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Negative Photoconductivity Effects of Titanium Dioxide and Tungsten Oxide Prepared by Sol-Gel Method*

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Abstract: Titanium oxide and tungsten oxide are prepared by sol-gel method. Intensity dependence of photocurrent was studied at different voltages under visible illumination which indicates that the nanoparticles exhibit negative photoconductive behavior. The variation of photocurrent with visible illumination was found to be sub linear in nature at low as well as high voltages. Voltage dependence was also studied. Structural studies using XRD and TEM have been performed. Particle size of TiO_2 and WO_3 nanoparticles are found to be ~35 nm and 40-50 nm respectively.

Keywords: Photoconductivity, visible illumination, sol-gel method, titanium dioxide, tungsten oxide.

1. Introduction

Titanium dioxide has attracted much attention during the past few years in view of many applications such as sensors, optical devices, photoelectrochemicals, solar cells etc. It has wide bandgap, around 3.0eV for rutile and 3.2eV for anatase. Also tungsten oxide is a semiconducting transition metal oxide .It has a number of electrical and optical properties suitable for various applications such as electrochromic devices, gas sensors, and light emission devices.

TiO_2 and WO_3 nanoparticles have been considered, to be a photoconductive materials in previous few reports. There are reports on phototoconductivity of sol-gel derived TiO2 films[1-4]. Also there are reports on photoconductivity properties of tungsten oxide thin films[5- 6]. In this text we have focused on photoconductivity of TiO_2 and WO_3 prepared by sol-gel method.

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2. Experimental

2.1 Preparation of samples

The TiO_2 (anatase) is prepared by sol-gel method. The sol-gel precursor was made by adding Titanium isopropoxide ($Ti[OCH(CH3)_2]_4$) to propanol drop by drop, then 0.1 M dilute HNO_3 solution was added under stirring. The solution was heated at 80˚ C for 15 minutes. Then it was poured to polypropylene dish and dried.

WO_3 is also prepared by sol-gel method using Sodium tungustate (Na_2WO_4) as starting material. Na_2WO_4 was dissolved in deionized water. Then concentrated HNO_3 solution was added. The reaction mixture was stirred at room temperature for 6 hrs until yellow precipitate appeared. Further precipitate was filtered and dried to get WO_3.

2.2 X-ray diffraction

The structural characterizations of as prepared TiO_2 and WO_3 were carried out through XRD by employing a Philips PW 1710 Diffractometer equipped with a graphite monochromator.

2.3 Photoconducivity measurements

For photoconductivity measurements, a cell was formed by spreading a thick layer of powdered samples in between two Cu electrodes etched on a Cu plate (PCB), having a spacing of 1 mm. The powdered layer was pressed with transparent glass plate. This glass plate has a slit for providing illumination area of 0.25 cm ^{2}. In this cell type device, the direction of illumination is normal to field across the electrodes. The cell was mounted in a dark chamber with a slit where from the light is allowed to fall over the cell. The visible photo-response was measured using a commercial bulb of 200 W as a photo-excitation source. A stabilized dc field (50 V/cm to 500 V/cm) was applied across the cell to which a digital dc nano-ammeter, NM-121 (Scientific Equipment, Roorkee) for the measurement of current and RISH Multi 15S with adapter RISH Multi SI 232 were connected in series. The light intensity over the cell surface was changed by varying the distance between slit and light source. Before measuring photoconductivity of the sample, the cell is first kept in dark till it attains equilibrium.

3. Results and discussion

3.1 Structural study

Broadening of peaks in XRD patterns (Fig. 1(a) and Fig. 1(b)) revealed formation of nano TiO_2 and nano WO_3.

