Photoconductivity of sensitization (ZnO/ Polystyrene(PS))Composites by Rose Bengal Dye

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Abstract

The photoactive behaviour of rose bengal dye sensitized (ZnO/ Polystyrene (PS)) composites was studied. Two concentrations of composite(30% ZnO/70% PS) and (50% ZnO /50% PS) with (0.05, 0.1.0.3,1%)weight percentages of dye were used. The composites are photoconductive and the photoconductivity action spectrum gives the effect of the dye in the visible region.

In the absence of dye within the composites, no photoactivity is observed in this region of the spectrum. The photoconductivity is affected by the dye content.

Time of flight technique was used to measure response time. The rise time of the photocurrent is fast and the decay is slow.

Introduction

Binder- Containing photoconductive compositions were widely used in the preparation of electrophoto-graphic elements (1,2). Typical binders are ordinary polymeric materials, polymers(e.g., phenolic resins, acrylic ester resins and polystyrene)which may be used as binders for photoconductive materials (e.g., ZnO,Se,SnO_2)for the use in electophotographic reproduction. However these binders usually do not impart any particular improvement in light sensitivity to the system (3).

Semiconductors e.g., ZnO, SnO_2 are attractive materials for photodectors because of their conductivity which is highly sensitive to illumination (4-6).ZnO has received much attention over the past few years because it has a wide range of properties including high transparency, piezoelectiricity, wide- band gap semicoductivty (7).

Spectral sensitizing dyes extend the wavelengths of light to which inorganic and organic semiconductors and chemical reactions can be photosensitized as sensitizers, dyes were shown to be capable of causing charge injection into semiconductors and insulators (8,9). When ZnO of wide band gap Semiconductors is combined with sensitizer (dye), the molecules are strongly absorbed in the visible range the efficiency of charge carriers generation increases and extends the photoaction spectrum(10).

The photoconductive of polymer composites can also be sensitized by the addition of effective amounts of sensitizing dyes to exhibit the improved electrophotosensitivity (11,12).

Experimental Section

Polystyrene (PS) grains of ICI company, ZnO(Aldrich chemicals) and rose bengal dye(Fluka) were used. Tumbling mills were used for grinding the polymer grains to fine particles.

A certain (ZnO/PS) concentration,(50%ZnO/50%%PS) composite was doped with rose bengal dye in weight percentage(0.05,0.1,0.3,1%) respectively, and (30%ZnO/70%PS) composite was doped with 0.1%dye. The dyed (ZnO/PS) composites were obtained by mixing proper quantities of polymer, ZnO and rose bengal dye (R.B) in a mortar. The mixed powder was compacted in cylindrical die under a pressure of about 110 bar and a temperature (150°C). The undyed (50%ZnO/50%PS)and (30% ZnO/70%PS) composites were prepared under the same conditions.

The out-coming samples were disc of a diameter (30mm) and thickness about(0.5mm). Aluminum electrodes were deposited in a coplanar configuration form. The test sample was mounted on a sample holder, and conductivity measurements were made by using the experimental set up shown in Figure(1).

The darkcurrent- voltage (I_d-V) characteristics of the shielded sample were measured over a voltage range (1-250volts), while measurements of the photocurrent- voltage(I_{ph}-V)characteristics and the photocurrent spectral response were carried out by using the light source xenon arc lamp(150W) with the monochromator, D.C power supply (Phyew), a voltmeter and Keithley 616/digital solid state electrometer which was grounded and shielded to avoid extraneous electrical noise. The light source was switched on and waits for about 15minutes for stability.

The desired voltage was applied to the shielded sample and then the photocurrent was measured at each scanning wavelength after removing the cover from the sample.

The light intensity was measured about 20mW/cm^2 at test sample position.

