Rise and Decay of Photocurrent: A Study in (TiO_2- CdO) Mixed Composite

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Abstract- In this paper an attempt has been made to study the rise and decay of photocurrent in (TiO_2- CdO) mixed composite. The mixed composite of TiO_2 and CdO were prepared by heat treatment technique taking firing temperature 700 ˚C for 30 min. Five samples having different compositions were prepared. 100% TiO_2 sample heated at 700 ˚C for 30 minutes was found to be best photosensitive. However (80% TiO_2 - 20% CdO) samples shows maximum photosensitivity amongst all other compositions. For measurement purpose the thick binder layer were fabricated in the form of parallel plate capacitor. The response time of 100% TiO_2 and (80% TiO_2 - 20%CdO) samples are 36sec and 25 second respectively. Rise and decay of photocurrent under different experimental conditions such as under ultra violet radiations, different voltages and different light intensities have been studied.

Keywords- Photoconductivity, Rise and Decay Curves, Thick binder layer, Mixed composite

I. INTRODUCTION

It is well known that rise and decay curves of photocurrent are governed by the trapping states and recombination centres lying in the forbidden Zone of a photoconductor. Therefore these curves can be used to understand the nature and distribution of traps and recombination centres in materials [1]. A good photosensitive material should not only show a large change in conductivity but also respond fast. If trapping centres are in abundance, the response time is slow [2]. The interaction of photons having energy equal to greater than the band gap, with bound electrons of lattice atoms, creates free electron-hole pairs which causes rise in current called photocurrent.

Rise and decay of photocurrent (Photoconducting properties) of large number of single mono crystals have been studied[3],[4]. Several researchers measured photocurrent on thin films [5], [6]. Rise and decay of photocurrent study have been also made on nanomaterials and glassy materials [7], [8], [9], [10]. However relatively fewer attempts have been made for mixed binder layers. Photoconducting properties of TiO_2 has been made by some workers [11],[12]. In present investigations, the two base materials i.e TiO_2 and CdO having different energy gaps of values 3 eV and 2.2 eV respectively have been mixed in different proportion by weight in order to use the effect of composition and synthesizing conditions on photoconducting properties of mixed systems. The photoconductivity of CdO has been studies by workers [13]. The CdO with energy gap (2.2 eV) does not give any change in conductivity under illumination. The TiO_2 with higher energy gap (3 eV) shows photoconductivity.

II. EXPERIMENTAL

The samples were prepared by heat treatment technique as described in [14].The various synthesizing parameters such as firing temperature concentration and firing time were changed to get the optimum conditions for best photoresponse. For measurement purpose the photoconducting cells were fabricated in the form of parallel plate capacitor. The cell area was 3.1cm^2 with thickness varying from 0.037 to 0.042 cm. The conducting glass surface was kept in direct contact with the material. The cell was kept in dark metallic chamber. The cell was illuminated with Hg-lamp the intensity of illumination is changed by changing slit width and measure through luxmeter. The stabilized dc field was applied and the photocurrent was measured by a Nanoammeter.

III. RESULTS AND DISCUSSIONS

Five samples having different compositions, i.e. 100% TiO_2, (80% TiO_2 - 20%CdO), (40% TiO_2 - 60%CdO) and 100% CdO were prepared by heat treatment technique. The 100% TiO_2 sample heated at 700℃ for 30 minutes was found to be best photosensitive. However (80% TiO_2 - 20% CdO) sample heated at 700 ℃ for 30 minutes shows

maximum photosensitivity amongst all other mixed composites. The other mixed composites i.e. (40% TiO_2 - 60% CdO), (20% TiO_2 - 80% CdO) and 100% CdO samples have not give any change is conductivity under illumination. For this reason (80% TiO_2 - 20% CdO) combination has been selected for general measurements. Rise and decay of photocurrent has been measured under different experimental conditions, which are shown by Figure 1, 2, 3 and 4 and 5. The results are as following:

2.1 Rise and Decay of Photocurrent for Different Compositions

Figure 1 shows the rise and decay of photocurrent for different compositions. There is no change in conductivity under illumination for 100% CdO and (40% TiO_2 - 60%CdO), (20% TiO_2 - 80%CdO), mixed systems. The photosensitivity of (80% TiO_2 - 20%CdO) composition is more than the other mixed systems except pure TiO_2 under same experimental conditions.

