A_f/A_o$ of the prepared films, which was measured at 352 nm for PVA films at different intervals time during the storage period of 30 days. It can be seen that films exhibit excellent stability before irradiation.
Fig (27) Pre-irradiation stability of ferrotitanium Alloy/PVA films stored in dark and light at room temperature, wavelength of analysis at 352nm

III.1.8.2. Post-Irradiation Stability

Ferrotitanium alloy/PVA films containing 1.2 phr of alloy irradiated to a dose of 150 kGy, then stored at room temperature (25°C ± 2) in the laboratory fluorescent light. The absorbance of these films was measured at 352 nm for PVA films at different intervals of time during the storage period of 30 days. The change in absorbance as a function of storage time relative to that zero time immediately after irradiation is shown in Figure 28. From this figure, it can be seen that ferrotitanium alloy/PVA films show a good stability, until the end of storage period.
Fig (28) Post-irradiation stability of ferrotitanium Alloy/PVA films stored in dark and light at room temperature, $\lambda_{\text{max}} = 352$ nm.

### III.1.9. Humidity during Irradiation

The effect of relative humidity (RH) during irradiation on the response of ferrotitanium alloy/PVA films were investigated by irradiating (1.2 phr) films to dose of (50 kGy) at the different relative humidities (0%, 11%, 33%, 76%, 92% and 100% RH). The different relative humidity was maintained by using different standard salts [107]. The films were stored before irradiation for three days period under the same relative humidity conditions as when irradiated, so that equilibrium moisture content in dosimeter is established during irradiation. **Figure 29** represents the relative variation in $\Delta$Amm$^{-1}$ at 352 nm for ferrotitanium alloy/PVA as function of percentage relative humidity during irradiation, relative to that at 33%, the response of the films are almost flat in the range of relative from 0% - 100%.
III.1.10. Conclusion

Ferrotitanium alloy polymer films, prepared by a simple technique of casting aqueous solutions of poly (vinyl alcohol) PVA containing Ferrotitanium alloy with different concentration of alloy on a horizontal glass plate, are useful as routine high-dose dosimeters up to 200 KGy; dose range depends on the concentration of alloy. These flexible plastic film dosimeters, which have yellow color, are bleached when exposed to gamma rays. The chemical composition of alloy was determined by EDX, and structure of alloy was determined by XRD. The response of these dosimeters depends on the concentration of alloy. The energy band gap $E_g$ was calculated and the effect of gamma radiation on its value was determined. The optical absorption spectra showed that the absorption mechanism is an indirect allowed transition which found that energy band
gap $E_g$ decreases after irradiation. The decrease in the energy gap with increasing absorbed dose may be attributed to an increase in structural disorder of the irradiated Ferrotitanium/PVA film. These films have negligible humidity effect in the range from 0-100%. Also, it exhibits good pre-and post-irradiation stability in dark and light.
III.2. 2\textsuperscript{nd} Unit: Study of the physical properties of some chalcogenide alloy materials and effect of gamma radiation.

In this part of work, thin film of chalcogenide glasses were prepared from Ge, As, Se and Te elements with purity 99.999\%. The structural properties of Ge\textsubscript{20}As\textsubscript{20}Se\textsubscript{(60-x)}Te\textsubscript{x} and differential thermal analysis have been investigated. The density of the prepared chalcogenide glasses of system Ge\textsubscript{20}As\textsubscript{20}Se\textsubscript{(60-x)}Te\textsubscript{x} film has been determined. The effect of gamma radiation on optical band gap has been investigated. The present study is undertaken in order to investigate the influence of addition of tellurium (0, 10, 15 and 20 at. %), which is higher in atomic weight (more electropositive) than selenium on the optical properties of the new amorphous Te\textsubscript{x}Ge\textsubscript{20}Se\textsubscript{(60-x)}As\textsubscript{20} thin films. In addition, the optical band gap ($E_g$), the average heat of atomization ($H_s$) and the cohesive energy ($CE$) of the Te\textsubscript{x}Ge\textsubscript{20}Se\textsubscript{(60-x)}As\textsubscript{20} glasses have been examined theoretically.

Chalcogenide glasses are alloy materials which are composed of two or more elements. In our study we took chalcogenide glasses as an example for the alloy. Chalcogenide glasses are a recognized group of inorganic glassy materials which always contain one or more of the chalcogen element S, Se ,or Te, in conjunction with more electro negative elements as Sb, As and Bi. Chalcogen glasses are generally less weakly bonded materials than oxide glasses [108].

Chalcogenide glassy semiconductors have been the subject of considerable attention due to their interesting optical properties and technological applications, like optical imaging or storage media and especially in the fields of infrared optical transmitting materials, fiber optics and memory device [109].

The absence of long–range order of chalcogenide glassy semiconductors allows the modification of their optical properties to a
specific technological application by continuously changing their chemical composition. Hence the study of the dependence of the optical properties on composition is important to improve technological application.

III.2.1. Physical properties of chalcogenide glass

This chapter deals with the experimental results of \((\text{Te}_x\text{Ge}_{20}\text{Se}_{60-x}\text{As}_{20})\) investigated by X-ray diffraction analysis (XRD) and differential thermal analysis (DTA) for the powder and thin film at constant thickness 100 nm.

III.2.1.1. X-ray Diffraction Identification Samples

The X-ray diffraction technique was used to investigate the structure and character of our system \(\text{Te}_x\text{Ge}_{20}\text{Se}_{60-x}\text{As}_{20}\), (where \(x=0, 10, 15\) and \(20\)%). The X-ray diffraction patterns of the amorphous prepared samples are shown in Figure 30.

![Figure 30](image-url)  

**Figure (30)** X-Ray Diffraction patterns of bulk sample of the system \(\text{Te}_x\text{Ge}_{20}\text{Se}_{(60-x)}\text{As}_{20}\), (where \(x=0, 10, 15\) and \(20\)at.%)
The patterns show the characteristic diffraction peaks which reflect the absence of regular crystalline structure. Such diffraction pattern characterizes the pure amorphous state of the investigated samples.

III.2.2. Differential Thermal Analysis (DTA)

Differential Thermal Analysis, DTA, for Te$_x$Ge$_{20}$Se$_{(60-x)}$As$_{20}$ in the powder form showed that an endothermic peak in the DTA curve results from an increase in specific heat at the glass transition temperature $T_g$. The absence of any sharp exothermic peak in the DTA curve is a good indicator for absence of the structural changes, shown in Figures 31,32,33,34.

