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Effect of 130 MeV Au ion irradiation on CO_2 gas sensing properties of In_2Te_3 thin films

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ABSTRACT

CO and CO_2 are harmful pollutants. The main objective of monitoring CO and CO_2 is to prevent intoxication. Though these pollutants were monitored by metal oxide gas sensors, it operated at high temperature. Selectivity of metal oxides over a wide range of gas is limited. Additional contribution of sensor heaters and its associated electronics may induce poor stability of a sensor. In addition to that room temperature gas sensor is always essential to monitor the CO_2 pollutant. In the present work, we have prepared In_2Te_3 thin films from In/Te bilayer by SHI (Au 130 MeV) irradiation. Structural, surface morphology, elemental composition and gas sensing behavior of the as grown and irradiated samples were analyzed by XRD, SEM, RBS and I–V analysis. The observed results were discussed in connection with the SHI induced modification at the interface. As fluence increases, the crystallanity also found to increase. In addition to that dewetting structure is observed at higher fluence. The films prepared by SHI route shows better gas sensing behavior of In_2Te_3 thin film than from conventional method of synthesis.

1. Introduction

Thin film sensors are used as toxic gas monitor [1], humidity sensor [2], touch sensitive switches [3], and infrared detectors [4]. Gas sensors put forward to monitor and control the green house gases like CO_2, CO, nowadays which are essential to control the air pollution [5]. Synthesis of new materials in different structural forms will lead to the development of miniaturized devices. At present, material engineering of metal oxide films is well established. Though these materials are used in practice, the selectivity of a sensing material for different gas is a major issue in metal oxides and its composites.

Three major factors affecting the performance of the gas sensors such as sensitivity, selectivity and response time. It was shown that deposition parameters, post deposition treatments and doping during synthesis really influence the properties of metal oxides, which are important for gas sensor applications. The surface modification by noble metals improves the sensitivity and reduces the response and recovery time. Numerous works have been carried out to sense CO_2 gas using SnO and SnO_2 thin films, whereas high temperature is always necessary for its operation [6–8]. Additional circuits for onsite heater and its associated electronics makes the gas sensor fabrication tedious. Moreover malfunction/failure of heater circuit also affects the performance of the gas sensor. We are in a situation to meet out these challenges and a new material is in need, which works at room temperature.

For sensing applications, the surface and interface interactions between the test molecules and the sensing material are important. The test molecule at the surface of the sensor induces a change in the electrical resistance. Swift heavy ion irradiation, in which an energetic ion beam is allowed to pass through a material, is a very effective technique to induce changes in microstructure and electronic energy levels, and has been used to tailor properties of various metallic, semiconducting, and insulating thin films. Not much works have been carried out by modifying the surface structure and crystallization parameters via ion beam irradiation toward the gas sensor application. Effect of SHI (Swift Heavy Ion) 75 MeV Ni ion irradiation on structure, optical, and gas sensing properties of SnO_2 thin films were studied by Rani et al., but the sensing properties were investigated for ammonia as a test gas [9]. Singh et al. studied the effect of oxygen ion (100 MeV O) irradiation on ethanol sensing response of nanostructures of ZnO and SnO_2 [10]. Sedghi et al. investigated the sonochemically prepared SnO_2 quantum dots as a selective and low temperature CO gas sensor [11]. Electron beam irradiation does not affect the chemical composition of the semiconductor, but produces only structural defects. Electron beam irradiation does not affect the chemical composition of the semiconductor, but produces only structural defects [12].

CO and CO_2 are harmful pollutants. The main objective of monitoring CO and CO_2 is to prevent intoxication. This necessitates a need for development of effective and sensitive pollution monitors. A new semiconductor material for CO_2 gas sensing family (i.e.

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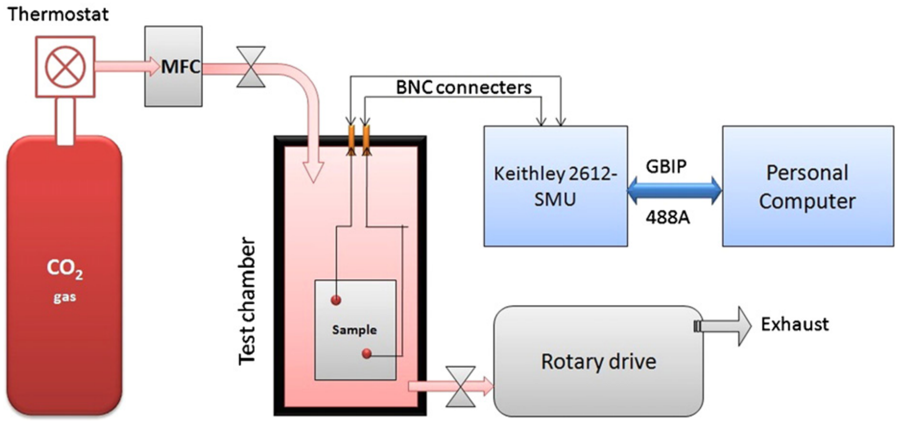

Fig. 1. Schematic diagram of the experimental set up of CO_2 gas sensor.

