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# Electrophotographic characteristics of michlers ketone in polycarbonate binder layers

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Surface potential decay characteristics of corona-charged michlers ketone (MK) and polycarbonate (PC) binder layers have been studied for their utility in electrophotography. The effects of illumination intensity and of temperature on the acceptance and contrast potentials and on the half-decay time of the surface potential have been investigated. The 30:70 MK:PC binder layer is suitable at 33° C, while at lower temperatures (23° C) a higher percentage of MK in the binder layer is required. These layers show a contrast potential of 700 V and the residual potential is less than 10%. The spectral sensitivity of the binder layer has also been determined.

## 1. Introduction

Document copying in electrophotography is done by the electrostatic image of the document formed on a corona-charged layer by selective photodissipation of charge. The characteristics required of a film for its use in electrophotography are: high charge acceptance; dark retentivity; and rapid decay of surface potential when exposed to light. Inorganic photosensitive materials as such, or in binder layers, are generally used in xerography [1, 2] but it has been observed that the thin films of organic photosensitive materials dispersed in polymer binder are also suitable for this purpose [3, 4]. The polymer binder, because of its low conductivity, gives rise to high charge acceptance and its retention in the dark. Commercially this is a more viable proposition, because of the relatively low costs of the polymer and the photosensitive material, compared to ultrapure selenium or ZnO.

The present paper deals with the electrophotographic characteristics–acceptance potential, half-decay time, contrast potential and residual potential–of michlers ketone (MK) in polycarbonate (PC) binder layers.

## 2. Experimental procedure

Solution-cast films of michlers ketone (obtained from Fluka AG, Switzerland) and polycarbonate (obtained from Bayer, FR Germany) were made on an aluminium substrate. The two substances taken in weight proportion, were dissolved in methylene chloride. By controling the viscosity of the solution, different samples of the same thickness were obtained. The films were initially dried in the solvent atmosphere and later baked in an oven maintained at 65° C to remove the traces of solvent. These films were preserved in a desiccator to avoid any contamination and were taken out only for taking readings.

The films were placed on a grounded platform, which could be moved under a corona unit as well as under the charge-measuring probe, without handling disturbances. A hollow cylindrical aluminium probe [5] for charge measurement and a d.c. corona unit for negative charging of the film were used in the present experiment. The charged samples were exposed to an ordinary 250 W tungsten bulb. The light intensity was varied by changing the bulb-to-sample spacing and was monitored by a luxmeter.

The different samples used in this experiment were 10:90, 20:80, 30:70, 35:65, 40:60 and 50:50 in weight proportions of michlers ketone and polycarbonate, respectively. The film thickness was 160 $\mu$m. Charging and all other observations were done in ambient conditions and are referred to as dark decays unless specified otherwise. The

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room-temperature and relative humidity were 23° C and 65 %, respectively.

## 3. Results

The initial surface potential, half-decay time and contrast potential for different MK:PC ratios are given in Table I. It can be seen that the acceptance potential decreases with the increase of MK in the layer. The half-decay time decreases and contrast potential increases up to a 30:70 MK:PC ratio. Above this ratio the half-decay time increases and the contrast potential decreases, with increase of MK percentage in the film.

Fig. 1 shows the absorption spectra of the 20:80 MK:PC binder layer. The layer shows almost 100% absorption for ultra-violet light. The absorption for 608 nm is about 60%.

The effect of intensity of illumination on the surface-potential decay is shown in Fig. 2. An almost linear relationship is observed between the illumination intensity and half-decay time.

The temperature dependence of the initial surface potential and the dark and photo decay of surface potential are shown in Fig. 3 for a 45:55 MK:PC layer. It is evident from the figure that the initial potential and contrast potential are higher at lower temperatures, and even this ratio can be used for electrophotography at lower temperatures. The exposure time required for this ratio is 20 sec for a contrast potential of 800 V. The residual potential is less than 6%.

The contrast potential and percentage residual potential for different exposure times are shown in Fig. 4.

## 4. Discussion

At atmospheric pressure the negative corona consists of $CO_3^-$ ions followed by hydrated species of this ion $CO_3^-$ $(H_2O)$ and also $O_3^-$, $NO_2^-$ and $O^-$ [6]. In addition to these ions, the corona discharge contains reactive molecules (Ozone) and ultra-violet light which subject the polymer to mechanical and chemical changes. Carlson and Wiles [7] and others [8] have observed the formation of a double bond (>C=C<) and the carbonyl group (>C=O) in the corona-exposed polymer, which act as trapping sites. The diffused oxygen, carbon dioxide and water molecules provide additional trapping sites [9]. Besides these the unsaturation sites along the main chain of the polymer and grain boundaries, crystal defects act as traps in the bulk [10, 11]. During negative corona charging, the incoming negative ion injects an electron in the film which becomes localized at these trapping sites. The high-energy ions can also produce carriers as a result of direct collision with bound electrons in the bulk, which later become trapped there. The charge carriers coming from the metallic substrate (holes during negative charging) because of the high field during corona charging, are also trapped, thus creating a high potential barrier for the further inflow of holes into the film. Detrapping and recombination of charge carriers also take place along with trapping and when the two processes are in equilibrium the film is charged to the maximum acceptance potential [12].