Time response measurements were carried out by time of flight technique (TOF) figure (2). Pulsed light from flash xenon lamp of 30ns pulse duration irradiated the sample under the applied voltage30volt. These parameters rise(t_r), transit (T_r), fall (T_f) and life (τ)times were measured through the storage oscilloscope. The drift mobility of carriers and gain were calculated by the following relations:

$$\mu = \frac{L^2}{VT_r} \text{.......[1]}$$

$$G = \frac{\tau}{T_r} \text{........[2]}$$

Where μ is the drift mobility, V is the applied voltage, (L=0.01cm) is the electrode separation and G is the gain.

Results and Discussion

Zinc oxide is photosensitive to ultra-violet light. The photosensitivity is extended into the visible region of the spectrum by using dyes(8,9).

Figure(3) shows the photoconductivity action spectrum for the rose bengal dye sensitized (ZnO/PS) composite. The photo current spectral response measurements revealed that the photosensitization mechanisms is operative in extending the photoresponse into the visible region (500-~600nm) for(ZnO/PS) composite. As shown in figure(4) no photocurrent is observed in this region of the spectrum for the undyed composites.

The photoconductivity is dependent on the concentration of the dye. The maximum photocurrent sensitized by the dye is obtained by using (0.3%) of R.B.

The dye-sensitized photoconductivity process for ZnO is interpreted by the photodesorption process of adsorbed oxygen ions, O^-_2, resulting in the release of surface trapped electrons (11,13), while the lower response with the higher amounts of dye is probably due to desensitization or shielding of the light by dye in the polymer that is not on the ZnO surface(11).

The ZnO content also influences the photoactivity as indicated of dyed (ZnO/PS) composites of 30% and 50% ZnO content shown in figure(5). The Photocurrent of the later content composite is higher than the former one at the dye absorption region, moreover at the fundamental absorption region of the ZnO. This behaviour can be explained according to percolation theory(14).At 50% of ZnO content. The Probability of particle - particle contact occurs in the bulk of the polymer.

The photocurrent-voltage (I_{ph}-V) characteristics of the sensitized polymer composite were produced by using white xenon lamp given in figure(6). The photocurrents are quite high relative to the dark currents as indicated in the figure for (50%ZnO/ 50%PS) composite sensitized by0.05% rose bengal dye. Moreover the dark current of the sensitized (ZnO/PS) composite was changed to lower level in contrast to that of the undyed (ZnO/PS) composite which can be regarded as good sensitizers to press the dark current to lower level.

The photocurrent dependence on the applied voltage revealed that at low voltage region, the photocurrent increases more steeply than in the high voltage region.

Table(1) outlined the measuring times, drift mobility and gain for the samples.

As noticed from the Table (1), that the time response of photoconductivity of (ZnO/PS) composite is fast when the composite is sensitized by rose bengal dye, accordingly mobility and gain values were increased. In general the fall time is relatively long which may be associated with a longer residence time in shallow traps.

Conclusions

The photosensitization properties of rose-bengal dye in extending the photocurrent response of (ZnO/PS) composites into the visible region of the spectrum were studied. The amount of dye content with the (ZnO/PS) composite influences the photoresponse. The lower response with the higher amount of dye is probably due to desensitization. The amount of ZnO used influences the photoresponse, this effect suggests that the charge-transfer process can be described by percolation theory. The dyed (ZnO/PS) composites were given measurable time parameters according to applied TOF technique, the rise in the photocurrent is fast, while the decay is slower.

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Table (1) Data of TOF measurements

Composite	Rise time(t_r) μ_{sec}	Transit time T_r μ_{sec}	Life time τ	Fall time T_f	Mobility $\frac{cm^2}{V.sec}$	Gain
50%ZnO/ 50%PS	27	40	200 μ_{sec}	3.8msec	8.3	5
50%ZnO/ 50%PS +0.05%dye	24	35	210 μ_{sec}	3 msec	9.5	6
50%ZnO/ 50%PS +0.1%dye	20	30	218 μ_{sec}	2.3 msec	11.1	7.3
30%ZnO/ 70%PS+ 0.1% dye	30	37	190 μ_{sec}	3.7 msec	9.0	5.1