![DTA Measurement](image)

**Figure (31)** DTA measurement for Te$_x$Ge$_{20}$Se$_{(60-x)}$As$_{20}$ (where $X=0$)
Figure (32) DTA measurement for Te$_x$Ge$_{20}$Se$_{(60-x)}$As$_{20}$ (where X=10)

Figure (33) DTA measurement for Te$_x$Ge$_{20}$Se$_{(60-x)}$As$_{20}$ (where X=15)
Figure (34) DTA measurement for Te\textsubscript{x}Ge\textsubscript{20}Se\textsubscript{(60-x)}As\textsubscript{20} (where X=20)

Table (10) shows values of T\textsubscript{g} for composition with different ratio of Te. From the table glass transition temperature (T\textsubscript{g}) decreases as the tellurium percent increases.

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<td>145.90</td>
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<tr>
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<td></td>
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<tr>
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<td></td>
<td>Te\textsubscript{20}As\textsubscript{20}Se\textsubscript{40}Ge\textsubscript{20}</td>
<td>133.98</td>
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### III.2.2. The density dependence of (Te) content

The density of the as prepared glasses of the system Te\textsubscript{x}Ge\textsubscript{20}Se\textsubscript{(60-x)}As\textsubscript{20} films has been determined by the hydrostatic method with an accuracy of ±0.05%. The obtained results are given in table (11) where
it is noticed that the density increases by increasing Te from 4.93 gm/cm$^3$ for the composition Te$_x$Ge$_{20}$Se$_{(60-x)}$As$_{20}$ at x=0% up to 5.53 gm/cm$^3$ for composition Te$_x$Ge$_{20}$Se$_{(60-x)}$As$_{20}$ at x=20%. Te is greater than those of Se which means that the molecular weight increases by increasing Te content.  

Table (11) the composition dependence of density.

<table>
<thead>
<tr>
<th>Te at%</th>
<th>Composition</th>
<th>$d_{Th}$ gm/cm$^3$</th>
<th>$d_{Exp}$ gm/cm$^3$</th>
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<tr>
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<td>5.106</td>
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</table>

As it is known, the change of density is related to the change in the atomic weight of the elements constituting the system. The atomic weights of Ge, Se, As and Te are 72.64, 78.96, 74.9216 and 127.6 and their respective atomic radius are 1.62, 1.40, 1.70, 1.66 respectively.

Figure (35) Dependence of density on Te content in the system Te$_x$Ge$_{20}$Se$_{(60-x)}$As$_{20}$ (with x=0, 10, 15, 20 at %).
Some physical parameters of Se, Ge, As, and Te elements are given in Table (12).

Ioffe and Regel [106] have suggested that the bonding character in the nearest neighbor region, which is the coordination number, characterizes the electronic properties of the semiconducting materials. The coordination number obeys the so-called 8-N rule, where N is the valency of an atom; the number of the nearest-neighbor atoms for Ge, As, Se and Te are calculated and listed in Table (13). The average coordination number in the quaternary compounds \( A_\alpha B_\beta C_\gamma D_\lambda \) is as:

\[
N_{co} = \frac{\alpha N_{co}(A) + \beta N_{co}(B) + \gamma N_{co}(C) + \lambda N_{co}(D)}{(\alpha + \beta + \gamma + \lambda)}
\] (17)

Where \( \alpha, \beta, \gamma, \lambda \) are the valencies of the elements of compound

The determination of \( N_{co} \) allows the estimation of the number of constraints (\( N_s \)). This parameter is closely related to the glass-transition temperature and associated properties. For a material with coordination number \( N_{co} \), \( N_s \) can be expressed as the sum of the radial and angular valence force constraints [111].

\[
N_s = \frac{N_{co}}{2} + (2N_{co} - 3)
\] (18)

The calculated values of \( N_{co} \) and \( N_s \) for the \( \text{Te}_x\text{Ge}_{20}\text{Se}_{(60-x)}\text{As}_{20} \) system, using the elemental coordination number of Ge, Se, As and Te given in Table (12). are listed in Table (13).

<table>
<thead>
<tr>
<th>Physical characteristics</th>
<th>Ge</th>
<th>Se</th>
<th>As</th>
<th>Te</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy gap(ev)</td>
<td>0.95</td>
<td>1.95</td>
<td>1.15</td>
<td>0.65</td>
</tr>
<tr>
<td>Density(g/cm³)</td>
<td>5.3</td>
<td>4.79</td>
<td>4.7</td>
<td>7.31</td>
</tr>
<tr>
<td>coordination no.</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Bond energy(kcal/mol)</td>
<td>37.6</td>
<td>44.02</td>
<td>32.1</td>
<td>33</td>
</tr>
<tr>
<td>Hs(kcal/mol)</td>
<td>90</td>
<td>54.17</td>
<td>69</td>
<td>46</td>
</tr>
<tr>
<td>Electro negativity</td>
<td>2.01</td>
<td>2.4</td>
<td>2.18</td>
<td>2.1</td>
</tr>
<tr>
<td>Radius(pm)</td>
<td>122</td>
<td>115</td>
<td>119</td>
<td>140</td>
</tr>
<tr>
<td>C.E(ev/atom)</td>
<td>3.13</td>
<td>2.45</td>
<td>2.17</td>
<td>2.51</td>
</tr>
</tbody>
</table>
Table (12) Shows values of the optical band gap, density, coordination number, heat of atomization (H_s), bond energy and electro negativities of Ge, Se, As and Te respectively which are used for calculations. Table (13) shows the average coordination number (Nco) and the constraints number (Ns) as function of Te content of Te_xGe_20Se_(60-x)As_20 glass.

<table>
<thead>
<tr>
<th>Te content at %</th>
<th>Nco</th>
<th>Ns</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.6</td>
<td>3.5</td>
</tr>
<tr>
<td>10</td>
<td>2.6</td>
<td>3.5</td>
</tr>
<tr>
<td>15</td>
<td>2.6</td>
<td>3.5</td>
</tr>
<tr>
<td>20</td>
<td>2.6</td>
<td>3.5</td>
</tr>
</tbody>
</table>

III.2.3. Optical Band Gap of Te-Se-As-Ge Thin Films

Values of the absorption coefficient (α) for the studied films were calculated according to urbach rule [103] as follows

\[
\alpha = \frac{1}{L} \ln \frac{I_o}{I_t}
\]  

(15)

Where, I_o and I_t are the intensities of the incident and transmitted light, respectively, L is the thickness of the sample (cm).

