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Study of optoelectronic properties of Michler's ketone/Cd(S,Se):Cu double layer system for electrophotographic applications

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Xerographic properties of the double layer system consisting of Michler's ketone (tetramethyl diaminodiphenyl ketone) pigment–resin layer as the charge storage layer with an overlayer of photoactive Cd(S, Se):Cu as the top layer, have been investigated. The experiment shows that the charge carriers generated in Cd(S, Se):Cu could be injected into and transported through the Michler's ketone pigment–resin layer. Acceptance potential, fractional dark and photo-induced decrease, contrast potential and the relative spectral sensitivity are the important xerographic characteristics studied. The double layer shows a maximum surface potential of 844 V and 99.7% fractional decay of surface potential under illumination as calculated 10 sec after the start of illumination. The spectral sensitivity peaks of the system lie at 484, 534 and 591 nm in the visible region.

1. Introduction

Amorphous selenium and zinc oxide pigment–resin layers have dominated the two important electrophotographic techniques, namely, xerography and Electrofax* [1, 2]. Binder type xerographic films consist of photoconductive pigments dispersed in a suitable resin binder. The presence of insulating resin binder not only increases the charge acceptance of the xerographic film, but also offers greater freedom in the selection of photosensitive materials. In recent years, mixed layer and multilayer systems, utilizing the combination of the independent properties of several photoconductors have been receiving appreciable attention [3–8]. CdS, CdSe and their solid solutions are well known photoconductive materials [9, 10]. Faria and Chiola [11] have reported copper activated Cd(S, Se):Cu as a photoconductive material for electrophotography. It has been shown particularly suitable for canography (Cannon NP Process) technology [12], where high speed photoreceptors are required. Photoconductors with low dark resistivity can be used in NP electrophotography. However, photosensitive layers with rapid dark decay cannot be used in conventional electrophotography. The CdS–CdSe solid solutions have been found faster [3] than either constituent, indicating the effect of enhanced defect structure on photogeneration of carriers.

Michler's ketone has been studied for its xerographic properties [13]. In the present studies, a single layer of Michler's ketone, using polystyrene as binder, is found to exhibit slow photo-induced decay characteristics which are too slow to be used for xerographic applications. An overlayer of Cd(S, Se):Cu binder layer on Michler's ketone base layer provides tremendous enhancement of the xerographic properties of the system. The xerographic characteristics of Michler's ketone/Cd(S, Se):Cu double layer have been reported in this paper.

For brevity Michler's ketone and acrylonitrile–butadiene–styrene will be abbreviated as MK and ABS respectively.

2. Experimental procedure

A viscous resin solution of polystyrene dissolved in benzene was used as binder for the MK base layer.

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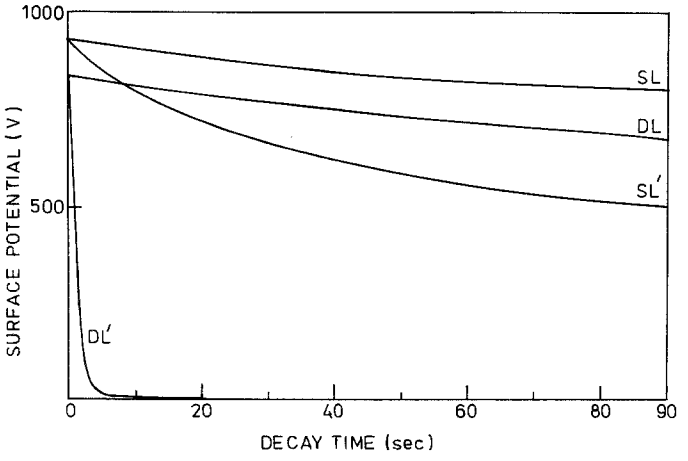

Figure 1 Dark and photo-induced decay characteristics for MK single layer (SL, SL') and Mk/Cd(S, Se):Cu double layer (DL, DL').

MK pigment powder (obtained from Polyscience Inc., Warrington, PA) was dispersed in this resin solution. It was then milled to form a homogeneous suspension of the pigments in the resin (50 wt % polystyrene). The layers were cast on clean aluminium substrates and were dried in a controlled solvent atmosphere by slow evaporation. Traces of solvent were removed by curing the samples for several hours in an oven maintained at 50° C. The thickness of the base layer was kept uniform at 130 μm. The coating thickness was measured with a micrometer accurate to 5 μm. Cadmium sulphoselenide, Cd(S, Se):Cu pigment was obtained from Sylvania Inc., USA. The work reported here was done using pigment powder with about 1.7% CdSe (by weight approximately 200 ppm copper, and about 3 wt % $CdCl_2$ of CdS). ABS was dissovled in a solution of acetone and benzene to obtain a resin solution for the overlayer. A homogeneous dispersion of Cd(S, Se):Cu pigment powder in ABS resin solution (30 wt % ABS) was then cast on the MK base layer. The double layer thus obtained was dried in a controlled solvent atmosphere and cured at 50° C. The thickness of the overlayer was kept 60 μm. The studies were conducted at 30° C and 50% humidity atmospheric conditions.