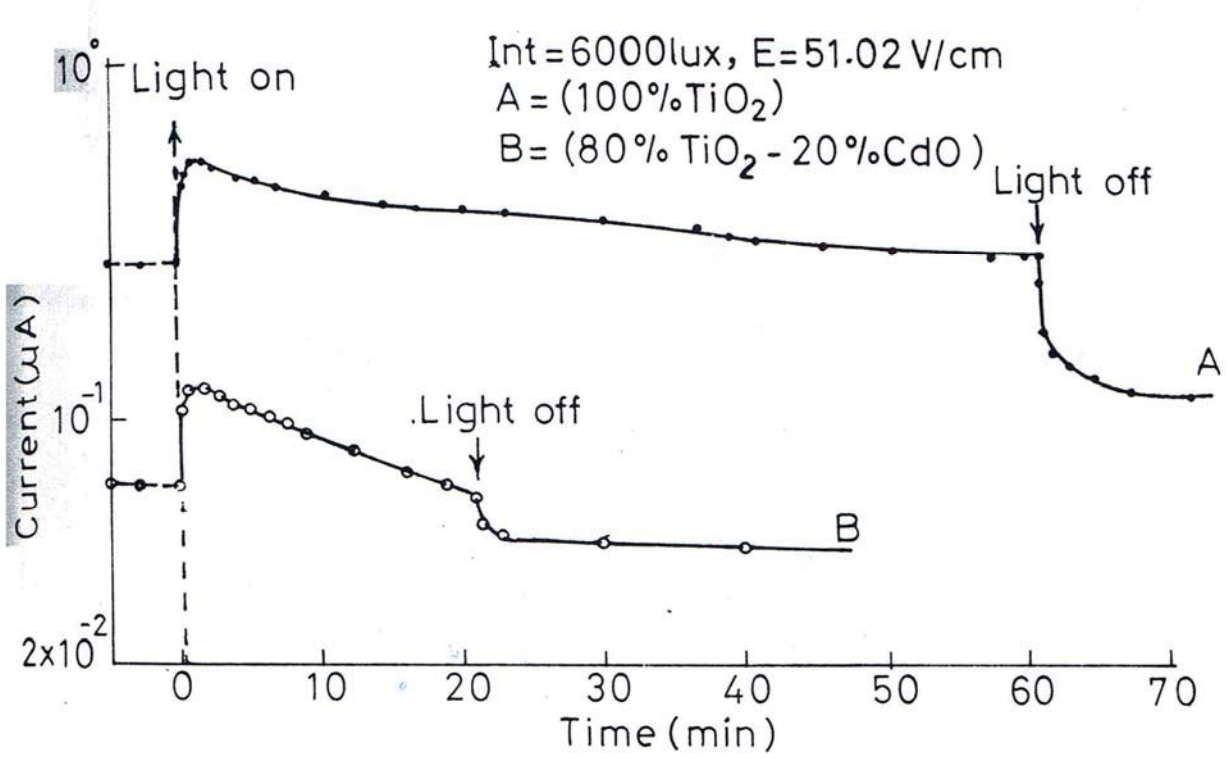

Figure. 1 – Rise and decay of photocurrent for different compositions (Temp. 28°C)

The response time of 100% TiO_2 and (80% TiO_2 - 20%CdO) are 36 sec and 25 sec respectively, where response time is defined as the time required by the photocurrent to take 90 percent of its maximum value. The response of (80% TiO_2 - 20%CdO) sample is faster than 100% TiO_2 sample. For both the samples, the photocurrent rises as soon as the light is switched on but after acquiring a maximum value, it continues to decay for a very long time tending towards a saturation value i.e. both positive and negative photoconductivity results, where negativity photoconductivity[1] is defined as the decrease in conductivity in presence of light. For 100% TiO_2 sample the positive photoconductivity is almost equal to the negative photoconductivity. For (80% TiO_2 - 20%-CdO) composition negative photoconductivity becomes greater than the positive photoconductivity. When illumination of the photoconductor increases the density of electrons or holes or both, positive photoconductivity results. If with the elapse of time, the minority carriers are also excited from the imperfection centres, a negative photoconductivity results. This is due to the rapid recombination of minority carriers with majority carriers. This is due to the rapid recombination of minority carries with majority carriers. This explains why negative photoconductivity results with positive photoconductivity[1].

2.2 Rise and Decay of Photocurrent Under Ultra-Violet Radiations

Figure 2 shows the rise and decay of photo current for different samples under ultraviolet radiations. Under UV region, the negative photoconductivity of (80% TiO_2 - 20%CdO) sample disappears and of 100% TiO_2 sample reduces. This is due to decrease in the rate of recombination of minority carriers with majority carriers.