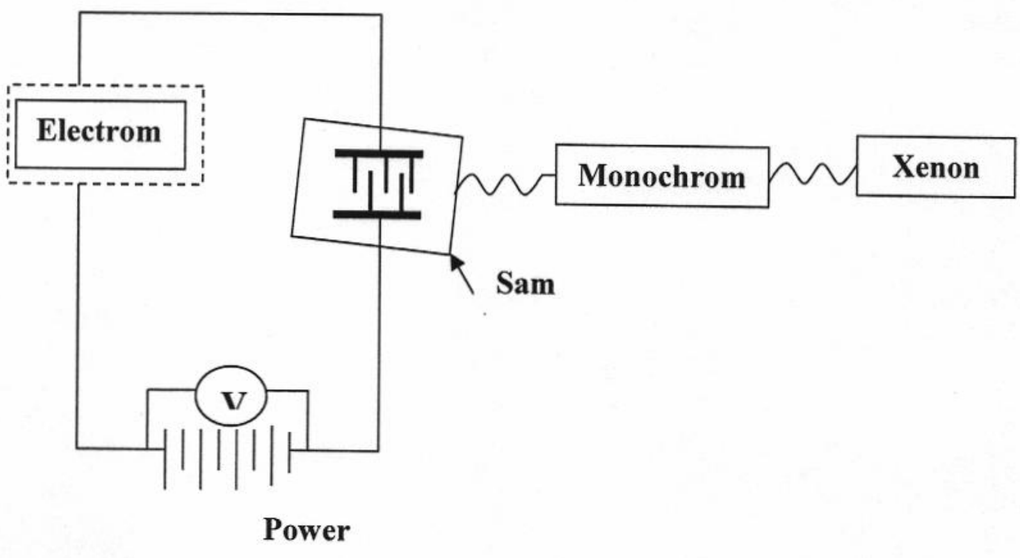

Fig. (1) Experimental Setup For CCCCCConductivity Measurements

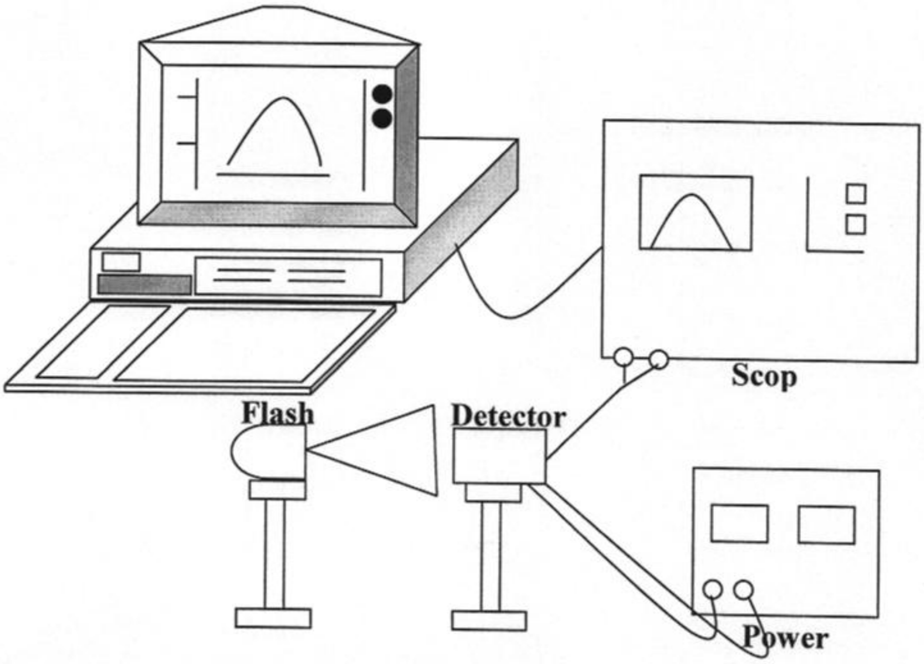