The maximum absorption in these films, as shown in Fig. 1, takes place in ultra-violet light. The absorbed light produces charge carriers, which take part in the electrical conduction. The generation of electron-hole pairs, as a result of ultra-violet light produced during corona charging, will increase with increasing amount of michlers ketone in the film. The generated holes will neutralize some of the trapped negative charges while the electrons discharge at the metallic substrate and in the process may lower the potential barrier that is being formed by the holes coming from the metallic substrate. This could possibly

TABLE I Surface-potential decay of MK:PC binder layers at 330° C (intensity of illumination 6000 lux)

| Sample number | Sample MK:PC | Initial surface potential (V) | Photoexcitation | |
|---|---|---|---|---|
| | | | Half-decay time (sec) | Contrast potential after 5 sec (V) |
| 1 | 10:90 | 1300 | 8 | 200 |
| 2 | 20:80 | 1150 | 5 | 525 |
| 3 | 30:70 | 1040 | 1.5 | 700 |
| 4 | 35:65 | 750 | 2.5 | 350 |
| 5 | 40:60 | 600 | 3.5 | 300 |
| 6 | 45:55 | 580 | 4.5 | 320 |
| 7 | 50:50 | 525 | 6 | 250 |

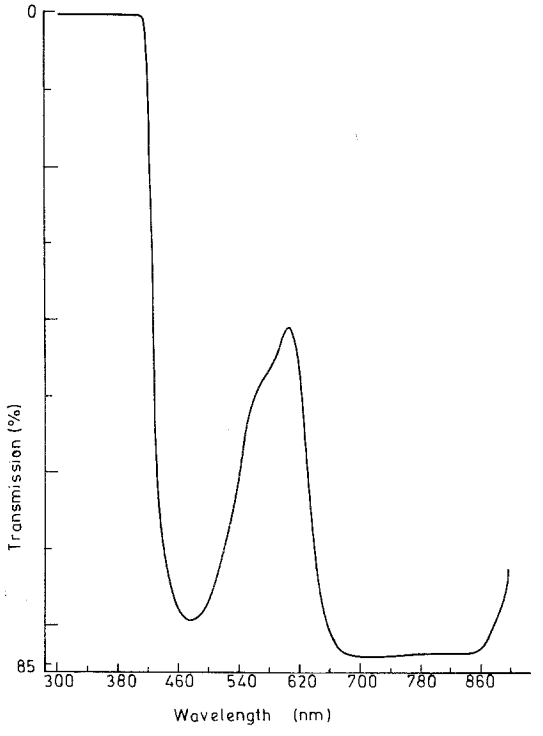


*Figure 1* Absorption spectra of the MK:PC binder layer.

be the mechanism for the lowering of acceptance potential with increase of michlers ketone in the film.

The lowering of acceptance potential with increase in temperature (Fig. 3) may be due to the thermal detrapping from shallow trapping levels and recombination, and also the temperature dependence of mobility [13].

The decay of the surface potential has been measured in an open circuit and under these conditions the total current (sum of the displacement and conduction currents) is zero. The charge escaping from the surface traps is injected into the insulator under the field of the remaining trapped charge. The surface traps control the carrier injection and the bulk traps their transport. The rates of injection and bulk conduction are not equal, and hence a space charge develops until equilibrium is established, yielding an almost constant surface potential. This agrees well with the dark and photo surface potential decay curves and suggests the presence of bulk traps.

The half-decay time, i.e. the time in which the initial surface potential decreases to half, is governed by the number of charge carriers produced during exposure and their transport in the film. The free carrier generation will depend on the light intensity, its absorption and the carrier's recombination and trapping, while the transport is controlled by the carrier mobility and the presence of traps in the bulk. Thus the higher the light intensity, the faster will be the surface-potential decay (Fig. 2).

Generally a faster decay rate and hence a lowering in the half-decay time is expected with increase in the percentage of michlers ketone in the layers for this will increase the number of photo-generated carriers. But the increase in half-decay time with increase in michlers ketone could be explained on the basis of assuming the carrier mobility to be field dependent [14]. The initial potential and, consequently, the field, decreases considerably with the increase of michlers ketone percentage in the film. This reduces the mobility of charge carriers. Moreover, the smaller the carrier