Figure(36) shows calculated values of the absorption coefficient (α) for the Te_xGe_20Se_(60-x)As_20 where x=0, 10, 15, and 20 at % thin films. The present results were found to obey equation (14) with r=2 for all films. This indicates indirect allowed transitions. Figures (37) and (38) are a best fit of (αhν)^1/2 versus photon energy(hν) for Te_xGe_20Se_(60-x)As_20 thin films before and after radiation up to 200 KGY. The intercepts of the straight lines with the photon energy axis give the values of the optical band gap.

The variation in E_g as a function of Te content before and after irradiation is shown in Figure 39. It is clear that E_g decreases with
increasing Te content of the investigated films, and after irradiation no change in its values means these thin films are inert to gamma rays.

**Figure (36)** Absorption coefficient ($\alpha$) versus photon energy ($h\nu$) for the Te$_x$Ge$_{20}$Se$_{(60-x)}$As$_{20}$ thin films.

The variation of $E_g$ as function of Te content is depicted in Figure (39). From this figure, it is clear that $E_g$ decreases with increasing Te content of the investigated glasses.
Fig (37) Shows a typical best fit of $(\alpha h\nu)^{1/2}$ versus photon energy ($h\nu$) for the Te$_x$Ge$_{20}$Se$_{(60-x)}$As$_{20}$ thin film before irradiation.

Fig (38) Shows a typical best fit of $(\alpha h\nu)^{1/2}$ versus photon energy ($h\nu$) for the Te$_x$Ge$_{20}$Se$_{(60-x)}$As$_{20}$ thin film after irradiation.
Figure (39) The variation in the optical band gap ($E_g$) as function of Te content of the $Te_xGe_{20}Se_{(60-x)}As_{20}$ thin films.

The bond energies $D (A-B)$ for hetero-nuclear bonds have been calculated by using the empirical relation:

$$D(A-B) = D(A-A)D(B-B)^{1/2} + 30(\gamma_A - \gamma_B)^2$$  \hspace{1cm} (20)

Where $D (A-A)$ and $D (B-B)$ are the energies of the homo-nuclear bonds (in units of Kcal/mol); $\gamma_A$ and $\gamma_B$ are the electro negativities for the involved atoms.

Knowing the bond energies, we can estimate the cohesive energy (CE). The stabilization energy of an infinitely large cluster of the materials per atom is given by summing the bond energies over all the bonds expected in the system under test. The (CE) of the prepared samples is evaluated from the following equation:

$$CE = \sum (C_iD_i/100)$$  \hspace{1cm} (21)

Where $C_i$ and $D_i$ are the numbers of the expected chemical bond and the energy of each corresponding bond, the calculated values of C.E for all compositions are presented in Table13 with the exception of $Te_x$ $Ge_{20}$ $Se_{(60-x)}$ $As_{20}$ glass, C.E decreases with increasing Te content.
Table (14) Bond energy of formation of various bonds in Te$_x$Ge$_{20}$Se$_{(60-x)}$As$_{20}$Films.

<table>
<thead>
<tr>
<th>Bond</th>
<th>Bond energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ge-Se</td>
<td>49.4</td>
</tr>
<tr>
<td>Se-Se</td>
<td>44.02</td>
</tr>
<tr>
<td>As-Se</td>
<td>41.7</td>
</tr>
<tr>
<td>Se-Te</td>
<td>40.87</td>
</tr>
<tr>
<td>Ge-Ge</td>
<td>37.6</td>
</tr>
<tr>
<td>Ge-As</td>
<td>35.61</td>
</tr>
<tr>
<td>Ge-Te</td>
<td>35.46</td>
</tr>
<tr>
<td>Te-Te</td>
<td>33.1</td>
</tr>
<tr>
<td>As-Te</td>
<td>32.7</td>
</tr>
<tr>
<td>As-As</td>
<td>32.1</td>
</tr>
</tbody>
</table>

![cohesive energy graph](image)

**Fig (40)** cohesive energy versus Tellurium%

**III.2.4. Effect of gamma-irradiation on Optical Band Gap**

The $\gamma$- radiation had a constant noticeable effect for a dose up to 200K Gy upon the addition of Te.
III.2.5. Conclusion

This part reports the effect of replacement of selenium by tellurium on the optical gap and some other physical parameters of new quaternary chalcogenide $\text{Te}_x\text{Ge}_{20}\text{Se}_{(60-x)}\text{As}_{20}$ ($x = 0, 10, 15$ and $20$ at. %) thin films. Thin films with thickness 100 nm of $\text{Te}_x\text{Ge}_{20}\text{Se}_{(60-x)}\text{As}_{20}$ were prepared by thermal evaporation of the bulk samples. Increasing tellurium content is found to affect the average heat of atomization, cohesive energy and energy gap of the $\text{Te}_x\text{Ge}_{20}\text{Se}_{(60-x)}\text{As}_{20}$ alloys. Optical absorption measurements showed that the fundamental absorption edge is a function of composition. The optical absorption is due to allowed indirect transition and the energy gap decreases with the increase of tellurium content. The chemical bond approach has been applied successfully to interpret the decrease of the optical gap with increasing tellurium content. It has also been observed that the increase of Te was followed by decrease in glass transition temperature. The prepared films were irradiated by gamma rays at doses up to 200kGy. It was found that the compositions were almost stable against gamma radiation, which means this alloy can be used as successful shield against gamma ray to protect the worker from the harmful effect can be done in the commercial irradiation facility.
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Study the Physical Properties of Some Alloy Materials and Effect of Gamma Radiation

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⁴Chemistry Department, Faculty of Science, Menoufia University, Cairo, Egypt

Abstract
The present paper reports the effect of replacement of selenium by tellurium on the optical gap and some other physical parameters of new quaternary chalcogenide Te₉Ge₂₀Se₆₀₋ₓAsₓ(20) (x = 0, 10, 15 and 20 at. %) thin films. Thin films with thickness 100 nm of Te₉Ge₂₀Se₆₀₋ₓAsₓ(20) were prepared by thermal evaporation of the bulk samples. Increasing tellurium content is found to affect the average heat of atomization, cohesive energy and energy gap of the Te₉Ge₂₀Se₆₀₋ₓAsₓ(20) alloys. Optical absorption measurements showed that the fundamental absorption edge is a function of composition. The optical absorption is due to allowed direct transition and the energy gap decreases with the increase of tellurium content. The chemical bond approach has been applied successfully to interpret the decrease of the optical gap with increasing tellurium content. It has also been observed that the increase of Te was followed by decrease in glass transition temperature. The prepared films were irradiated by gamma rays at doses up to 200kGy. It was found that the compositions were almost stable against gamma radiation.