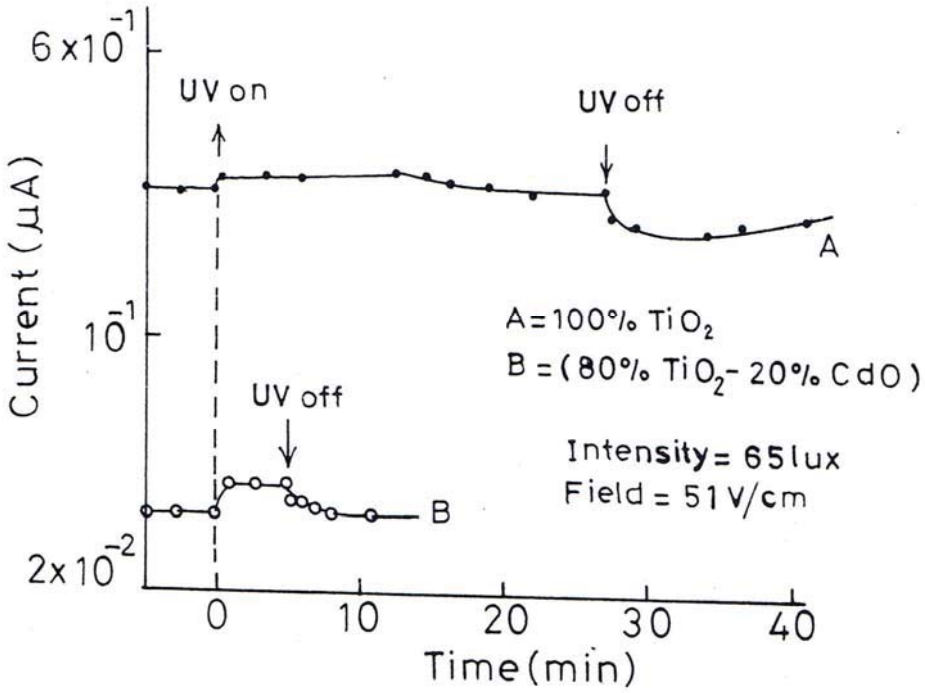

Figure. 2 – Rise and decay of photocurrent for different samples under ultra-violet radiations (Temp.=28°C)

2.3 Rise and Decay of Photocurrent under UV Region at Different Voltages

Figure 3 shows the rise and decay of photo current under UV region at different voltages for (80% TiO_2 - 20%CdO) compositions. This is clear from the figure that at all the voltages the negative photoconductivity is not observed. The response time at different voltages is listed in Table 3.1. The decay curves of photocurrent have been used to calculate the escape probability and trap depths at different voltages. The plots log I_p versus time for decay mode show that decay cannot be governed by a single exponential law. This implies that the traps of different nature are situated at different energy depths below the lower edge of the conduction band.

Thus the decay is given as,

$$I = I_0 \exp(-pt)$$

where escape probability p is given by relation

$$p = S \exp(-E/KT)$$

The escape probability at different voltages for (80% TiO_2 - 20%CdO) sample is given in Table 3.2 and the corresponding trap depths are given in Table 3.3.

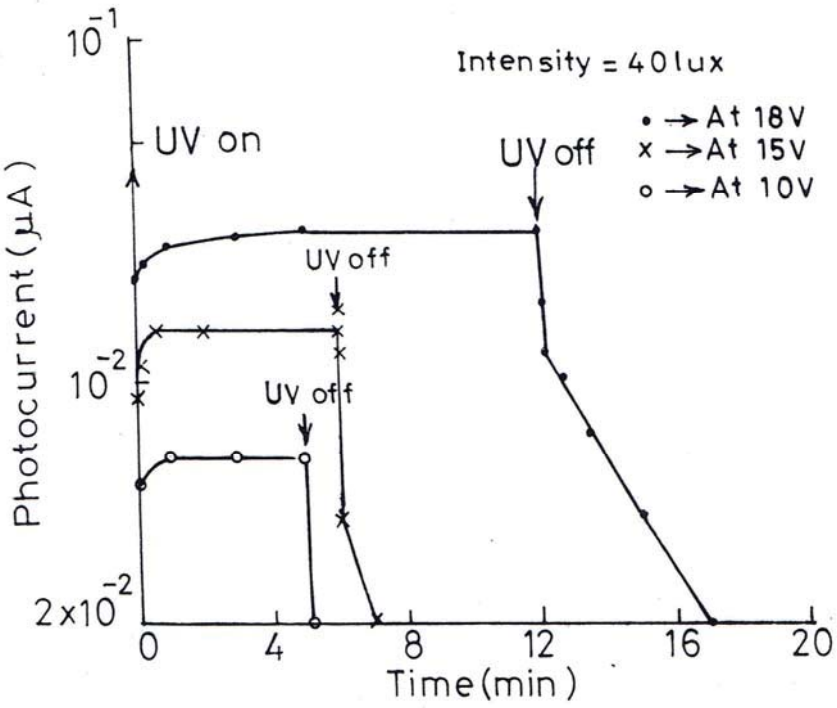

Figure. 3 – Rise and decay of photocurrent at different voltages under ultra-violet radiations for ((80% TiO_2 - 20%CdO) composition.

