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ZnCdS : Ag/Cd (S, Se) : Cu mixed photoconductor system for electrophotography

P. K. C. PILLAI, P. K. SHARMA, A. K. TRIPATHI
Department of Physics, Indian Institute of Technology, Delhi, New Delhi – 110016, India

Surface charge formation and decay characteristics of ZnCdS : Ag/Cd (S, Se) : Cu–polystyrene binder layers are discussed with special reference to their application in electrophotography. The binder layers are made with different compositions of ZnCdS : Ag and Cd (S, Se) : Cu. From the measurements of parameters such as the charge acceptance, contrast potential and surface potential decay in dark and light, it has been found that the layer containing ZnCdS : Ag and Cd (S, Se) : Cu in the ratio 90 : 10 by weight gives the best results for its use in charge transfer electrophotography. The acceptance potential of the charged layer was found to be 1060 V and contrast potential of 740 V.

1. Introduction

Electrophotography is the science of document copying by the selective photodissipation of electrosensitized layers. A good electrophotographic material should have high initial acceptance potential and slow decay of surface potential in the dark but rapid decay under photo-excitation. Work on the electrophotographic characteristics of photo-sensitive organic [1] and inorganic materials [2, 3] is not new, but recent trends have been to use mixed binder layer systems, in which the independent characteristics of several photoconductors are combined in one layer by dispersing these as separate components into a suitable resin binder.

In the present studies a mixed system of two pigment powders, ZnCdS : Ag and Cd (S, Se) : Cu in polystyrene (PS) binder has been investigated for its use in electrophotography. Copper doped zinc cadmium sulphide when dispersed in an appropriate binder has been shown to exhibit good xerographic characteristics [4, 5]. Electrophotographic characteristics of ZnCdS : Ag have also been reported [6], but no work has been done on the mixed system of these pigments. CdS, CdSe and their solid solutions are well known photoconducting materials [7, 8]. Faria and Chiola [9] have reported copper activated Cd (S, Se) : Cu as a photoconducting material for electrophotography. The material is suitable for the canography (Cannon NP Process) technology [10] where high speed photoreceptors are required. Therefore a mixed system of these photoconductors in various proportions in polystyrene binder has been chosen, as this system is expected to give better electrophotographic properties than the individual components. Following electrophotographic properties have been studied to find out the suitability of this mixed system: (a) charge acceptance (b) surface potential decay characteristics in dark and light and (c) contrast potential.

2. Experimental details

Cadmium sulphoselenide, Cd (S, Se) : Cu pigment powder was obtained from Sylvania Inc. U.S.A. The work reported here was done using pigment samples from batch No. PC105 Lot No. PPP8673 IIT and with the specifications: $\mathrm{Cd(S_x : Se_{1-x}) : } x = 0.98$. The sample contained 200 p.p.m. copper. ZnCdS : Ag was obtained from NPL, India. The amount of silver in the sample was 100 p.p.m. The particle size of the materials was about 2 μm. Samples were prepared by dispersing the pigments in polystyrene (obtained from Sri Ram Institute of Industrial Research, New Delhi, India), dissolved in benzene to get a viscous solution. In the first set of samples (Table I) the pigment to resin ratio was kept at 70 : 30 (by weight). Layers were cast on clean aluminium substrates and were dried in the solvent atmosphere by slow evaporation. The slow rate of evaporation was essential to obtain a uniform and non-porous layer. The layers were then cured by heating in air inside an enclosed oven maintained at 50° C, for about 12 h, to remove the traces of benzene.

Another set of samples (Table II), was prepared by adding different proportions of polystyrene to the 90 : 10 composition of ZnCdS : Ag/Cd (S, Se) : Cu. The thickness of the layers was kept uniform at 80 ± 5 μm. All studies were conducted at 30° C and 50% r.h.

The electrosensitizing of pigment resin layers was accomplished by spraying the layer surface with ions produced by corona discharge from a scorotron unit [11]. The corona voltage, grid voltage and charging time were optimized before starting the experiment.

TABLE I Composition of samples

Sample name	Composition of ZnCdS : Ag/Cd (S, Se) : Cu (by weight)
a	100 : 00
b	90 : 10
c	80 : 20

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TABLE II Sample of 90:10 ZnCdS:Ag/Cd(S, Se):Cu with different binder content

Sample name	Binder content (by weight)
A	20
B	30
C	40

The optimum values of the above parameters were positive 7 kV, positive 1.5 kV and 50 sec charging time, respectively. The surface potential of the charged layers was measured using a cylindrical double walled vibrating probe [12] and monitored in both the light and the dark using an a.c. microvoltmeter (Systronics, India). The sensitivity of the probe was 5.1 V. A 200 W tungsten filament lamp was used to expose the samples. The intensity of illumination was kept 12.77 mW cm^{-2} throughout the experiment. The absorption curves Fig. 4 of the sample were obtained by means of a spectrophotometer (Pye-Unicam, SP8-100 ultra violet visible spectrophotometer.