A scorotron unit [14] was used to charge the layers. The corona voltage, grid voltage and charging time were positive 7.5 kV, positive 1.5 kV and 60 sec, respectively. The surface potential of the charged layers was measured with the help of an especially designed hollow, cylindrical, double-walled vibrating probe [15] whose sensitivity was 5.1 V. A 100 W tungsten filament lamp was used to expose the samples. The intensity of illumination was 3.0 mW cm^{-2}. The wavelengths of the radiation were selected using Kodak narrow-band pass filters. The absorption spectra of the samples were taken with the help of a spectrophotometer. While calculating the relative spectral sensitivity, corrections were made to take into account the number of photons not absorbed by the samples and the interparticle scattering of light. The light reflected by the samples was measured for different wavelengths. Thus the relative spectral sensitivity per unit intensity of illumination absorbed by the samples was calculated for various wavelengths. The intensity of light was measured by means of a thermopile.

3. Results and discussion

The dark and photo-induced discharge characteristics of the Michler's ketone single layer (SL) and Michler's ketone/Cd(S, Se):Cu double layer (DL) are given in Fig. 1. The contrast potential against exposure plot for the DL is shown in Fig. 2. Fig. 3 depicts the relative spectral sensitivity of the double layer system as a function of wavelength, while the absorption spectra for the SL and DL are given in Fig. 4.

3.1. Charge acceptance

The charge acceptances is the maximum charge that can be applied to and retained by a photoconductive layer. Shahin [16], using mass spectrometer techniques, has proposed the chemical changes in the surface of the polymer as a result of corona charging. However, the exact nature of the charging on the polymer surface is not yet certain. The surface potential of the charged single layer in the present case was 930 V. However the surface potential for the double layer was 844 V. This shows the effect of a low dark resistive Cd(S,

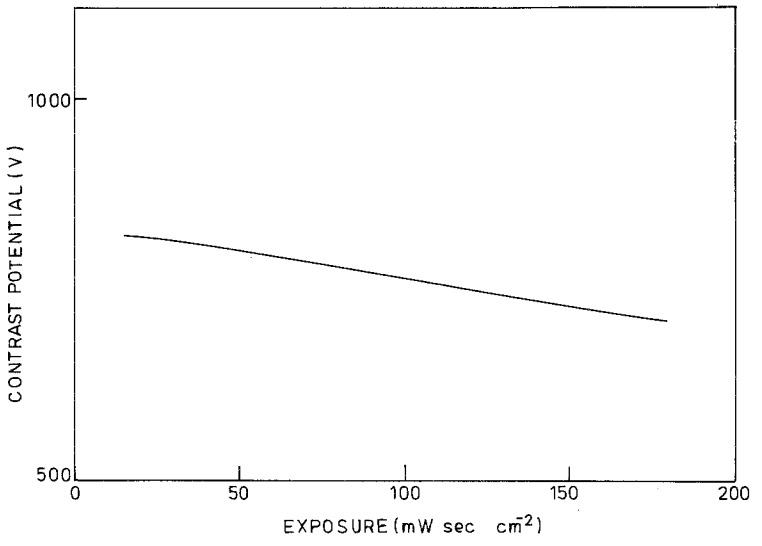

Figure 2 Contrast potential against exposure plot for the double layer.

Se):Cu overlayer on the Michler's ketone base layer.

3.2. Dark and photo-induced decay

The charge of a charged photoconductive layer decays slowly in the dark due to detrapping of carriers in the surface states. Because of the low dark resistivity of Cd(S, Se):Cu the dark decay rate of the double layer becomes faster as compared to that of the single Michler's ketone layer. The fractional dark decrease in the surface potential was 11.9 and 14.8% for single layer and double layer respectively as calculated 60 sec after the charging of the layers. On exposure, the charge carriers are generated in the photoactive Cd(S, Se):Cu layer and are transported through the Michler's ketone layer. The sensitivity to light is markedly increased. The fractional decrease in the surface potential, as calculated 10 sec after the start of illumination, were 13.3 and 99.7% for the SL and DL, respectively. The intensity of illumination was 3.0 mW cm^{-2}. The residual potential for the double layer becomes almost zero in 15 sec.

3.3. Contrast potential

The difference in electrostatic potential between dark and light areas is known as the contrast potential. For the double layer, the contrast potential was 816 V as observed 10 sec after the start of illumination. In 90 sec the contrast potential becomes 655 V. Hence it remains considerable up to 150 mW sec cm^{-2} exposure.