Keywords: amorphous, chalcogenide, optical properties.

1. Introduction
Alloy materials are substances composed of two or more elements. In our study we took chalcogenide glasses as an example for the alloy. Chalcogenide glasses are a recognized group of inorganic glassy materials which always contain one or more of the chalcogen element S, Se, or Te, in conjunction with more electronegativity elements as Sb, As and Bi. Chalcogen glasses are generally less weakly bonded materials than oxide glasses (¹). Chalcogenide glassy semiconductors have been the subject of considerable attention due to their interesting optical properties and technological applications, like optical imaging or storage media and especially in the fields of infrared optical transmitting materials, fiber optics and memory device (²).

The absence of long–range order of chalcogenide glassy semiconductors allows the modification of their optical properties to a specific technological application by continuously changing their chemical composition. Hence the study of the dependence of the optical properties on composition is important to improve technological application.

The present study is undertaken in order to investigate the influence of addition of tellurium (0, 10, 15 and 20 at. %), which is higher in atomic weight (more electropositive) than selenium on the optical properties of the new amorphous Te₉Ge₂₀Se₆₀₋ₓAsₓ(20) thin films. In addition, the optical band gap (Eg), the average heat of atomization (Hf) and the cohesive energy (CE) of the Te₉Ge₂₀Se₆₀₋ₓAsₓ(20) glasses have been examined theoretically.

2. Experimental procedures
Te₉Ge₂₀Se₆₀₋ₓAsₓ(20) (where x = 0, 10, 15 and 20 at%) films were prepared using the melt-quenching technique. The constituent elements Ge, As, Se and Te (99.999% purity) were weighed and mixed in the appropriate stoichiometric proportion and sealed in evacuated (10⁻⁵ torr) silica tubes. These tubes were then placed in a furnace and were heated; stepwise to 900°C to allow the elements to react completely. The tubes were kept at the maximum temperature for 10h, to ensure that the melt was homogeneous. After quenching in ice water, the alloy was removed by cutting the tubes. The film samples were deposited by the thermal evaporation techniques which were performed inside a coating (Edward FTMS) System at pressure (10⁻⁵ torr) cleaned glass slides with acetone then de-ionized water were used as substrates. The substrates holder was continuously rotated with slow motor and the evaporation rate kept constant to ensure the homogeneity of films. The thicknesses of these films were controlled by using a quartz crystal (Edward FTMS) thickness monitor to be about 1000Å. The elemental compositions of the investigated specimens were checked using the energy dispersive X-Rays spectroscopy. Deviations in the elemental composition of the evaporated thin films from the initial bulk specimens did not exceed 1.0 mol%. The amorphous state of the films was checked using an x-ray diffract meter (Philips type 1710 with Cu as a target and Ni as a filter) the absence of crystalline peaks confirmed the glassy state of the prepared
samples. Density measurements of the considered samples were made by germanium crystal which was used as reference material for determining the toluene density, \( \rho_{\text{toluene}} \). The sample density was obtained from the
\[
d_{\text{sample}} = \frac{W_{\text{air}}}{W_{\text{air}} - W_{\text{toluene}}} \times d_{\text{toluene}}
\]  
(1)

Where \( W \) is the weight of the sample. For each composition, the experiment was repeated three times to get the average density of the sample (\( \rho_0 \)). The thermal behavior was also investigated using shimadzu 50 differential scanning calorimeter. About 20 mg of each sample in powdered form was sealed in standard aluminum pan and scanned over a temperature from room temperature to about 773 K at uniform heating rate 8K/min. double beam (Shimadzu 2101 UV-VIS) Spectrophotometer was used to measure reflectance and transmittance for the prepared films in the spectral wavelength range 200-1100 nm. Gamma irradiation was applied to films with doses up to 15 Mrad using the gamma cell of the Co-60 source at the National Center for Radiation Research and Technology, Cairo, Egypt.

3. Result and Discussion

Ioffe and Regel\(^{(3)}\) have suggested that the bonding character in the nearest neighbor region, which is the coordination number, characterizes the electronic properties of the semiconducting materials. The coordination number obeys the so-called 8-N rule, where N is the valence of an atom; the number of the nearest-neighbor atoms for Ge, As, Se and Te are calculated and listed in table 1. The average coordination number in the quaternary compounds \( \text{A}_2 \text{B}_2 \text{C}_2 \text{D}_2 \) is as:

\[
\alpha \text{N} \text{e} \text{v} \text{u} \text{A} + \beta \text{N} \text{e} \text{v} \text{u} \text{B} + \gamma \text{N} \text{e} \text{v} \text{u} \text{C} + \lambda \text{N} \text{e} \text{v} \text{u} \text{D}) / (\alpha + \beta + \gamma + \lambda)
\]  
(2)

Where: \( \alpha, \beta, \gamma, \lambda \) are the valences of the elements of compound. The determination of \( N_{\text{co}} \) allows the estimation of the number constraints \( N_s \). This parameter is closely related to the glass-transition temperature and associated properties. For a material with coordination number \( N_{\text{co}}, N_s \) can be expressed as the sum of the radial and angular valence force constraints.\(^{(4)}\)

\[
N_s = \frac{N_{\text{co}}}{2} + (2 N_{\text{co}} - 3)
\]  
(3)

The calculated values of \( N_{\text{co}} \) and \( N_s \) for the \( \text{Te}_x \text{Ge}_{2-x} \text{Se}_{(60-x)} \text{As}_{20} \) system are given in table 2. The parameter \( r \), which determines the deviation of stoichiometry and is expressed by ratio of the covalent bonding possibility of chalcogen atoms to that non-chalcogen atoms, was calculated using the following relation:\(^{(5,6)}\)

\[
r = \frac{(60 - x) N_{\text{co}}(\text{Se})}{20 N_{\text{co}}(\text{Ge}) + 20 N_{\text{co}}(\text{As}) + x N_{\text{co}}(\text{Te})}
\]  
(4)

The calculated values of \( r \) for the \( \text{Te}_x \text{Ge}_{2-x} \text{Se}_{(60-x)} \text{As}_{20} \) films are given in Table 2. According to Pauling\(^{(7)}\) the heat of atomization \( \text{H}_s (\text{A-B}) \) at standard temperature and pressure of a binary semiconductor formed atoms A and B is the sum of the heats of formation \( \Delta H \) and the average of the heats of atomization \( H_A \) and \( H_B \) corresponding to the average non-polar bond energy of the two atoms:\(^{(8,9)}\)

\[
\Delta H = \alpha \chi_A + \gamma \chi_B
\]  
(5)