3. Results and discussion

The variation of initial acceptance potential with grid potential and charging time is shown in Figs 1 and 2, respectively. It was observed that the initial acceptance potential increases with both charging time and the grid potential and attains a saturation value. The surface potential decay of corona charged layers in dark as well as in light is shown in Fig. 3.

It was also observed that the initial acceptance potential decreases with increasing amount of Cd(S, Se):Cu in the binder layer. But at the same time the dark photo decay rate increases with increasing amount of Cd(S, Se):Cu. These results can be understood on the basis of electrosensitization of polymer films. Nothing conclusive is known about the mechanism of corona-charging of polymers and photoconducting materials [13]. Carlson [14] and Baum *et al.* [15] have suggested the formation of double bonds ($>C=C<$) and of carbonyl groups ($>C=O$) in the corona exposed polymers, which act as trapping sites. The electron trapping by direct attachment of an electron to oxygen molecules of an oxide layer formed on the polymer surface on exposure to air and the presence of ozone in the corona [16] can also occur. Moreover, in the present experiment, ZnCdS : Ag and Cd (S, Se) : Cu have been dispersed in a polymer matrix. The phase boundaries thus created and the polymer side chain will provide additional trapping sites [17].

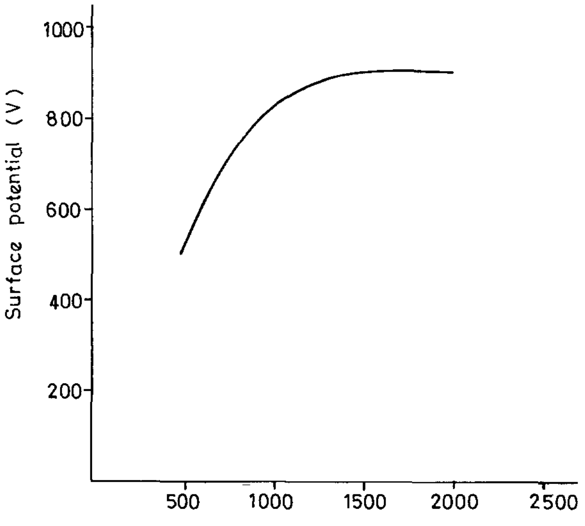

Figure 1 Effect of variation of grid potential on initial surface potential.

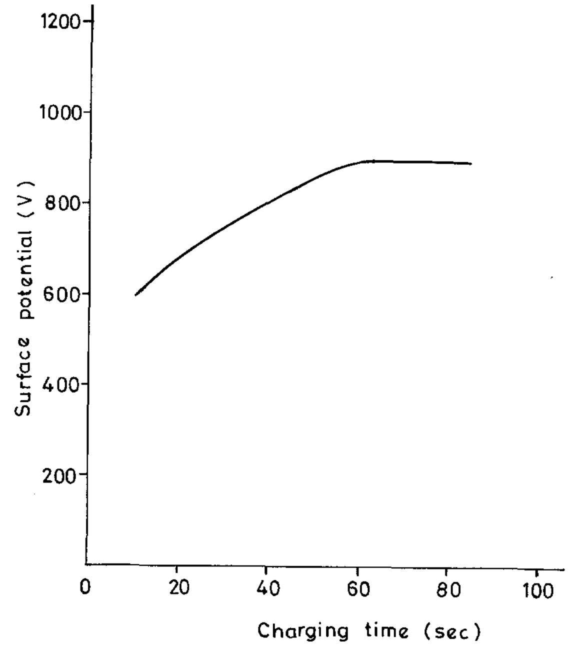

Figure 2 Effect of corona charging time on initial surface potential.

The charge carriers (holes during negative corona charging) coming from the metallic substrate can be trapped in them. These trapped holes create a high potential barrier and stop the further flow of holes into the film from the substrate, and hence a negative charging of polymer film takes place. Detrapping and recombination of charge carriers also takes place along with trapping when the two mechanisms (trapping and detrapping) are in equilibrium the film is charged to the maximum [18]. This is the reason that the initial charge increases with charging time at first and then attains a saturation value (Fig. 1). Increasing the grid potential means increasing the number of charge carriers reaching the film, and also their energy. This increases the surface potential with increasing grid voltage (Fig. 2). The dark resistivity of a photoconductive film is a decreasing function of the electrical field across the film. By increasing the grid potential, the decreased resistance of the film allows a greater amount of current to flow through the film, and as grid potential is further increased, a point is reached where charges leak away as fast as they are supplied and no further charging is possible.