Fig. (2) Diagram for time of flight

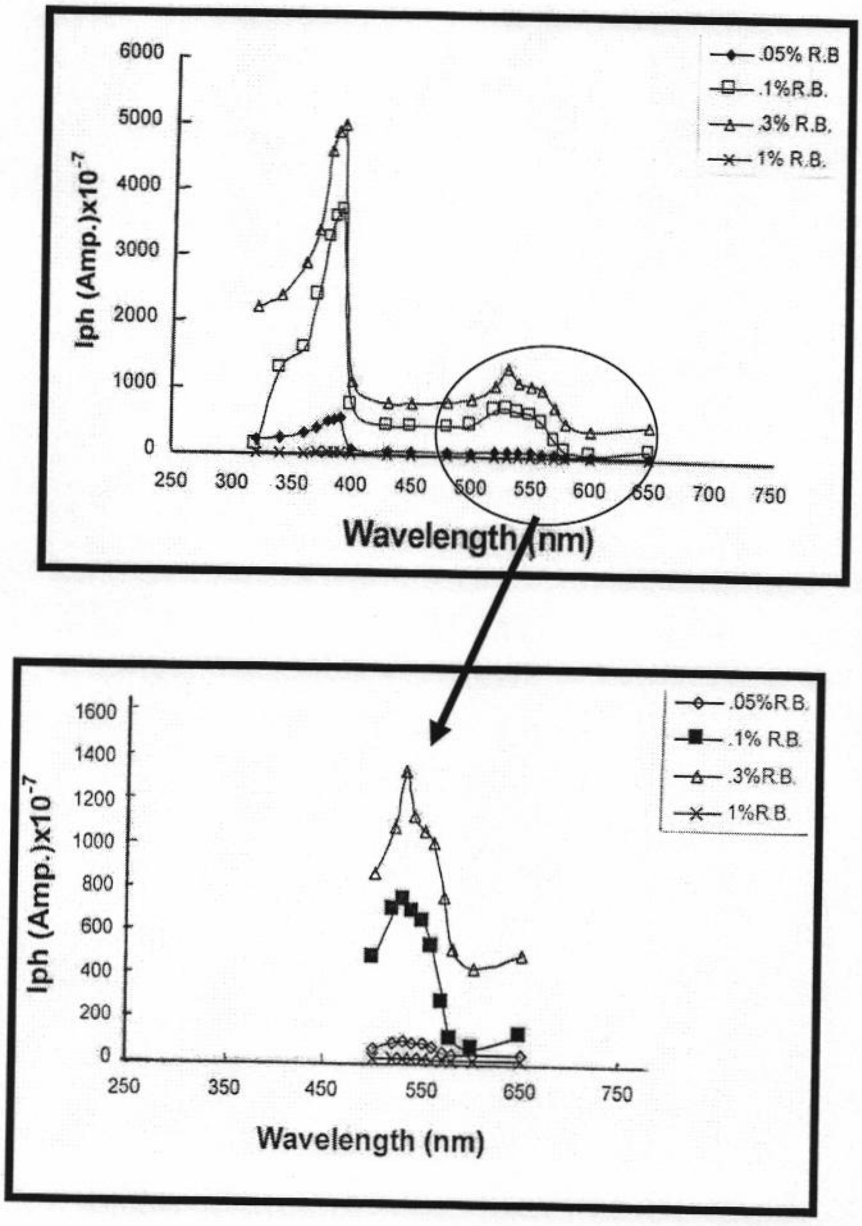

Fig.(3) Photo current spectral response of dyed (50%ZnO /50% PS)composites at applied voltage (50volt).