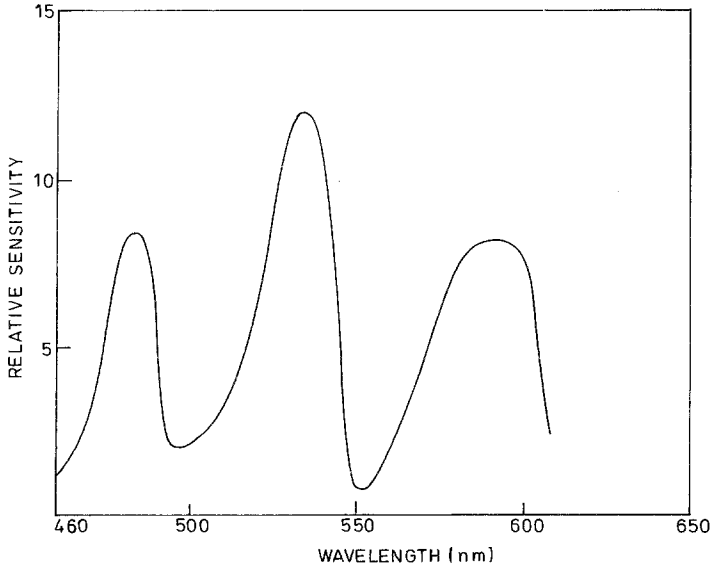

Figure 3 Relative sensitivity as a function of wavelength for the double layer.

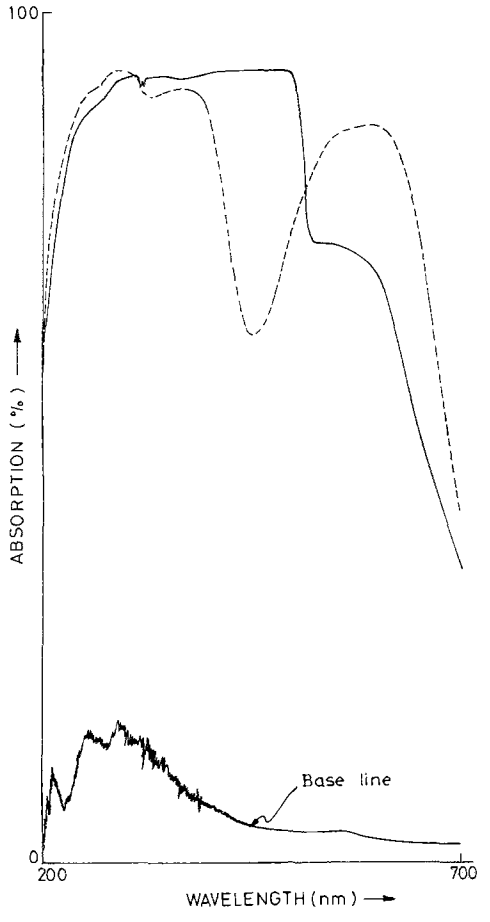

Figure 4 Absorption spectra for MK layer (dashed line) and MK/Cd(S, Se):Cu double layer (solid line).

3.4. Spectral sensitivity

The photosensitivity of a xerographic layer is related to the rate of charge decay under illumination with light of a given intensity and a given wavelength band. This rate, in turn, depends upon the quantum efficiency for exciting charge carriers to a conduction state, the mobility of charge carriers, the absorption of incident light within the layer, and upon the energy per photon as determined by the wavelength or range of wavelengths of incident radiations. The spectral response was calculated here using the parameter

$$S_\lambda = \frac{C\Delta V_f}{I_\lambda t_h}$$

where C is the capacitance per unit area, ΔV_f is the change in surface potential at half decay time, I_λ is the intensity of illumination absorbed by the sample, and t_h is the half decay time. The spectral sensitivity peaks of the system lie at 484, 534 and 591 nm. The absorption spectrum of the MK layer shows sensitivity in the UV region, a dip at about 450 nm and another peak in visible region. the absorption spectra of Michler's ketone binder layer using polystyrene as binder (Fig. 4) and using polycarbonate as binder [13], show a definite peak in the visible region. The maximum absorption in the double layer system occurs in the 200 to 500 nm region (above 90%) and then up to 620 nm (about 70%) (Fig. 4). Fig. 3 shows the relative spectral sensitivity of the double layer in the visible region. The peak at 534 nm is the characteristic absorption band of CdS and that at 591 nm is mainly due to CdSe and the effect of copper on the matrix. The 484 nm peak can be attributed to the absorption in the double layer which is quite high at this wavelength. The sensitivity of the double layer is thus spread over a wide range up to 600 nm.

4. Conclusions

The double layer system of Michler's ketone and Cd(S, Se):Cu is found to have improved xerographic properties. The acceptance surface potential was 844 V. Under the illumination (3.0 mW cm^{-2}), the fractional decrease in surface potential 10 sec after the start of illumination was 99.7%. The system shows tremendous photosensitivity. The double layer has broad absorption response and can be used with the conventional light sources available for xerography.

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