Proportional to the square of the difference between the electro-negativities \( \chi_A \) and \( \chi_B \) of the two atoms:

\[
H_s (\text{A} - \text{B}) = \Delta H + \frac{1}{2} (H_A + H_B)
\]  
(6)

In most cases the heat of formation of chalcogenide glasses is unknown, the heat of formation \( \Delta H \) is about 10% of the heat of atomization and, therefore, can neglected. To extend the idea to ternary and higher order semiconductor compounds, the average heat of atomization is defined for a compound \( \text{A}_2 \text{B}_2 \text{C}_2 \text{D}_2 \) as:\(^{(10,11)}\)

\[
H_s = \frac{\alpha H_A + \beta H_B + \gamma H_C + \lambda H_D}{\alpha + \beta + \gamma + \lambda}
\]  
(7)
Values of $H$ of Ge, As, Se and Te are given in table 2. As shown in table 2, the values of $H$ decrease with increasing Te content. To correlate $H$ with $E_g$ in non-crystalline solids, it is reasonable to use the average coordination number instead of the iso-structure of crystalline semiconductors. It was found that the variation in the theoretical values of the energy gap ($E_{g,th}$) with composition in quaternary alloys can be described by the following simple relation \[^{(12)}\] 

$$E_{g,AB}(Y) = Y E_g(A) + (1-Y) E_g(B)$$ \[(8)\]  

Where, $Y$ is the volume fraction of element. For quaternary alloys:

$$E_{g,n} = a E_g(A) + b E_g(B) + c E_g(C) + d E_g(D)$$ \[(9)\]  

Where $a$, $b$, $c$ and $d$ are the volume fractions of elements $A$, $B$, $C$ and $D$ respectively. $E_g(A)$, $E_g(B)$, $E_g(C)$ and $E_g(D)$ are the corresponding optical gaps. The conversion from a volume fraction to atomic percentage is made using the atomic weights and densities tabulated in table 1 \[^{(11)}\]. The calculations of ($E_{g,n}$) based on the above equation for the $Te_xGe_{20}Se_{(60-x)}As_{20}$ films, are given in table 2, which reveals that the addition of Te lead to change in the considered properties. The bond energies of films were listed in table 3. By increasing the Te content, the average bond strength of the compound decreases and hence $E_g$ will decrease. Fig. 1 shows the x-ray diffraction patterns for $Te_xGe_{20}Se_{(60-x)}As_{20}$ thin films. The absence of diffraction lines in the x-ray patterns indicates that the films have amorphous structures. Transmission spectra, corresponding to amorphous $Te_xGe_{20}Se_{(60-x)}As_{20}$ thin films before and after radiation of 1 and 200 KGY are plotted in figs. 2, [a,b] and 3 shows a clear ultraviolet shift of the interference free region with increasing Te content.

### 3.1 Optical Energy gap

For the optical energy gap in which the minimum of the conduction band and the maximum of the valence band, applying Mott and Davis model, $\alpha(\nu) = B(\nu - E_{opt})$ the absorption edge coefficient $\alpha(\nu)$ is function of photon energy \[^{(13)}\]. $(\alpha\nu)^n$ is plotted for different $n$ versus $(\nu)$. The extrapolations of the lines of $(\alpha\nu)^{1/2}$ gives the optical energy gap. The best line was obtained for the indirect allowed optical band gap for all the studied films Fig 7 the indirect optical band gap ($E_g$), which was evaluated from the linear plots of $(\alpha\nu)^{1/2}$ versus $(\nu)$. The optical absorption coefficient ($\alpha$) for indirect transition was given by ($\alpha$) was given by Fahrenbruch and Bube \[^{(14)}\] 

$$\alpha(\nu) = A (\nu - E_{opt})^n$$ \[(10)\]  

Where $A$ is constant, $h$ is Plank’s constant, $\nu$ is the frequency of the radiation, $E_{opt}$ is the optical energy gap, and $n$, is a number which characterizes the optical absorption processes, $n = 1/2$, 1, 3/2, 2, 3 according to direct and non-direct transition depending on the nature of the electronic transition responsible for the absorption $n=1/2$ for allowed direct transition. $n=3/2$ for the forbidden indirect transition. And $n=2$ refers to indirect allowed transitions. The absorption coefficient for direct transition takes the values from $10^4$ to $10^5$ cm$^{-1}$, while the absorption coefficient for indirect transition takes the values from 10 to $10^3$. According to Urbach rule \[^{(15)}\] the absorption coefficient, $\alpha$, can be calculated as follows:

$$\alpha = \frac{2}{L} \ln \frac{I_0}{I}$$ \[(11)\]  

Where, $I_0$ and $I$ are the intensities of the incident and transmitted light, respectively, $L$ is the thickness of the sample (cm). The present results were found to obey equation (10) with $r=1/2$ for all films. This indicates direct allowed transitions. Values of absorption coefficient were taken between $10^3$ to $10^5$ cm$^{-1}$. Figurers (4.a) and (4.b) are a best fit of $(\alpha\nu)^{1/2}$ versus photon energy $(\nu)$ for $Te_xGe_{20}Se_{(60-x)}As_{20}$ thin films before and after radiation of 1 and 200 KGY. The intercepts of the straight lines with the photon energy axis give the values of the optical band gap. 

The variation in $E_g$ as a function of Te content before and after radiation of 1 and 200 kilo-gray are shown in fig 5. It is clear that $E_g$ decreases with increasing Te content of the investigated films. Fig 6 shows the density of amorphous $Te_xGe_{20}Se_{(60-x)}As_{20}$ and it is clear that density increases with increasing Te content. The possible bond distribution at various compositions using chemically ordered network (CNO) model. This model assumes that a) Atoms combine more favorably with atoms of different kinds than with the same and b) bonds are formed in the sequence of the bond energies. The bond energies $D(A-B)$ for hetero-nuclear bonds have been calculated by using the empirical relation:

$$D(A-B) = [D(A-A).D(B-B)]^{1/2} + 30(\chi_A - \chi_B)^2$$ \[(12)\]
Prepared samples is evaluated from the following equation which represents the so-called stoichiometric composition. This glass is composed of completely cross-linked structural units of GeSe, AsSe and TeSe without any excess “Se” in the system. The effect of gamma radiation which represents the optical behaviour of amorphous systems. This approach explains the behaviour in the terms of the cohesive energy (CE). It allows the determination of the number of possible bonds and their type (heteropolar and homopolar). The authors assumed that:

a) atoms combine more easily with atoms of a different rather than the same type.
b) Bonds are formed in the sequence of decreasing bond energy until all the available valencies of the atoms are saturated.
c) Each constituent atom is coordinated by 8-N atoms, where N is the number of outer shell electrons and this is equivalent to neglecting the dangling bonds and the other valence defects. The energies of various possible bonds in the TeGe_{20}Se_{(60-x)}As_{20} system are given in Table 3. Depending on the bond energy (E), the chemical bond approach could be applied to the present system.