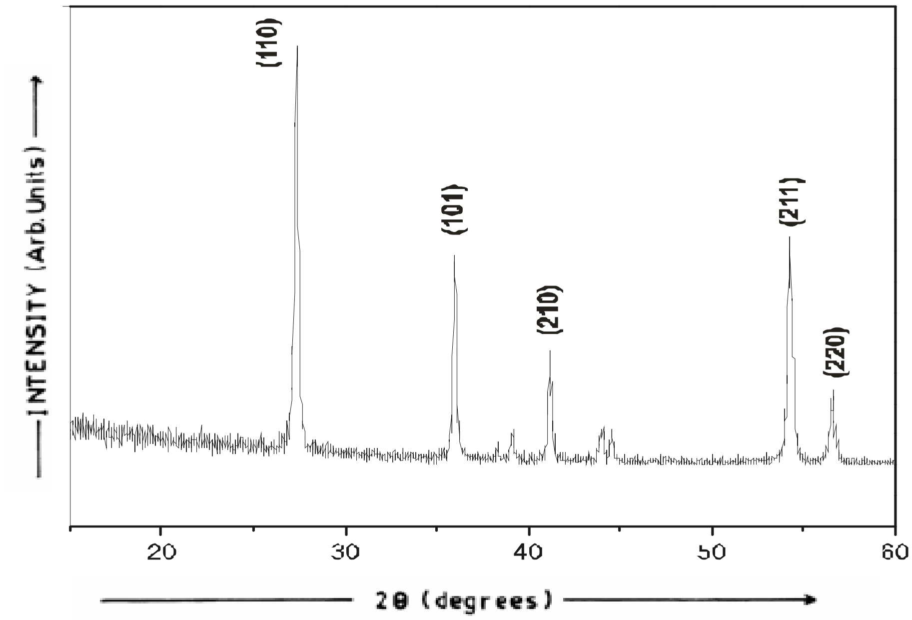

Figure 1(a): XRD pattern of TiO_2 nanoparticles

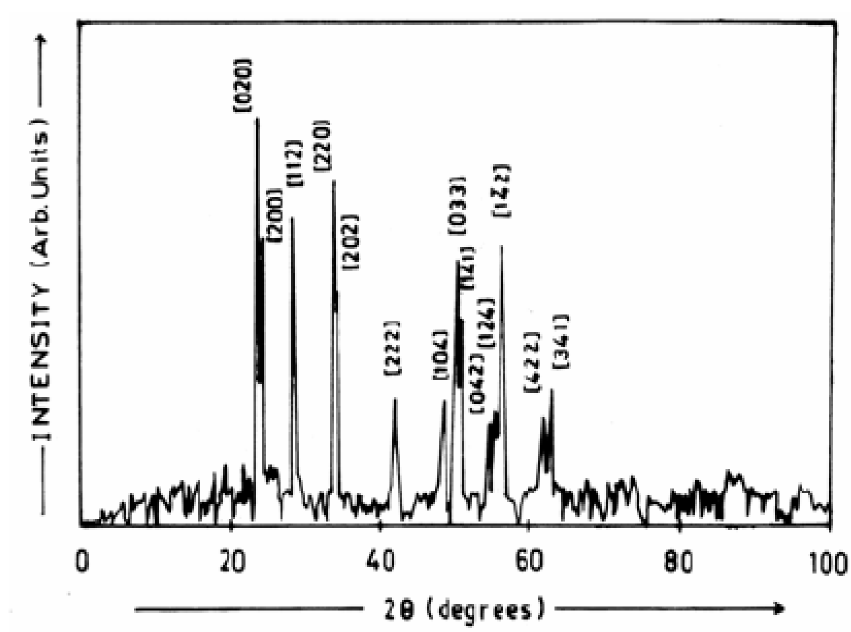

Figure 1(b): XRD pattern of WO_3 nanoparticles

The crystallite (or grain) size of TiO_2 and WO_3 nanoparticles was estimated using the Scherer's formula

$$D = \frac{0.94\lambda}{\beta Cos\vartheta}$$

where β is full width at half maximum [FWHM] in radians, λ is the X-ray wavelength and θ is the Bragg's angle. The average particle size of TiO_2 nanoparticles is estimated as ~35 nm and that of WO_3 is 40-50 nm.

3.2 Photoconductivity study

3.2.1 Intensity dependence of photocurrent

Fig.3 (a) depicts the intensity dependence of photocurrent under visible illumination for TiO_2 nanoparticles at different voltages. Fig.3(b) depicts the same for WO_3 nanoparticles. It exhibits sub-linear behavior for low as well as high voltages for both the nanoparticles. Negative photoconductive behavior is observed for both TiO_2 as well as WO_3 nanoparticles.

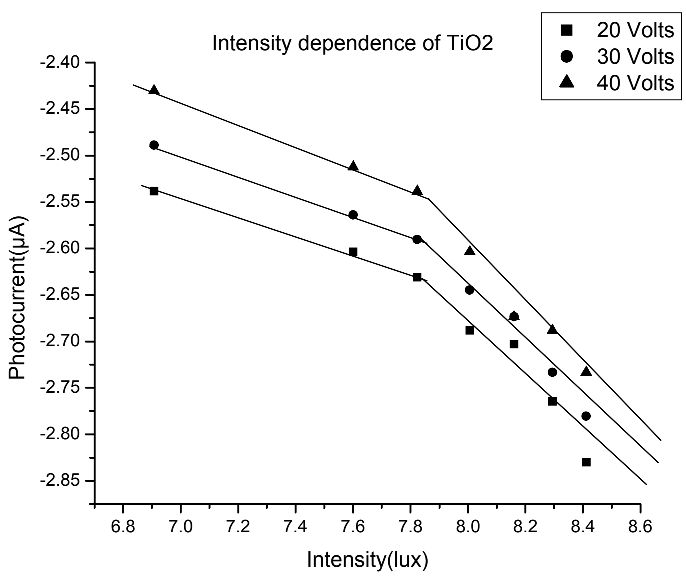

Fig.3(a) Intensity dependence of photocurrent for TiO_2 nanoparticles.