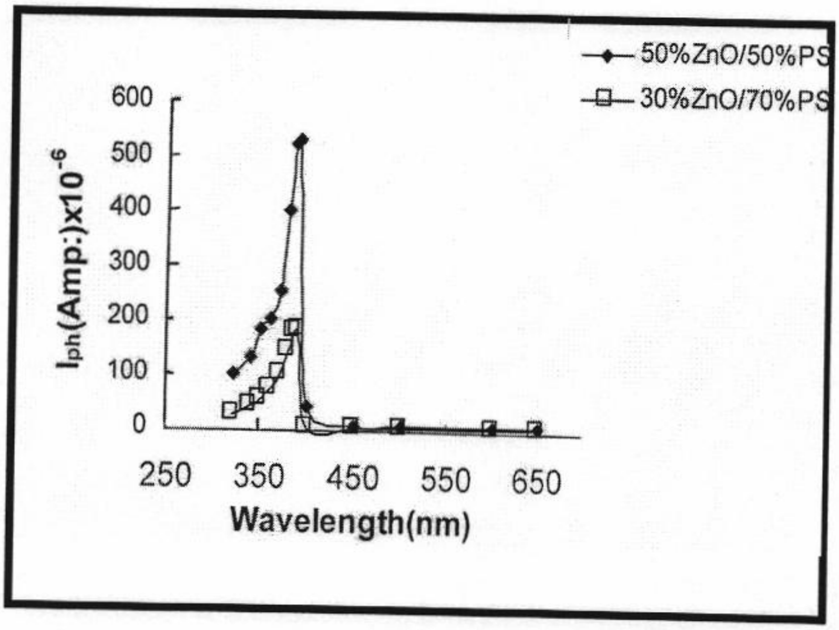

Fig.(4) Photo current spectral response of undyed (ZnO / PS)composites at applied voltage (50volt).

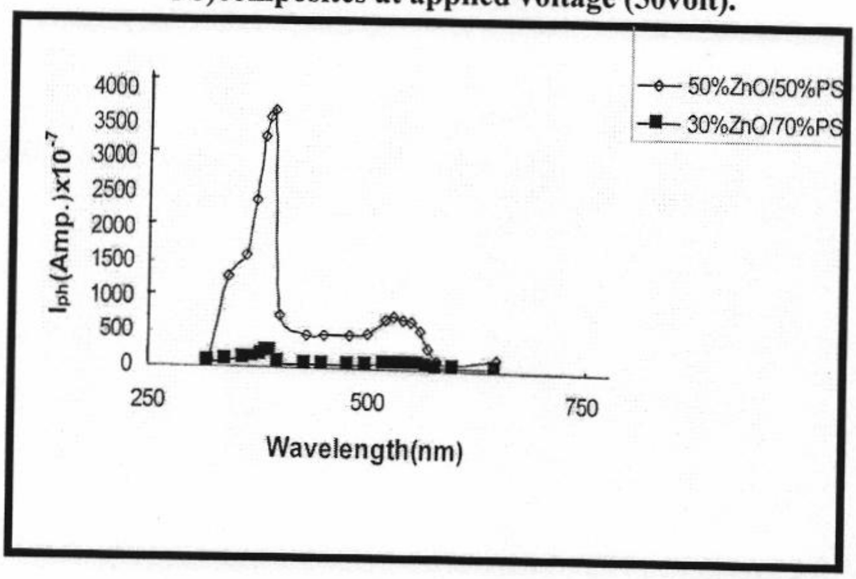

Fig.(5) Photo current spectral response of dyed (ZnO / PS)composites with 0.1% R.B. by weight at applied