The decrease in the initial acceptance potential of layers having higher amount of Cd(S, Se):Cu (samples b and c) may be due to the increase in the conductivity of these layers. This is also clear from the comparatively fast photo and dark decay of surface potential, with the increasing amount of Cd (S, Se) : Cu in the layers (Fig. 3 and Table III). This may be due to the fact that Cd(S, Se):Cu is a fast

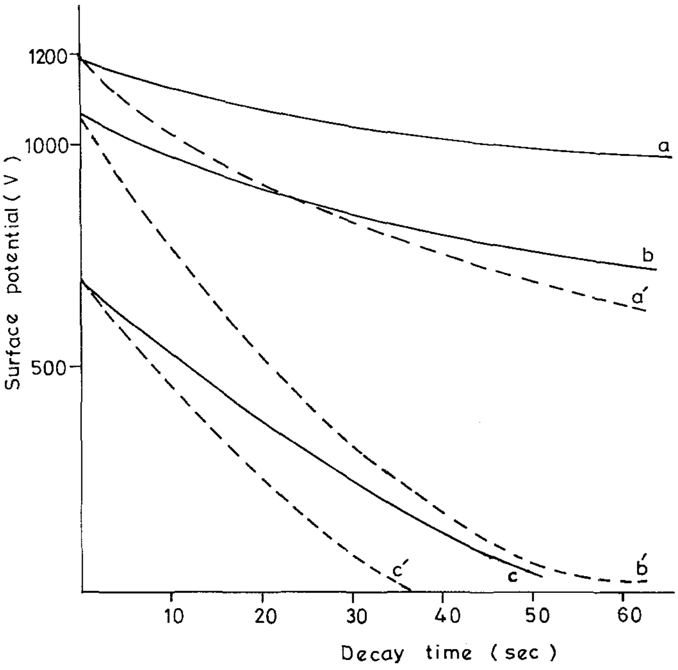

Figure 3 Dark and photo-induced decay characteristics of ZnCdS : Ag/Cd (S, Se) : Cu mixed system (Table I).

TABLE III Results obtained with various samples of ZnCdS : Ag/Cd (S, Se) : Cu mixed system

Sample	Initial acceptance potential (V)	Contrast potential 30 sec after start of illumination (V)	Fractional light decay after 30 sec (%)
a	1200	220	31.6
b	1060	520	69.8
c	700	160	87.1

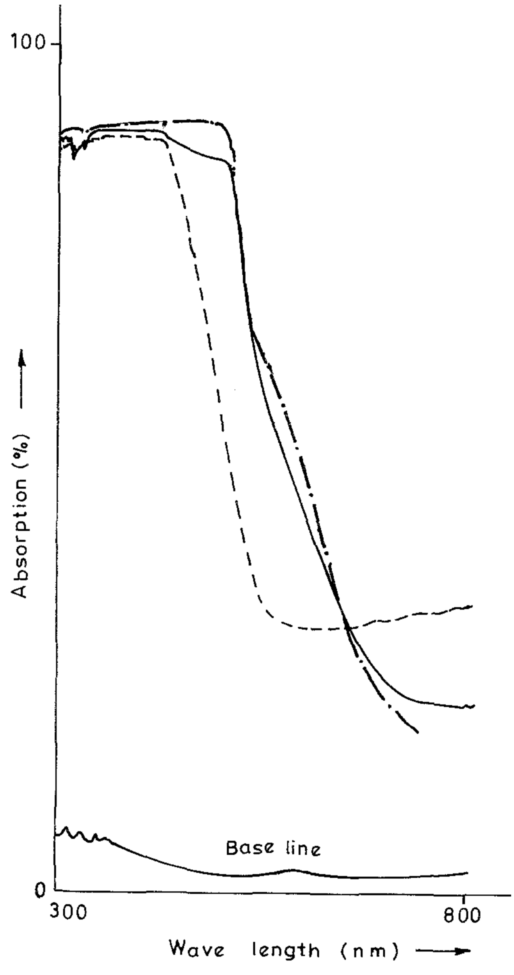

Figure 4 Absorption spectra for ZnCdS : Ag binder layer (– – –) Cd (S, Se) : Cu binder layer (–·–·–) and ZnCdS : Ag/Cd (S, Se) : Cu (90 : 10) binder layer (——).

photoconductor [9] and also the fact that the absorption in the visible region becomes almost flat (Fig. 4). The contrast potential at a particular time after charging the layer is defined by the difference of the surface potential in dark and light at that moment and is an important parameter in electrophotography. The contrast potential and fractional light decay for different mixed systems studied are given in Table III.

