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Gamma Radiation Induced Effects in TeO_2 Thin Films

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Gamma radiation induced effects on electrical and optical properties of thin films of tellurium dioxide (TeO_2), a wide band gap semiconductor material, of different thicknesses prepared by thermal evaporation method have been studied in detail. The current-voltage characteristics for the thin films before and after gamma irradiation were analysed to obtain normalised current versus gamma dose plots at different applied voltages. The plots obtained clearly show that the normalised current increases almost linearly with the radiation dose up to certain limit and this limit is found to be dependent on thickness of the thin film. Beyond this limit the current is found to decrease. For gamma sources emitting higher gamma energy, this linear behaviour extends to higher radiation doses. The optical characterization of the as-deposited thin films as well as gamma irradiated thin films clearly shows that the optical band gap decreases with increase in the gamma radiation dose up to a certain limit. However, the optical band gap has been found to increase beyond this limit. The observed changes in electrical and optical properties clearly indicate the possibility of using TeO_2 thin film as a gamma radiation dosimeter.

Keywords: Tellurium dioxide, Thin films, Gamma radiation, Dosimetry.

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1. INTRODUCTION

Ionizing radiations such as X-rays, gamma-rays, beta particles, alpha particles, fission fragments, etc. are present in several fields that include industry, medicine, military, particle accelerator based research, nuclear power plants, etc. It is very much essential to ensure that the radiation levels in the environment surrounding these fields are within the permissible limit which can be determined by proper dosimeters. There are many types of ionizing radiation dosimeters, active and passive, that include electronic, quartz fibre electroscope, film badge, thermo luminescent, optical stimulated luminescent, nuclear emulsion, etc. It is well known fact that the ionizing radiation produces changes in the physical properties (such as optical, electrical, structural, etc.) of the material. In particular, devices made up of metal oxides and mixtures of two or more metal oxides have been observed to be highly sensitive to gamma irradiation.

Several studies have been made on thin films made up of metal oxides and their mixtures for their use in radiation dosimetry, sensing, memory cells [1-6]. The observed changes in structural, electrical, optical and other physical properties of thin films of metal oxides due to the exposure to ionizing radiations clearly revealed that thin films of metal oxides can be used in radiation dosimetry. Naturally, an in-depth understanding of the changes in the physical properties of metal oxide thin films when they are exposed to ionizing radiations is necessary in order to design and develop the thin film based gamma radiation dosimeters. Thins films of tellurium dioxide (TeO_2) which is a versatile wide band gap semiconductor material [7] seems to be one of the promising materials.

TeO_2 is used in wide range of applications such as deflectors [8], modulators, optical storage [9], laser devices [10], etc. Arshak and Korostynska [11] have reported changes in the optical properties of thin films of NiO and TeO_2 under the influence of gamma rays. The observed changes are due to the effect of gamma rays on the concentration of defects which are already present in the materials and play a very important role in determining the properties of the materials. Atanassova et al. [12] have studied the changes in thin films of TaO_2 due to the gamma irradiation and observed the degradation in the characteristics of these films. The changes are found to be dependent strongly on the thickness of the film. The changes are observed to be different when the mixtures of two or more materials have been prepared [13-15]. Very recently, Riyadh et al. reported the effects of gamma radiation on the absorption spectra and optical energy gap of SeO_2 thin films [16]. The present work reports our studies on the effect of gamma radiation on electrical and optical properties of tellurium dioxide (TeO_2) thin films prepared by using thermal evaporation method. These studies have been made for different values of thickness of thin films and different energies of gamma radiation.

2. EXPERIMENTAL DETAILS

Thin film samples of the TeO_2 having coplanar structure [17] were prepared by thermal evaporation method. Powdered sample of TeO_2 with 99.9995 % purity purchased from Sigma Aldrich Company was used to prepare the thin films of thicknesses in the range 180-800 nm. Thickness of thin film samples was controlled by varying different parameters like distance between source and sample, amount of powdered sample etc. Glass slides of 1 mm thickness were used as substrates that are optically pure and with flat surfaces. Molybdenum boat was used to hold powdered sample. For electrical characterization of thin films, metal contacts have been made using aluminium wire. A tungsten filament in the form of a coil was used for the evaporation of aluminium wire. On the top of these aluminium contacts, thin films of TeO_2 of different thicknesses were deposited. A vacuum of the order of 10^{-5} mbar was maintained inside the chamber during the growth of the thin films by thermal evaporation from the