In_2Te_3) has been introduced by Desai et al. [13]. He demonstrated the room temperature CO_2 gas sensor for wide range of CO_2 gas concentration. With increase in the concentration, the sensitivity of the sensor is found to increase. The sensitivity of the gas sensor was found to dependent upon the thickness of the film. The In_2Te_3 films deposited at the substrate temperature of 473 K, having thickness of 150 nm showed the maximum sensitivity to CO_2 gas. In this present work, an attempt has been made to increase the sensitivity of In_2Te_3 thin film by SHI irradiation.

2. Experimental

A maiden attempt has been made to prepare In_2Te_3 semiconductors, a material of interest for gas sensing behavior for specific gas (CO_2), prepared by sequential thermal evaporation followed by ion beam irradiation. When a semiconductor thin film is exposed to particular gas, the resistance of the material differs, called as Chemiresistive gas sensor. The variation in resistance may be due to the chemical and electronic interaction between the gas and the material. Indigenously developed gas sensor measuring unit with Keithley 2612 Source-Measure Unit (SMU) is used to monitor the electrical conduction of the In_2Te_3 thin film under test gas. The prepared In/Te thin films of thickness 600 nm were irradiated using Au (130 MeV) ion with different fluence (1×10^{12}, 3×10^{12}, 1×10^{13}, and 3×10^{13} ions/cm^2) in order to study SHI irradiation induced modification over the electrical conduction properties. We found that the single-phase In_2Te_3 is achieved by Au (130 MeV) with 1×10^{13} and 3×10^{13} ions/cm^2. Schematic diagram of the experimental set up of CO_2 gas sensor is shown in Fig. 1. Electrical conduction of the pristine and irradiated samples was measured in a dark chamber in order to avoid photo-induced conduction during experiment. Silver electrodes were coated on In/Te thin films which are irradiated by (130 MeV) Au ion irradiation of different fluence. The electrical connections were made with fine copper wires attached to the electrodes by silver paste. All electrical connections were made by Bayonet Neill–Concelman (BNC) cables through leak proof chamber. Resistance variation of the gas sensor is monitored by Keithley 2612 SMU.

3. Results and discussion

3.1. Structural analysis

XRD pattern of pristine and irradiated In/Te samples at different fluence (1×10^{12}, 3×10^{12}, 1×10^{13}, and 3×10^{13} ions/cm^2) are shown in Fig. 2. Pristine sample shows the crystallographic peaks correspond to the elements In and Te. No compound formation is achieved in the case of pristine sample. The sample irradiated with the fluence of 1×10^{12} ions/cm^2 shows the decrease in intensity of the elemental peaks, which implies that the sample slowly leads to form nearly amorphous phase. When fluence increases to 3×10^{12} ions/cm^2, the new peaks are evident in the XRD spectra which corresponds to In_2Te_3 phase at $2\theta = 24.94°$, 41.39° and 49.0° along with the elemental peaks (Te (1 0 0), Te (1 0 1) and In (1 0 1)) with weak intensity. When the films are irradiated with Au 130 MeV ion of fluence 1×10^{13} ions/cm^2, the bilayer mixing starts and leads to the formation of In_2Te_3 phase along with trace amount of Te phase. Further, the sample irradiated with the fluence of 3×10^{13} ions/cm^2 shows the increase in intensity of In_2Te_3 phase, which implies that the improvement in crystallanity of In_2Te_3 phase. It implies that the fluence of 3×10^{13} ions/cm^2 is required to synthesis single-phase In_2Te_3 from In/Te bilayer by 130 MeV Au ion irradiation. In the present case also, the mixing in In/Te is a consequence of inter-diffusion during the transient molten state and form the In_2Te_3 compound. Thermal spikes are responsible for inter mixing in In/Te bilayer [14]. From XRD pattern, the grain size of the different samples was measured using Scherrer formula. Average Grain size for the sample irradiated with 1×10^{12}, 3×10^{12}, 1×10^{13} and 3×10^{13} is found to be 24.82 nm, 24.17 nm, 21.88 nm and 20.2 nm respectively. It is observed that the grain size decreases

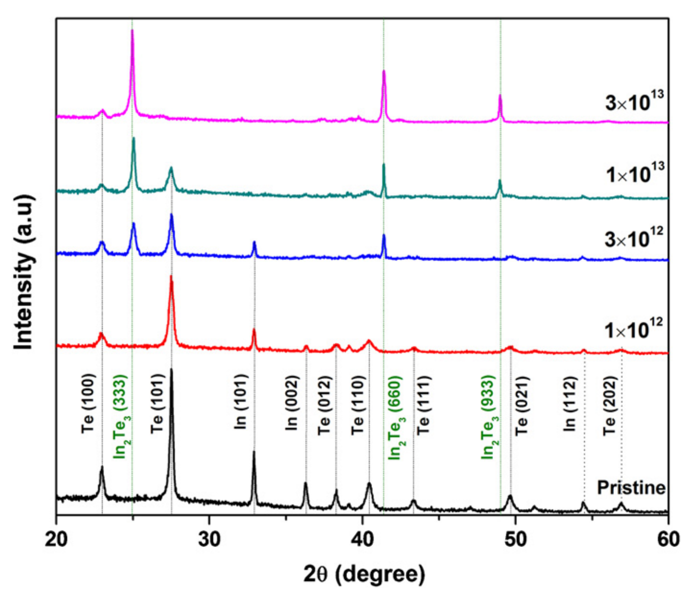

Fig. 2. XRD pattern of Pristine and irradiated In/Te thin films.