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SYNTHESIS AND CHARACTERIZATION OF SPRAYED ZnO, Fe_2O_3, AND Fe_2O_3/ZnO THIN FILMS

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Abstract:

Highly transparent ZnO, Fe_2O_3, and Fe_2O_3/ZnO thin films are successfully deposited by using simple chemical spray pyrolysis technique. The structural and optical properties of these thin films are studied by using X-ray diffraction and UV-Visible spectroscopy. X-ray diffraction pattern shows all the peaks are correspond to hexagonal crystal structure of ZnO, Fe_2O_3 and Fe_2O_3/ZnO with highest peak intensity corresponds to (002) and (104) crystal plane respectively. The optical energy gap, E_g= 2.11 eV, 3.3 eV, and 2.15 eV are deduced for Fe_2O_3, ZnO and Fe_2O_3/ ZnO thin films respectively. These films are further useful for photocatalytic degradation of various organic and inorganic compounds.

Keywords: Spray Pyrolysis; Zinc oxide; Ferric oxide; Structural; Optical

Introduction:

The field of thin films has become evergreen in last year's, due to the technical values and scientific curiosity in the properties, until sufficient technology development has not been made to give reasonable scientific confidence to thin films research. Thin films study includes the relationship between the structure of solids and their physical properties. The thin film study also includes the some practical applications such as optical, electrical and magnetic information storage devices. Thickness of the thin film is usually expressed in terms of angstrom units (A°). Thin films are formed by depositing material onto a clean supporting substrate to build up film thickness, rather than by thinning down bulk material.

To study the applications like sensors, electrochemical cells, and photosensitive coatings, which requires material is to be in the nanocrystalline form to enhance their properties. Nanocrystalline materials can consists of large surface area, enhanced diffusivity, reduced density, higher electrical resistivity, increased strength/hardness, high thermal expansion coefficient, lower thermal conductivity and better soft properties in comparison with conventional coarse-grained materials. For producing the nanomaterials, there are two distinct ways. The first way is to create a bulk material and then breaks it into smaller pieces using mechanical, chemical or other form of energy. An opposite approach is to amalgamate the material from atomic or molecular species via chemical reactions. Many researcher and manufacturers are capacity to control the particle size, shape, particle composition and degree of particle agglomeration. There are many novels as well as usual chemical routes to synthesis (bulk/thin films) allow materials towards the nanocrystalline form. The properties of thin films depend on the method of deposition techniques.

Researchers have used large number of methods for deposition of the ZnO, Fe_2O_3, and multilayered Fe_2O_3/ZnO thin films viz. sol-gel method [1–3], chemical vapor deposition method [4-5], evaporation method [6], sputtering method [7–9], pulsed laser deposition method [10], electro- deposition method [11] and spray pyrolysis method [12-13]. Reproducibly uniform, adherent and pinhole free undoped and doped ZnO thin films have been prepared by spray pyrolysis technique. Lare et al. [14] have fabricated ZnO thin films by spray pyrolysis method and it is used as buffer layer inorganic solar cells. Jia et al. had grown ZnO nano-structure using spray pyrolysis method, he conclude that uniformly distributed ZnO nanorods with diameter 80 nm-120 nm and several micrometers long have been successfully grown at low temperatures on different substrates [15]. Chu et al. [16] had prepared ZnO thin films by spray pyrolysis method and studied combined effects on the structural and electrical properties of ZnO films and he also reported the lowest resistivity about 6×10^{-3}cm. Wu et al. [17] have formed ZnO films on glass substrates by controllable spray pyrolysis method using the precursor solution of zinc nitrate, ammonium citrate, tribasic and sodium hydroxide at 50°C. Ouerfelli et al. [18] have reported synthesis of ZnO thin films by spray pyrolysis method, he studied annealing effect on the conductivity of the material in vacuum and in air atmosphere. Lai et al. [19] reported dye-sensitized solar cells based on ZnO thin films grown by spray pyrolysis method. Fe_2O_3 is one of the most significant transition metal oxides with a bandgap of 2.2 eV.