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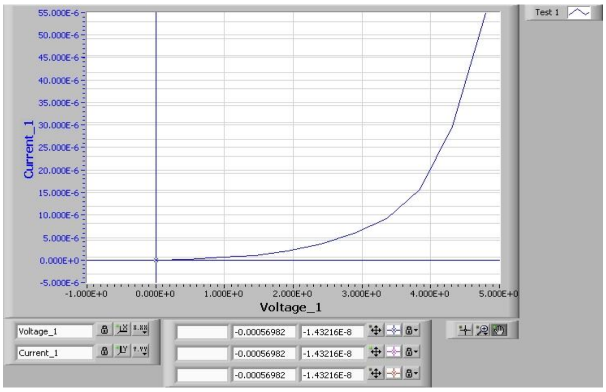
boat. For electrical measurements, thicker films were taken in order to reduce resistance of thin films. To study the gamma radiation induced effects in optical properties, TeO_2 thin films of small thickness were prepared as thicker films were not suitable due to specular reflection. Offline measurements of thicknesses of thin films were carried out using Surface Profilometer. Gamma radiation exposure to thin films was done at room temperature using different gamma sources i.e. ^{137}Cs that emits 662 keV gamma and ^{60}Co that emits 1173 and 1332 keV gammas with proper lead bricks shielding arrangement. Current-Voltage characteristics were measured with a standard four-probe method at room temperature. Transmittance measurements have been carried out for different samples using UV-Visible transmittance measurement set-up. This gives the data values of transmittance at different wavelengths of incident light in the range of 300-900 nm.

3. RESULTS AND DISCUSSION

To study the changes in electrical properties of thin films upon exposure to gamma radiation, thin films of different thicknesses and different gamma radiation sources have been used. Typical current-voltage plot for a thin film of thickness 280 nm before gamma irradiation with ^{137}Cs is shown in Fig. 1. Similar plots obtained before irradiation and after irradiation with different dose levels are presented in Fig. 2 which shows that the shape of the plot depends on the gamma dose. The normalized current has been calculated at different applied voltages and its variation has been seen with change in gamma dose. Fig. 3 shows the variation of normalized current with gamma dose at an applied voltage of 3 Volts. Clearly, normalized current increases fairly linearly with the gamma dose up to the value of 7 Gy. The normalized current has, however, been observed to decrease beyond this dose.



Voltage_1
Current_1

-0.00056982 -1.43216E-8
-0.00056982 -1.43216E-8
-0.00056982 -1.43216E-8

Fig. 1 – Typical I-V plot for TeO_2 thin film of thickness 280 nm before gamma irradiation

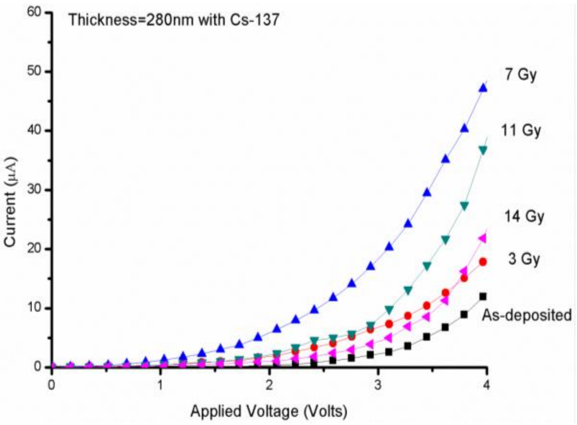


Fig. 2 – I-V plots for TeO_2 thin film of thickness 280 nm before and after gamma irradiation with ^{137}Cs

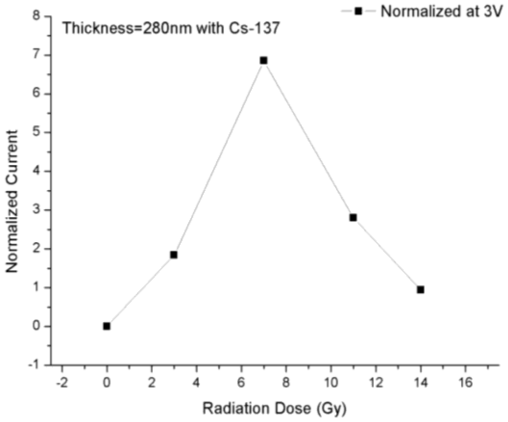


Fig. 3 – Variation of normalized current with dose for an applied voltage of 3 V for ^{137}Cs

Similarly, current-voltage characteristics for the TeO_2 thin films of thickness 280 nm before and after irradiation using ^{60}Co source are shown in Fig. 4. The corresponding variation of normalized current with gamma dose at an applied voltage of 3 Volts is shown in Figure 5. In this case, normalized current increases quite linearly with the dose up to the value of 3 Gy. This shows the effect of gamma energy in determining the upper limit of dose up to which normalized current increases. TeO_2 thin films of other thicknesses were also exposed to gamma radiation source ^{60}Co which have shown that the critical value of radiation dose up to which normalized current varies linearly depends on thickness of films. Value of this dose is observed to be higher for the thicker films. These changes are strongly believed to be because of the healing effect [18]. When thin films are prepared, some intrinsic defects are always present. The interaction of gamma radiation induces defects during its passage through the thin film which results in change in the order at the micro struc- tural level of the film. For small gamma doses, these thin films possess fine uniform grains with no big pores. Also, there will be some intrinsic defects due to the recombination which reduces the resistivity of thin film which results in the increase of the current. These results are supported by studies on change in optical band gap with gamma radiation dose. Fig. 6 shows the variation of optical band gap with gamma dose for a thickness of 180 nm. The optical band gap for the as-deposited thin film has is found to be about 3.8 eV, which is reasonably close the value reported in the literature [15]. At 15 Gy, the band gap drops to 3.5 eV. Arshak and Korostynska [14] reported the decrease in the optical band gap from 3.75 eV for as-deposited TeO_2 thin films to 3.45 eV for the gamma irradiated TeO_2 thin films for a dose of 36 Gy. The results obtained have also shown that the rate of decrease of the optical band gap with dose is weakly dependent on the film thickness. The optical band gap has been found to increase with further increase in the gamma radiation dose beyond 15 Gy.