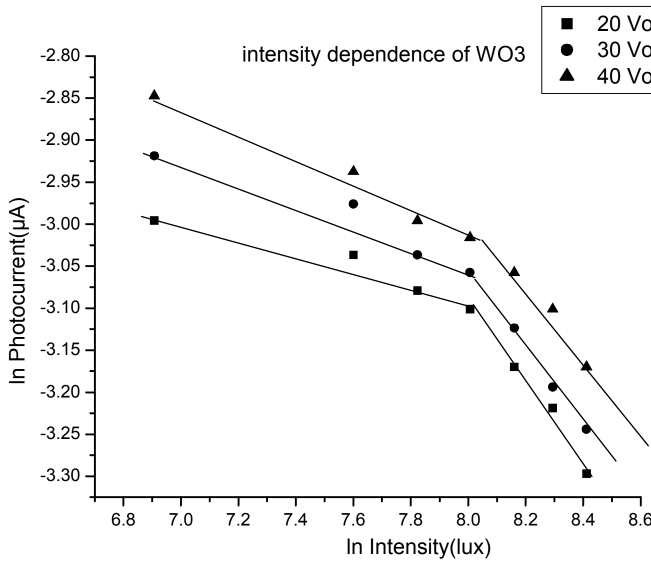

Fig 3(b): Intensity dependence of photocurrent for WO_3 nanoparticles.

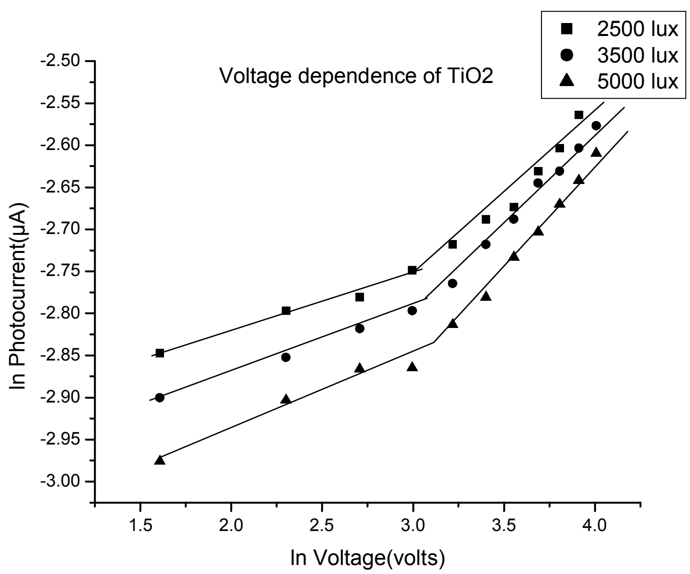

Fig. 4(a) Voltage dependence of photocurrent for TiO_2 nanoparticles.

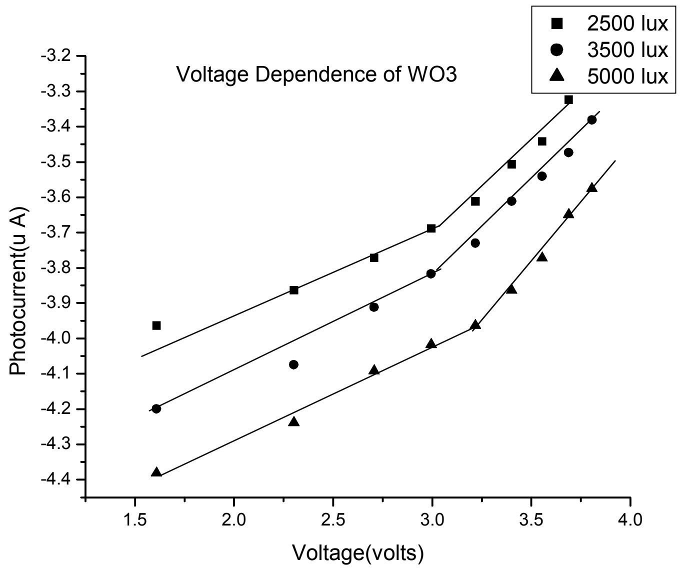

Fig. 4(b) Voltage dependence of photocurrent for WO_3 nanoparticles.

3.2.2 Voltage dependence of photocurrent

Fig. 4(a) and Fig. 4(b) depict the voltage dependence of photocurrent under visible illumination at different intensities for TiO_2 and WO_3 nanoparticles respectively. It exhibits sub-linear behavior for all intensities for both the nanoparticles.

4. Conclusions

TiO_2 and WO_3 nanoparticles were synthesized by sol-gel method. Particle size of TiO_2 and WO_3 estimated as ~35nm and 40-50nm respectively. Intensity dependence of photo- current reveals negative photoconductivity in which photocurrent decreases with increase in intensity of illumination.

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