It was found that 90 : 10 ratio of ZnCdS : Ag/Cd (S, Se) : Cu mixed system shows the maximum values for contrast potential and fractional light decay. The fractional dark decay observed 60 sec after charging was found to be 29.24%. With higher percentage of Cd (S, Se) : Cu in the samples the charge decays very fast both in light and in dark, thus it gives a very low contrast potential. The contrast and the percentage residual potential for different exposure times for layer (b) are shown in Fig. 5. The sample (b) gives the maximum contrast of 740 V for 50 sec of light exposure, while the residual potential is only 6%.

This indicates that 90 : 10 weight ratio of ZnCdS : Ag/Cd (S, Se) : Cu may be useful for electrophotographic work. The percentage of binder was optimized by maintaining the 90 : 10 weight ratio of ZnCdS : Ag/Cd (S, Se) : Cu in the layers (Table III). The surface potential decay in dark and light are shown in Fig. 6. It was observed that initial acceptance potential increases with increase of polystyrene in the binder layers but at the same time their light decay becomes slow. This may be due to the increase in the resistivity of the layers because of higher binder concentration. This indicates that 30% weight ratio of

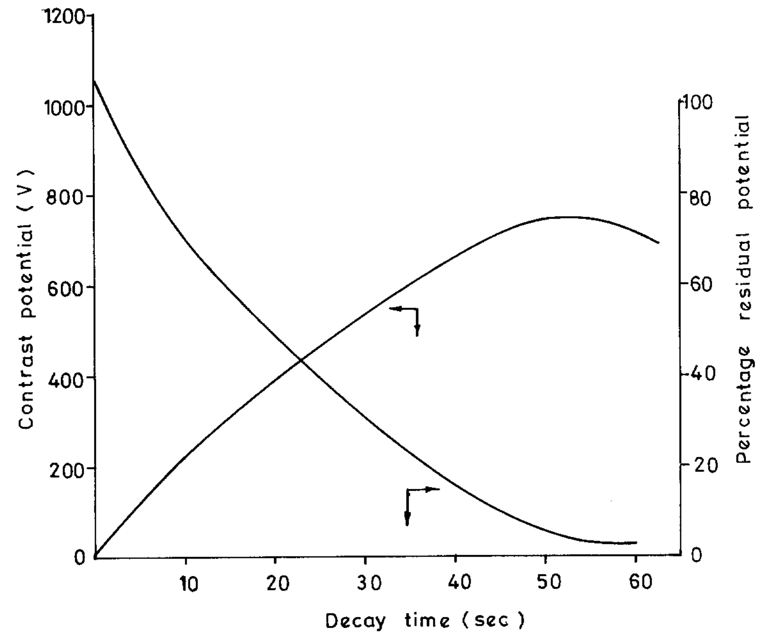

Figure 5 Contrast potential and per cent residual potential against decay time of 90 : 10 ZnCdS : Ag/Cd (S, Se) : Cu binder layer (pigment to binder ratio, 70 : 30).

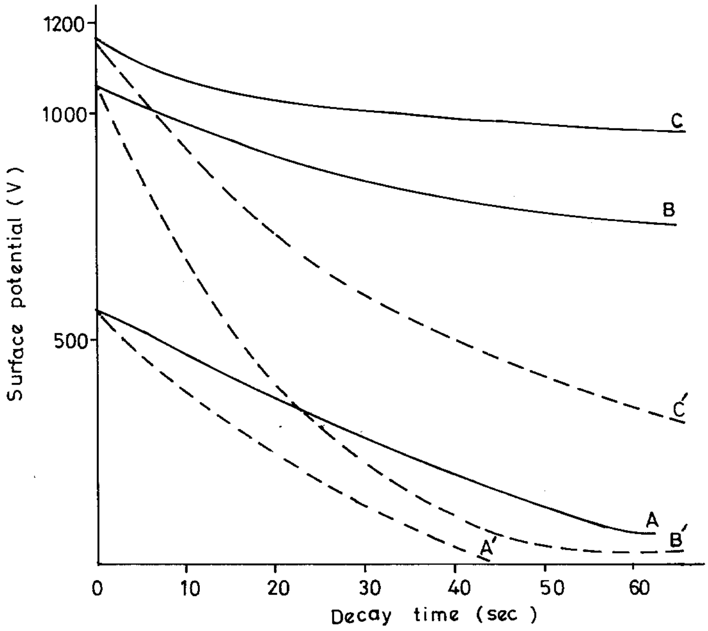

Figure 6 Dark and photo-induced decay characteristics of ZnCdS : Ag/Cd(S, Se) : Cu(90 : 10) layer with different binder contents (Table II) (——) dark decay; (– – –) photo decay.

the binder is optimum for electrophotographic work in this mixed system.

4. Conclusion

These results indicate that among the various systems studied the 90 : 10 ratio of ZnCdS : Ag/Cd (S, Se) : Cu mixed system gives the best results for electrophotographic work. When the pigment to binder ratio being 70 : 30. This mixed system has broad absorption response and can be used with conventional light sources available for xerography.

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