It is widely used in various applications due to its good intrinsic physical and chemical properties, such as its low cost, stability under ambient conditions, and environmentally friendly properties. [20] Due to these properties, Fe_2O_3 nanostructures can have wide applications in many fields including magnetic recording materials, catalysis, optical devices, gas sensors, photochemical degradation and pigments. [21] Qing Wei et al. were reported that, the different morphologies of α − Fe_2O_3 films including particles, porous, granular and nanosheets , which can be synthesized by directly oxidizing the as-deposited Fe films in air ,also the effect of the heating temperature ,duration of time and rate of heating were reported by adjusting the rapidly oxidation condition. [22].

Material and Methods:

For preparation of ZnO, Fe_2O_3, and Fe_2O_3/ ZnO thin films by spray pyrolysis method. In a typical synthesis, 100 ml of 0.1 M zinc acetate used as solution and 50 ml solution of ferric chloride ($FeCl_3$) as a another precursor solution was used for deposition of pure ZnO thin films, pure Fe_2O_3, layered Fe_2O_3/ZnO, 100 ml of 0.1 M Zinc acetate. The pure ZnO, pure Fe_2O_3, and Fe_2O_3/ ZnO thin films were deposited on to the preheated substrate using simple and cost effective chemical spray pyrolysis technique.100ml of 0.1 M zinc acetate, 50 ml solution of ferric chloride (Fe_2Cl_3, H_2O) was sprayed onto preheated substrates at 450℃ & 400℃ respectively. The other parameters such as spray rate (5 ml/min), and nozzle to substrate distance (32 cm) were kept constant during all experiments in order to get better structural and optical properties of the deposited thin films. The structural characterization of deposited ZnO, Fe_2O_3, and Fe_2O_3/ZnO thin films was carried out, by analyzing the X-ray diffraction patterns. Absorption spectra were recorded at room temperature using a UV-Visible spectrophotometer.

Results and discussion:

