OPTICAL AND DIELECTRIC PROPERTIES OF THE COBALT DOPED TiO_2 NANOPARTICLES

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Cobalt doped Titanium Dioxide (TiO_2) were synthesized by a standard solid-state reaction method. The dielectric constant and loss have been measured as a function of frequency (100 Hz–1 KHz) and temperature (50°C to 300°C). Similar behavior is observed between dielectric constant and dielectric loss. Both dielectric constant and dielectric loss are found to decrease with increasing frequency. Photoluminescence (PL) spectra were taken at different excitation wavelength. PL emission spectra shows a broad spectra in the range 400 nm to 500 nm.

Keywords: TiO_2 (Anatase phase), Co doped TiO_2 , PL, Dielectric.

1. Introduction

Titanium dioxide (TiO_2) nanomaterials are used in a wide range of application such as photocatalysis, separations, sensor devices, paints and dye-sensitized solar cell [1-3]. Dielectric property of prepared anatase and rutile TiO_2 shows that the main difference in the dielectric constant value is defined by oxygen content in TiO_{2-x} . It is also reported that at high temperature, phase transitions occur in anatase TiO_2 thin films [4]. Mustafa Okutan has reported on alternating current (AC) conductivity and dielectric properties of the Co-doped TiO_2 (rutile). They had observed an increase in dielectric constant with temperature which is due to polarization related to the thermal motion of electrons [5]. The TiO_2 nanowires can emit blue–green light peaked at 487 nm under excitation at 413 nm. The TiO_2 nanowires have a very strong PL band at blue–green wavelength range. The nanowires have many potential applications in photocatalysts and photoelectronics [6].

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2. Experimental Detail

The two samples 3% & 5% Co-doped TiO₂ has been prepared in this work. Precursor TiO₂ were calcinate at 450°C for 2 hours in silica crucible in air atmosphere. The 3% & 5% Co-doped TiO₂ was mixed and grind by agate mortar with pestle for one hours before each thermal treatment. The powder was calcined at 450°C for 10 hours in silica crucible in air atmosphere. The process was repeated several times to ensure homogeneous state with single phase powder.

3. Result and Discussion

3.1. Dielectric Analysis

Co-doped TiO₂ shows a linear dielectric behavior with increasing the doping concentration. Figure 1a, shows that initially in the range of 50 to 100°C the dielectric constant decreases, but after that, it increases in the temperature range from 100°C to 250°C. At higher temperature a fall in dielectric constant is observed. Because cobalt is a conducting transition metal, a decrease in dielectric constant is observed with increasing Co-concentration.

The dielectric behavior with variation in temperature is due to the random vibration of ions and electrons, which becomes less susceptible to orientation in the field direction. Cobalt doped TiO₂ shows high dielectric loss at low temperature and at high temperature dielectric loss is low.

Fig. 1b, shows the change in dielectric loss with temperature for the prepared samples. It is seen that pure TiO₂ shows greater dielectric loss and Co-doped TiO₂ shows comparatively low dielectric loss.

Fig. 1c and fig. 1d shows the variation of the dielectric constant and dielectric loss of the TiO₂, 3% Co doped TiO₂ and 5% Co doped TiO₂ with frequency at 50°C temperature. The dielectric constant of all samples decreases almost exponentially with operating frequency. The high dielectric constant arises from the very strong local internal electric field in TiO₂, which is caused by the external applied electric field, causing strong electronic polarization and ionic polarization. At higher frequency both dielectric constant and dielectric loss remain constant means in relaxation behavior, or in other words the frequency increases dipoles start to lag behind the field and dielectric constant slightly decreases and at very high frequency dipoles are not able to follow the field for large. The variation in the dielectric behavior in the sample is attributed to the interfacial polarization.

3.2. Photoluminescence Analysis

Photoluminescence study shows that the PL intensity of TiO₂ at room temperature is significantly higher than that of Co-doped TiO₂ in the range of 375-525 nm. The PL intensity gradually decreases with higher doping of cobalt. It is also observed that the main PL peak of TiO₂ occurs at 450.84 nm while those of cobalt doped TiO₂ turns up at

450.93 nm for 3% and 451.59 nm for 5%, respectively. These results indicate that the position of PL peaks is gradually shifted towards the Blue-red direction with the increase of Co-ion dosage from 3% to 5%. The doping is an effective approach to adjust the Fermi energy level for semiconductors. The relation between electron conduction and the Fermi level is given by S. M. Sze. [8].

The PL emission mainly results from the recombination of excited elements and holes, the lower PL intensity indicated the less recombination of electron hole pair and higher separation efficiency. The PL behavior of TiO_2 is also highly dependent on the grain size [9]. In the present work, we observe many tiny peaks which is due to the energies levels introduced by lattice defects.

4. Conclusion

Cobalt doped TiO_2 shows a more linear behaviour and low dielectric loss as compared with pure TiO_2 on increasing the operating frequency. PL study indicates that on increasing Co concentration the PL peak shift.

5. Illustrations and Photographs

Fig. 1a & 1b. Shows Dielectric constant Vs Temperature and Dielectric Loss Vs Temperature (50°C to 300°C) with 10kHz frequency.

Fig. 1c & 1d. shows Dielectric constant Vs Frequency and Dielectric loss Vs Frequency (at 50°C) of the samples.

Fig. 2a,2b and 2c. Shows Photoluminescence Spectra of the sample at the different excitation wavelength.

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