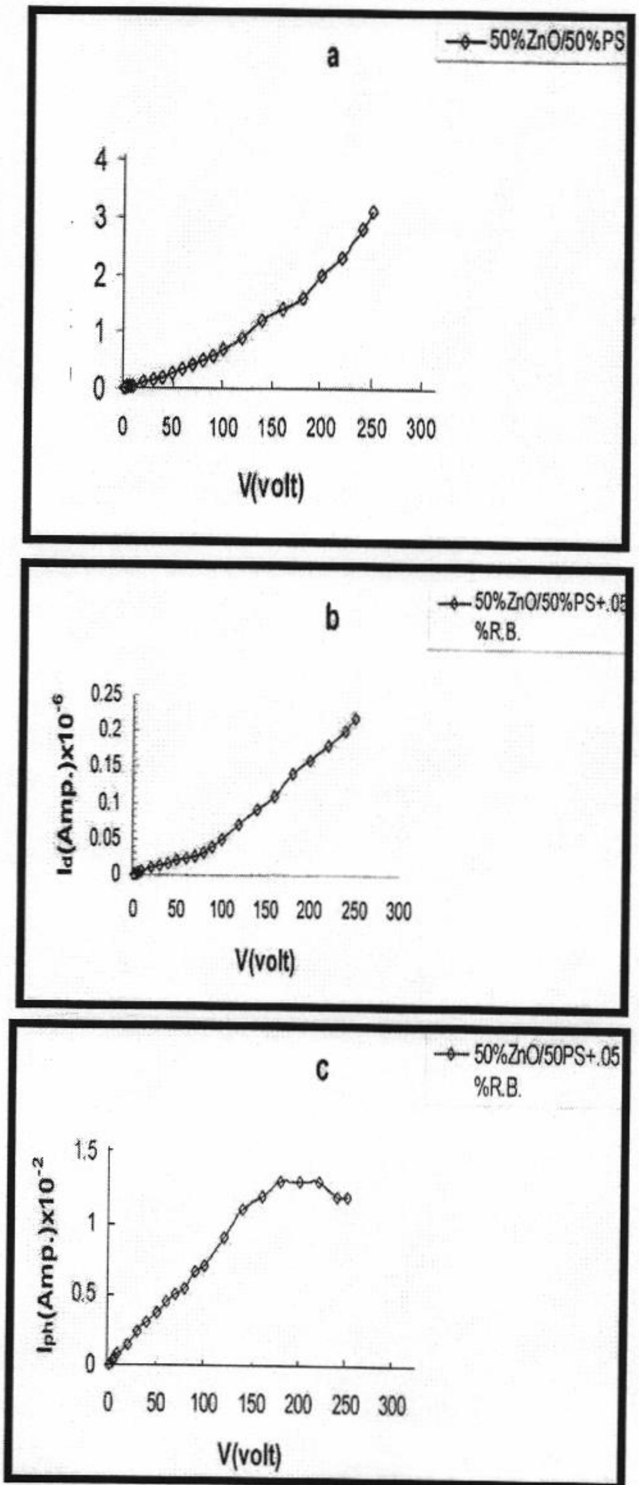

Fig.(6)Variation of dark current and photocurrent verse applied voltage for (50%ZnO/50%PS) composite

التوصيلية الضوئية للمتراكبات (اوكسيد الزنك ZnO/ بولي ستايرين PS) المتحسسة بصبغة Rose Bengal

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الخلاصة

درس سلوك النشاط الضوئي لمتراكبات (ZnO/بولي ستايرين PS) المتحسسة بصبغة (Rose bengal). استخدمت تركيزين للمتراكب (ZnO%30/ PS %70) و(ZnO%50/ PS%50) مع (0.05 ،1،0.3،0.1%) النسب الوزنية للصبغة. تمتلك المتراكبات توصيلية ضوئية، وان التوصيلية الضوئية الطيفية أظهرت تأثير الصبغة في الجزء المرئي من الطيف.

وفي حالة المتراكبات الخالية من الصبغة لايظهر النشاط الضوئي في الجزء المرئي من الطيف. ولقد تأثرت التوصيلية الضوئية بأحتواء المتراكب للصبغة.

استعملت تقنية زمن الطيران لقياس زمن الاستجابة فكان زمن صعود التيار الضوئي سريعاً مع انحلال بطيء في التيار الضوئي.