1. X-ray diffraction studies

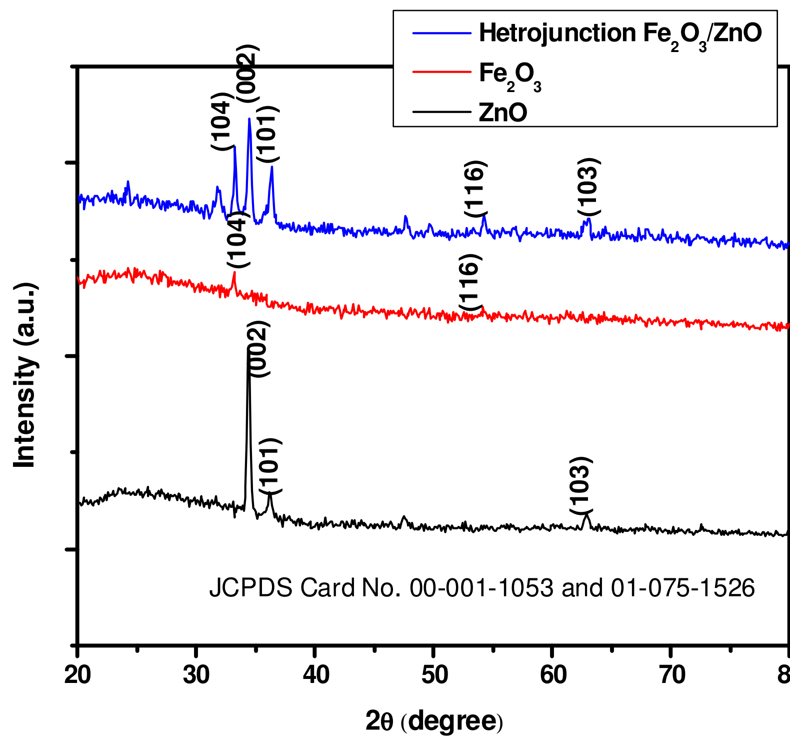

Figure 1: XRD pattern of ZnO, Fe_2O_3, and multilayered Fe_2O_3/ ZnO thin films

The X-ray diffraction patterns of Fe_2O_3, ZnO and multilayered Fe_2O_3/ ZnO thin films are shown in Fig 1. A comparison of observed and standard d values using JCPDS Card No. 00-001-1053 and 01-075-1526 for Fe_2O_3 and ZnO respectively. It is seen that films are polycrystalline and having dominant orientation (002) and (104) for pure ZnO (hexagonal) and Fe_2O_3 (tetragonal) thin films respectively while for coupled films it shows mixture of both phases. XRD depicts that required phases of respective materials has been achieved. The increase in (002) peak intensity is an indication of improvement in crystallinity. The XRD data well match with other reports of ZnO, Fe_2O_3, and multilayered Fe_2O_3/ ZnO thin films.[23].

2. Optical properties

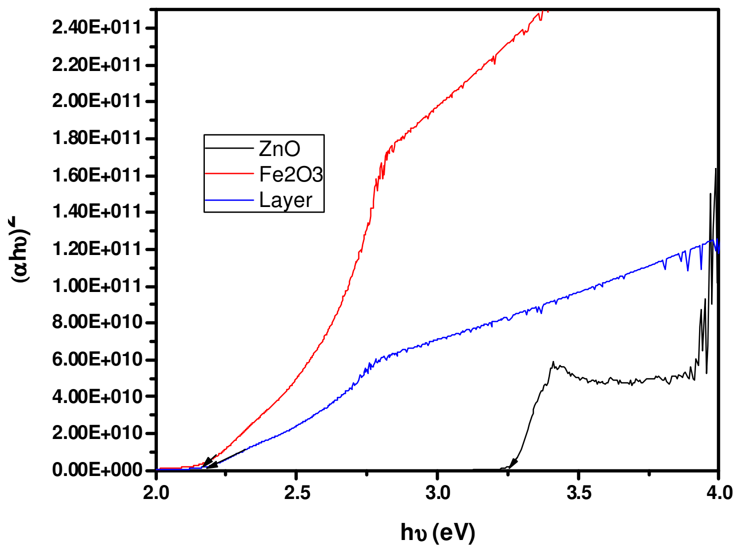

Figure 2. Plot of $(\alpha h\upsilon)^2$ Vs hυ for sprayed ZnO, Fe_2O_3 and multilayered Fe_2O_3/ ZnO thin film.

For the indirect transition, the optical band gap energy of ZnO, Fe_2O_3 and multilayered Fe_2O_3/ ZnO thin film was determined by using the equation,

$$\alpha = Const.\frac{\left(h\nu - E_g\right)^2}{h\nu} \qquad 1$$

where $h\nu$ is the photon energy and E_g is the optical band gap energy. By extrapolating the linear part of the plot of $(\alpha h\nu)^{1/2}$ vs hν to α = 0, optical band gap was estimated. The optical energy gap, E_g= 2.11 eV, 3.3 eV, and 2.15 eV are deduced for Fe_2O_3, ZnO, and Fe_2O_3/ ZnO films respectively as shown in Fig.2.

The significant blue-shift with lower band energy of Fe_2O_3/ ZnO film comparing with the ZnO film and Fe_2O_3 film may be owing to the differences in the surface state. The Fe_2O_3/ ZnO film need lower energy to be excited than the ZnO film and Fe_2O_3 film. It is reported in earlier case **[24].**

4. Conclusions

Fe_2O_3, ZnO, and Fe_2O_3/ ZnO films can be successfully synthesized using the chemical spray pyrolysis technique. In X-ray diffraction all the peaks in the pattern correspond to hexagonal structure of ZnO, Fe_2O_3 and highest peak intensity corresponds to (002), (104) crystal plane resp. The optical energy gap, E_g= 2.11 eV, 3.3 eV, and 2.15 eV are deduced for Fe_2O_3, ZnO, and Fe_2O_3/ ZnO films respectively. It is further useful for degradation of organic and inorganic compounds.

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