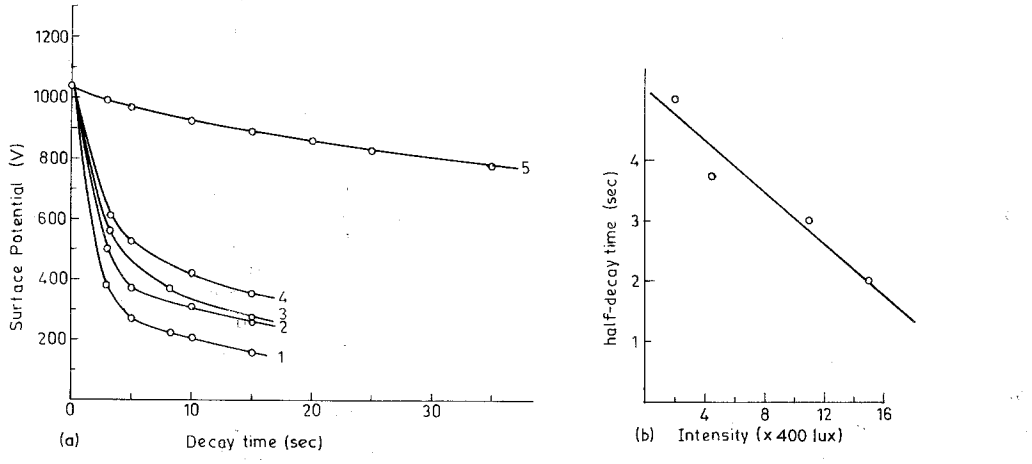


*Figure 2* (a) Surface potential decay of 30:70, MK:PC binder layer. Intensity of illumination (1) 6000 lux, (2) 4400 lux, (3) 1800 lux, (4) 800 lux, (5) ambient light. (b) Variation of half-decay time with intensity of illumination.

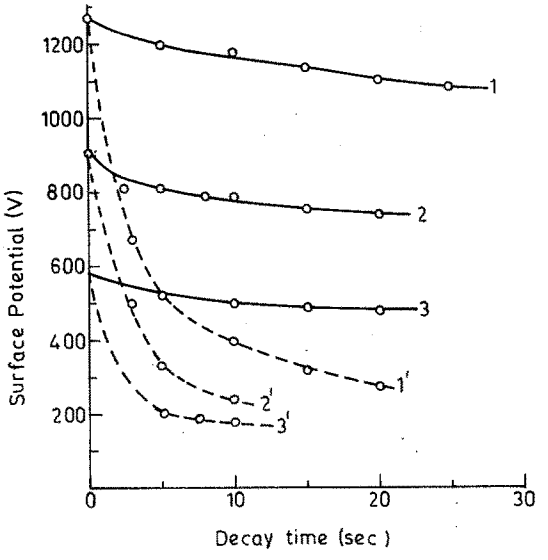


*Figure 3* Surface-potential decay of a 45:55 MK:PC binder layer at different temperatures. Continuous lines show dark decay, while dashed lines show decay at 6000 lux intensity; (1) 23° C, (2) 27° C, (3) 33° C.

mobility the greater the chances of their becoming trapped in the bulk [15]. This, in addition to increasing the half-decay time, gives rise to residual potential. The persistence of polarization (i.e. residual potential) even after 20 sec photo-excitation, also confirms that the carriers are being trapped in deeper levels in the bulk of the film, where the photo-release is not effective [12].

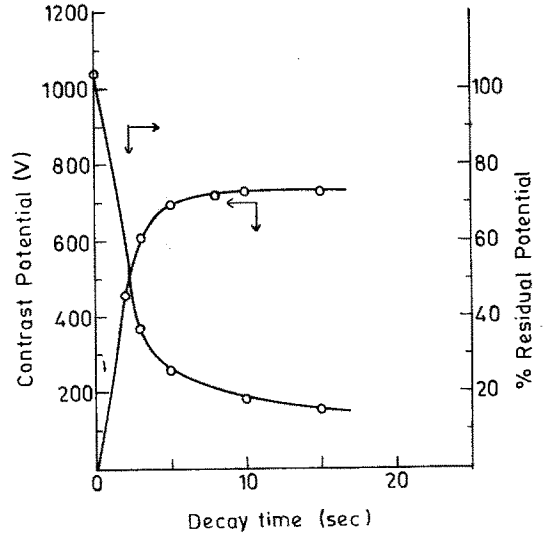


*Figure 4* Contrast and residual potential for different exposure times for 30:70 MK:PC layer. Intensity of illumination is 6000 lux, Temperature: 33° C.

A contrast potential of at least 400 V is required for the electrostatic image development [12]. The 30:70 weight proportion of MK:PC, as shown in Table I, gives a contrast potential of 700 V in a 5 sec exposure at 33° C. At lower temperatures even higher ratios of MK:PC give contrast potentials of this order, but for higher exposure times.

## 5. Conclusions

It is clear from these observations that depending upon the film temperature, 30 to 45% proportion by weight of michlers ketone in the polycarbonate binder layer is good for electrophotography. The recommended wavelength is 608 nm as the absorption for this wavelength is 60%, i.e. high enough to produce charge carriers. Since light of this wavelength will penetrate deep in the film to generate charge carriers there, it will thus be effective in reducing the bulk polarization [12]. This will also reduce the background effect in the print.

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