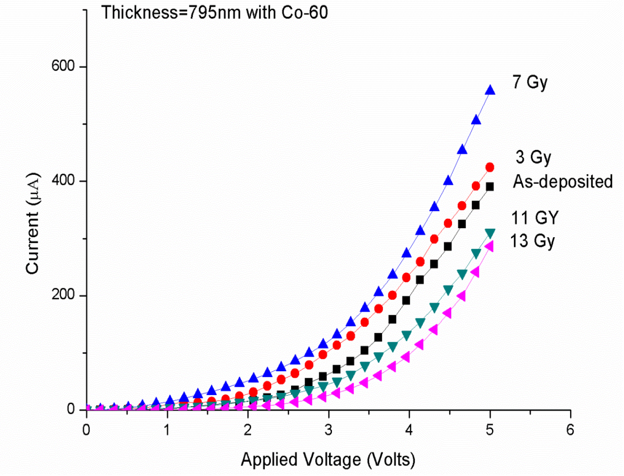


Fig. 4 – I-V plots for TeO_2 thin film of thickness 280 nm before and after gamma irradiation with ^{60}Co

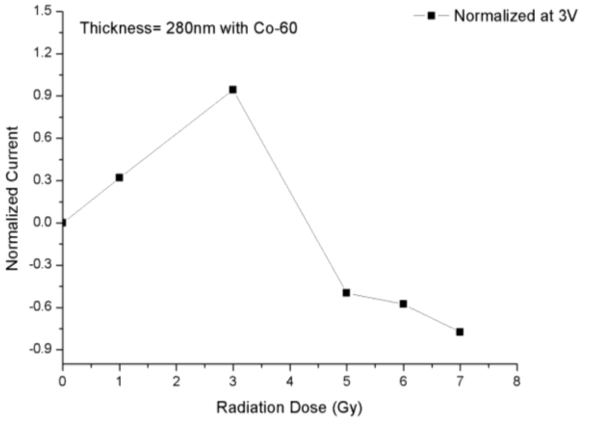


Fig. 5 – Variation of normalized current with dose for an applied voltage of 3 V for ^{60}Co

4. SUMMARY

The electrical characterization of thermally evaporated TeO_2 thin films have shown that the current increases near linearly with the gamma dose up to a certain value and that the current decreases for the gamma doses above this value. The change in the current with the gamma dose clearly indicates that the TeO_2 thin films can be used in the gamma dosimetry and sensing. The gamma dose up to which the thin film can be used in dosimetry is found to depend strongly on the thickness. The increase in the current due to gamma irradiation is due to the healing effect and also due to the lowering of the optical band gap. The optical absorption studies have clearly shown the decrease of optical band gap with the increase in gamma dose up to a certain dose and also shown its increase with further increase in the gamma dose.

For the first time, we have established that the linear variation with gamma dose also depends on the gamma energy used for irradiation of the thin films. For gamma sources emitting higher gamma energy, this linear behaviour extends to higher radiation doses. Further work is in progress that includes studies on the changes in electrical and optical properties due to mixture of metal oxides and on development dosimeters with high sensitivities.

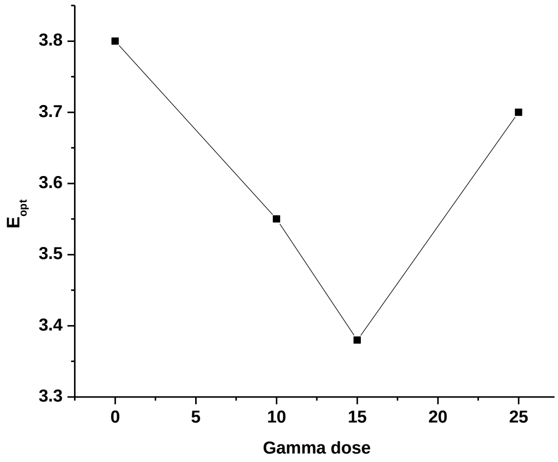


Fig. 6 – Variation of optical band gap with gamma dose using ^{137}Co for TeO_2 thin film of thickness 180 nm

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