Table 3.1

Response time of Photocurrent at different voltages for (80% TiO_2 - 20%CdO) sample excited with UV radiations.

Sl. No.	Voltage (Volts)	Response time (Sec)
1.	10	24
2.	15	18
3.	18	65

Table 3.2

Calculated values of escape probability p at different voltages for (80% TiO_2 - 20%CdO) sample excited with UV radiations.

Sl No.	Voltage (Volts)	$p \times 10^3$	
		First exponential	Second exponential
1.	10	183.11	--
2.	15	178.98	13.07
3.	18	73.72	6.11

Table 3.3

Trap Ionization energies of Different Traps Corresponding to Different Exponential.

Sl No.	Voltage (Volts)	Trap depth (eV)	
		First exponential	Second exponential
1.	10	0.58	--
2.	15	0.58	0.648
3.	18	0.603	0.668

2.4 Rise and Decay of Photocurrent at Different light Intensities

The rise and decay of photocurrent at different light intensities for (80% TiO_2 - 20%-CdO) sample at high voltage has been shown in Figure 4. We see that the negative photoconductivity decreases as the field value and intensity of illumination increases. But after a fix value of light intensity and field the negative photoconductivity increases with increasing light intensity.

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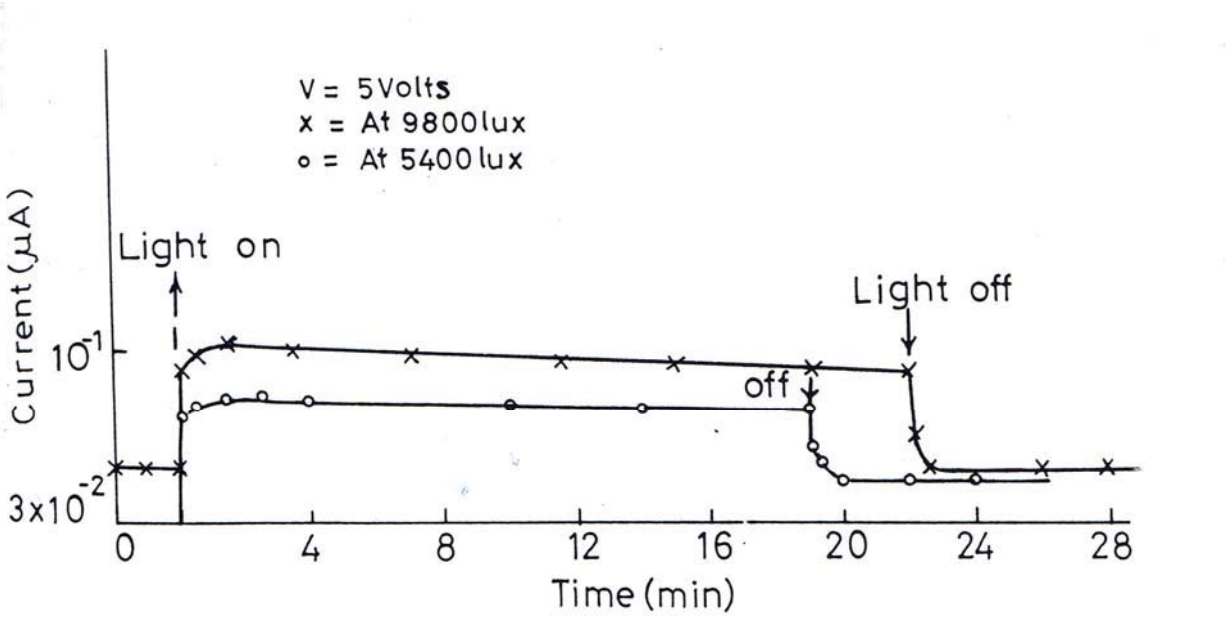

Figure. 4 –Rise and decay of photocurrent for different intensities for (80% TiO_2-20% CdO) sample.

IV. CONCLUSION

The maximum photosensitivity has been observed for (80% TiO_2 - 20%CdO) mixed system. Other mixed systems i.e. (40% TiO_2 - 60%CdO) and (20% TiO_2 - 80%CdO) have not shown any change in conductivity under illumination. The negative photoconductivity of (80% TiO_2 - 20%CdO) sample disappears, when illuminated with UV radiations.

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