For samples containing “Te” content Ge, As and Se atoms bond to Se atoms to form GeSe, AsSe and TeSe structural unit, respectively. After forming these bonds, there are still “Se” valencies which must be satisfied by formation of Se-Se bond (Se chains) for TeGe_{20}Se_{(60-x)}As_{20} which represents the so-called stoichiometric composition. This glass is composed of completely cross-linked structural units of GeSe, AsSe and TeSe with out any excess “Se” in the system. The effect of gamma radiation with different doses from 0 to 200KGY on the four compositions is shown in table 4. The results indicated that the prepared films were almost stable against radiation. However, there was a slight change in E_{opt} when gamma doses were increased in the different “Te” content.

4. Conclusion

Optical data indicated that the allowed direct gap is responsible for photon absorption in TeGe_{20}Se_{(60-x)}As_{20} thin film. Increasing Te content at the expense of Se atoms decrease the optical gap of the films. The values of heat of atomization, coordination number, number of constrains and cohesive energy for Te_{60-x}Ge_{20}Se_{(60-x)}As_{20} depend on the glass composition. The increase in Te content leads to a decrease with in E_{th} and H_{Na}. Cohesive energy decreases with the increase in Te content. The chemical-bond approach can be applied successfully to interpret the decrease in the optical gap with increasing Te content. It has also been found that the compositions were almost stable against gamma radiation at doses up to 200KGY.

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Table 1.

<table>
<thead>
<tr>
<th>Physical characteristics</th>
<th>Ge</th>
<th>Se</th>
<th>As</th>
<th>Te</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy gap (eV)</td>
<td>0.95</td>
<td>1.95</td>
<td>1.15</td>
<td>0.65</td>
</tr>
<tr>
<td>Density (g/cm$^3$)</td>
<td>5.3</td>
<td>4.79</td>
<td>4.7</td>
<td>6.24</td>
</tr>
<tr>
<td>Coordination no.</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Bond energy (kcal/mol)</td>
<td>37.6</td>
<td>44.02</td>
<td>32.1</td>
<td>33</td>
</tr>
<tr>
<td>Heat of atomization (H$_s$) (kcal/mol)</td>
<td>90</td>
<td>54.17</td>
<td>69</td>
<td>46</td>
</tr>
<tr>
<td>Electro negativity</td>
<td>2.01</td>
<td>2.4</td>
<td>2.18</td>
<td>2.1</td>
</tr>
<tr>
<td>Radius (pm)</td>
<td>122</td>
<td>115</td>
<td>119</td>
<td>140</td>
</tr>
</tbody>
</table>

Table (1) shows values of the optical band gap, density, coordination number, heat of atomization (H$_s$), bond energy and electro negativities of Ge, Se, As and Te respectively which are used for calculations.

<table>
<thead>
<tr>
<th>Composition</th>
<th>N$_{co}$</th>
<th>N$_s$</th>
<th>r</th>
<th>H$_s$ (kcal/mol)</th>
<th>H/N$_{co}$</th>
<th>E$_{g,th}$ (ev)</th>
<th>E$_{g,exp}$ (ev)</th>
<th>d$_{th}$ (g/cm$^3$)</th>
<th>d$_{exp}$ (g/cm$^3$)</th>
<th>CE (ev/atom)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% Ge$<em>{20}$As$</em>{20}$Se$_{60}$</td>
<td>2.6</td>
<td>3.5</td>
<td>0.857</td>
<td>64.302</td>
<td>24.73</td>
<td>1.59</td>
<td>1.63</td>
<td>4.865</td>
<td>4.93</td>
<td>4.43</td>
</tr>
<tr>
<td>10% Te$<em>{10}$Ge$</em>{20}$As$<em>{20}$Se$</em>{50}$</td>
<td>2.6</td>
<td>3.5</td>
<td>0.625</td>
<td>63.485</td>
<td>24.42</td>
<td>1.46</td>
<td>1.61</td>
<td>4.983</td>
<td>5.15</td>
<td>4.34</td>
</tr>
<tr>
<td>15% Te$<em>{15}$Ge$</em>{20}$As$<em>{20}$Se$</em>{45}$</td>
<td>2.6</td>
<td>3.5</td>
<td>0.529</td>
<td>63.076</td>
<td>24.26</td>
<td>1.39</td>
<td>1.60</td>
<td>5.043</td>
<td>5.32</td>
<td>4.29</td>
</tr>
<tr>
<td>20% Te$<em>{20}$Ge$</em>{20}$As$<em>{20}$Se$</em>{40}$</td>
<td>2.6</td>
<td>3.5</td>
<td>0.444</td>
<td>62.668</td>
<td>24.10</td>
<td>1.33</td>
<td>1.59</td>
<td>5.106</td>
<td>5.53</td>
<td>4.24</td>
</tr>
</tbody>
</table>

Table 2.

Table (2) Some physical parameters as function of Te content for Te$_x$Ge$_{20}$Se$_{(46-x)}$As$_{20}$ (where x=0,10,15, at. 20%) Films.
Table 3:

<table>
<thead>
<tr>
<th>Bond</th>
<th>Bond energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ge-Se</td>
<td>49.4</td>
</tr>
<tr>
<td>Se-Se</td>
<td>44.02</td>
</tr>
<tr>
<td>As-Se</td>
<td>41.7</td>
</tr>
<tr>
<td>Se-Te</td>
<td>40.87</td>
</tr>
<tr>
<td>Ge-Ge</td>
<td>37.6</td>
</tr>
<tr>
<td>Ge-As</td>
<td>35.61</td>
</tr>
<tr>
<td>Ge-Te</td>
<td>35.46</td>
</tr>
<tr>
<td>Te-Te</td>
<td>33.1</td>
</tr>
<tr>
<td>As-Te</td>
<td>32.7</td>
</tr>
<tr>
<td>As-As</td>
<td>32.1</td>
</tr>
</tbody>
</table>

Table (3) bond energy of formation of various bonds in Te$_x$Ge$_{20}$Se$_{(60-x)}$As$_{20}$ Films.

Figure (1) X-ray diffraction patterns of the amorphous Te$_x$Ge$_{20}$Se$_{(60-x)}$As$_{20}$ (where x = 0, 10, 15 and 20 at. %) glasses.

Figure (2-a) Transmission spectra of Te$_x$Ge$_{20}$Se$_{(60-x)}$As$_{20}$ (where x = 0, 10, 15 and 20 at. %) as deposited thin film.
**Figure (2-b)** Transmission spectra of $\text{Te}_x\text{Ge}_{20}\text{Se}_{(60-x)}\text{As}_{20}$ (where $x = 0, 10, 15$ and $20$ at. %) irradiated (with gamma rays) thin film.

**Figure (3)** Spectral dependence of the absorption coefficient ($\alpha$) for $\text{Te}_x\text{Ge}_{20}\text{Se}_{(60-x)}\text{As}_{20}$ (where $x = 0, 10, 15$ and $20$ at. %) as deposited thin films.
Figure (4-a) Dependence of \((\alpha h \nu)^2\) on photon energy, \(h\nu\), for the as deposited Te\(_x\)Ge\(_{20}\)Se\(_{(60-x)}\)As\(_{20}\) (where \(x = 0, 10, 15\) and 20 at. %) thin films, from which the optical band gap, \(E_g\), is estimated (Tauc extrapolation).

Figure (4-b) Dependence of \((\alpha h \nu)^2\) on photon energy, \(h\nu\), for the gamma irradiated Te\(_x\)Ge\(_{20}\)Se\(_{(60-x)}\)As\(_{20}\) (where \(x = 0, 10, 15\) and 20 at. %) thin films, from which the optical band gap, \(E_{gr}\), is estimated (Tauc extrapolation).
Figure (5) Variation in the optical band gap, $E_g$, as a function of Te content for Te$_x$Ge$_{20}$Se$_{(60-x)}$As$_{20}$ (where $x = 0, 10, 15$ and $20$ at. %) thin films.

Figure (6) Compositional dependence of the density for Te$_x$Ge$_{20}$Se$_{(60-x)}$As$_{20}$ (where $x = 0, 10, 15$ and $20$ at. %) glasses.
Figure (7) Cohesive energy versus Tellurium\% for Te\(_x\)Ge\(_{20}\)Se\(_{(60-x)}\)As\(_{20}\) (where x = 0, 10, 15 and 20 at. \%) glasses.
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بدأ المعالجة الإشعاعية لبعض المنتجات منذ عام 1950م. وظهرت نموا سريعا على مستوى العالم وتزايدت بشكل ملحوظ ويتضح ذلك من خلال التطبيقات المتعددة التي دخلت هذه الصناعة يوما بعد يوم ولكن تلك هذه العمليات بشكل طبقي لمعايير الجودة لابد من توافر مقياس للجرعة الإشعاعية (الداولمتر) مناسبة للتطبيق المختلفة. ومن هذه التطبيقات معالجة الأغذية، عمليات البسترة، معالجة المياه، وعمليات تعقيم المنتجات الطبية، معالجة المياه، وعمليات تعقيم المنتجات الطبية.

لقد تم التوصل إلى العديد من مقياسات الجرعة الإشعاعية والتي تستخدم الآن بشكل وفير، وتتم أيضا تحضير أنواع عديدة من SUCH الصلبة والصلبة على هيئة أفلام بلاستيكية ولكن لكي تواكب التوسع في عمليات المعالجة الإشعاعية لابد من محاولة البحث لتحسين خواص المقياس الحالي، وايضا لاستخدام مقياس جذيد بمواصفات أكثر ملاءمة لمقياس المعالجة التي سيتم رسمها في مجالها. وهذه الدراسة سوف تتضمن تحضير بعض الأفلام البلاستيكية لمواد بوليمرية مصبوبة واستخدامها في مجال قياس الجرعات الإشعاعية ثم يتم تصنيف هذه المواد حسب المدى الإشعاعي لها ومجال تطبيقها ونسب الخطأ فيها.

تتكون الرسالة من ثلاثة أبواب رئيسية مضافا إليها ملخصين باللغتين العربية و الإنجليزية و المراجع العلمية المتعلقة بموضوع الرسالة:

الباب الأول (المقدمة):
تم فيه عرض الدراسات والبحوث السابقة المتعلقة بموضوع الرسالة وكذا تم إعطاء نبذة مختصرة عن السبع المعدنية وأنواعها وهناك نوعين من السبطاك سبائك حديدية وسبائك لاحديدية. إذا كانت السبائك اللا حديدية تحتوي على عنصر شالكوجنيد واحد أو أكثر مثل الكبريت والسيلينيوم والتريل[j]وم بالإحتمال مع
الملخص العربي

مواد أكثر إيجابية كهربية مثل الزرنيخ والألومنيوم فإنها تسمى سبائك شلالكوجينية زجاجية، أما السبائك الحديدية تحتوي على عنصر الحديد وعنصر التيتانيوم بنسبة عالية ولذلك سميت بسبائك حديد التيتانيوم.

وتحتوي على نسب قليلة من عناصر أخرى مثل الألومينيوم والسيلانيك.

الباب الثاني (التجارب والقياسات العملية):

يتضمن هذا الجزء التجارب والقياسات العملية التي استخدمت لتحضير هذه السبائك ودراسة خواصهما. لقد تم تحضير سبائك الشلالكوجينيد من عنصر الزرنيخ والألومنيوم والتيتانيوم والسيلانيك بضوء النقاوة 99.99% إن هذه السبائك تتفاعل مع الأكسجين في درجات الحرارة المرتفعة ولذلك تم تصنيعها في أنابيب سيليكا نظيفة ومغفوة من الهواء، وتم غسل هذه الأنابيب بالماء المقطر ثم تجفيفها في فرن درجة حرارته حوالي 1011 درجة مئوية. ولقد تم إدخال المواد بعد وزنها في أنابيب السيليكا النظيفة حتى حوالي 10^{-4} ضغط جوي وتم غلقها. ولقد تم وضع الأنابيب المغلقة داخل الفرن الذي يتم رفع درجة حرارته إلى 900 درجة مئوية في خلال ساعة ثم تثبيتها لمدة 10 ساعات. ولقد كان من الضروري رج المواد المكونة داخل الأنابيب في الفرن لتحقيق تجانس التركيب، بعد التصنيع تم تبريد الأنابيب تبريد فجائي في ماء مثلث وتم الحصول على السبائك الناتجة بالتبخير السريع. وتم إخراج المواد من الأنابيب والاستفادة بها في مجالات أخرى، وتم تحضير الشرائح الرقيقة من المركبات بطريقة التبخير الحراري تحت ضغط 10^{-4} ضغط جوي بسمك ثابت 100 نانومتر.

أما عن النوع الثاني من السبائك وهو السبائك الحديدية فقد تم تحضيرها عن طريق احتزال خامات الزوتيك والألمنيوم في فرن درجة حرارته باستخدام بدرة الألومينيوم في وجود الفلورسبيت وترتر الصوديوم كمواد للتفاعل والماغنيسيوم كمواد للطاقة ليعمل على رفع درجة الحرارة إلى درجة المطلوبة وتشتهر هذه تفاعل لحظي، وبعد هذه تكون طبقتين، طبقة سفلية ثقلة وهي المعدن أما الطلقة العلوية الخفيفة فهي
الملخص العربي

الخليط، وتم أخذ كتلة من المعين المتكون ويتم طحنها ثم يتم تدوبها في حمض هيدروكلوروิก مركز ثم نخفف بماء مقطط، ثم يتم تحضير فيلم بوليمر باستخدام بولي فينيل الكحولي (PVA) ثم يتم إجراء عمليات التشبع المختلفة وقياس الأشعة الضوئية للأفلام المشعة باستخدام جهاز طيفي الأشعة فوق البنفسجية (UV spectrophotometer) وكذلك يتضمن هذا الجزء وصف التجربة العملية لدراسة تأثير بعض العوامل المختلفة على قياس الجرعات الإشعاعية (مثل تأثير الرطوبة النسبية أثناء وبعد عمليات تشبع الأفلام البلاستيكيات وكذلك ظروف التخزين المختلفة على الأفلام قبل وبعد التشبع).

ولقد تم دراسة الخواص التركيبية لكل من السبيكتين، وكذلك قياس التركيب الحراري التفاضلي لكل منهما على هيئة مسحوق، وأيضاً تعيين الكثافة.

الباب الثالث (النتائج والمناقشة):

و فيه يتم عرض النتائج ومناقشتها و ينقسم إلى جزئين وهما:

الجزء الأول:

في هذا الجزء يتضمن عرض النتائج الخاصة بسبيكة الفيروتيتانيوم، حيث أوضحت النتائج أن الخواص التركيبية للمركب من النوع الأمورفي وقد استخدم التحليل الطيفي بالأشعة السينية لمعرفة نسبة كل عنصر في سبيكة الفيروتيتانيوم والنسب هي 39.42, 6.14% لكل من الألومنيوم والسيلكون والتيتانيوم والهيدرو. تم تحضير أفلام بلاستيكة من سبيكة الفيروتيتانيوم بتركيزات مختلفة، هذا الفيلم البلاستيكي ذات اللون الأصفر، تم قياس اختصاص الفيلم البلاستيكي عند طول موجي 525 نانومتر قبل التشبع. وبعد التشبع تم القياس عند نفس الطول الموجي وجد أن الفيلم يحدث له اضمام في اللون الأصفر، وتم دراسة ثباتية الأفلام في ظروف التخزين المختلفة ووجد أن لها ثباتية عالية خلال فترة التخزين. وكذلك تم دراسة تأثير الرطوبة النسبية أثناء التشبع ووجد أن هذه الأفلام لاتأثر بالرطوبة.
الملخص العربي

النسبة في المدى من (0-100%)، ولقد استخدمت قيم الامتصاص في تعيين معامل الامتصاص والذّي استخدم في تعيبين الفجوة الضوئية وكذلك من خلال قيمه تم تعيبين نوع الإنتقال. حيث إن نوع النقل الإلكتروني المسئول عن الخواص الضوئية هو الإنتقال الغير مباشر المسطح. ولقد وجد أن قيم فجوة الطاقة الضوئية، Eν تتنافى بزيادة الجرعة الإشعاعية. وقد تم تعيين الكثافة لسبيكة الفيروتيتانيوم لثلاثة مركبات تحتوي علي نسب ثابتة من مختلفة من التيتانيوم والحديد ونسب ثابتة من السيليكون والألومينيوم وقد أن الكثافة تقل بزيادة نسب التيتانيوم علي حساب نسب الحديد.

الجزء الثاني:

هذا الجزء من النتائج خاص بالنوع الثاني من السبائك وهو سبائك الشالكوجينيد. تعتاد فكرة التحضير على زيادة نسبة عنصر السيلينيوم علي حساب نسبة التيليريوم. تم تداش الخواص السكايية، TG للمركب الشبه الموصل الأولموري. وكذلك تم تعيين المركب TM باستخدام التركيب الحراري التفاضلي للمركب علي هيئة مسحوق. لقد تم تعيبين كثافة الزجاجيات المحضرة من المركب Ge20As20Se60(TeX) (حيث (X=0%) إلى (X=20%)) 4.93 (gm/cm3) للمركب Ge20As20Se60(Te0) حيث (X=0%) 5.53 (gm/cm3) للمركب Ge20As20Se60(Te20) (حيث (X=20%)). ولقد تميزت الخواص الضوئية للمركب Ge20As20Se60(TeX) بقياسات الامتصاص لطول موجي من 200 إلي 1100 نانوميتر. إن نوع الإنتقال الإلكتروني المسئول عن الخواص الضوئية هو الإنتقال الغير المباشر المسطح وفجوة الطاقة الإبداعية في المجال إلي الكترون فولت. ولقد وجد أن قيم فجوة الطاقة "ν Ge20As20Se60(TeX) تتنافى بزيادة التيتانيوم. لقد تم تسجيل طيف الإمتصاص للمركب في منطقة لإضاءة الفوق البنفسجية. ولقد وجد أن بعض العوامل مهم دراستها مثل الرقم الإحصائي (Nc0) وقد لوحظ عدد المحددات، N0 وأخيرا فإن دراسة تأثير إضاءة جاما على شرائح"
ان التشبع ليس له تأثير واضح حتى الجرعة 200Kgy والتي اوضحت قيمة ثابتة للإمتصاص عند إضافة التيلوريوم.
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