

Effect of Titanium Dioxide Dopping on Charge Trapping in Polystyrene Films

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ABSTRACT

The charge storage properties of corona charged pure and TiO₂ doped polystyrene (PS) films have been studied. Thermally stimulated charge decay and open circuit thermally stimulated charges were measured. A half-value charge decay temperature $T_{1/2} \cong 140^{\circ}\text{C}$ is optimum at 3 wt % TiO₂ doping. This implies that charge trapping predominantly occurs at deep traps in 3 wt % TiO₂ doping. X-ray diffraction scanning method was employed to obtain structural information.

KEY WORDS

Titanium dioxide, Dopping, Charge, Polystyrene

1.0 INTRODUCTION

Charge storage has been studied in many polymers, because of its application in devices such as microphones, gas filters, underwater transducers, radiation dosimeters and piezo- and pyroelectric detectors (Sessler and West, 1987). A major contribution to the charge storage in polymers can come from charge trapping at the crystalline amorphous interfaces, at chain foldings, in the cavities and at the impurities and/or additives (Ieda, 1984). The crystalline amorphous interfaces have been postulated to provide deep traps (Davies, 1972) and contribute predominantly to the charge storage stability. Therefore any effect on crystalline amorphous interfaces can alter charge storage stability.

Since in amorphous polymers deep trapping at the crystalline-amorphous boundaries will be absent, therefore doping with appropriate deep trap dopant can be effective in increasing the charge storage stability. It has been shown that doping polyarylate (Nath and Perlman, 1990) and polyethylene (Perlman and Haridoss, 1987) with titanium dioxide (TiO₂) make them good charge storers. In view of this, titanium dioxide (TiO₂) was added to polystyrene to improve its charge storage properties. In this paper, studies of charge storage properties in pure and doped polystyrene films are reported. The experiments employed in the study were thermally stimulated charge decay (TSCD) and thermally stimulated currents (TSC). X-ray diffraction scan of PS was analysed for structural information.

2.0 EXPERIMENT

A homogenous and transparent benzene solution of PS (2g of PS in 50 cm³ of benzene) was poured onto a plane glass plate, kept in an oven maintained at 60°C for 24 hours in a benzene atmosphere. This enabled slow evaporation of benzene and resulted in a smooth and quite uniform transparent layer of solvent cast polystyrene film. Since the adhesion of PS film to the glass substrate is poor, the film could be detached easily and its thickness measured by a micrometer screw gauge. PS films of thickness about 40µm were prepared by this method. The films were heated at 100°C for 3 hours after detachment to remove all traces of the residual solvent. For obtaining TiO₂ doped films, TiO₂ was mixed in different proportions (1, 2, 3, 5 and 10 wt %) in benzene solutions of PS. The mixed solution was homogenised by prolonged shaking at 60°C and the films were prepared by the same process as in case of pure PS. Samples of 2 cm diameter were cut from the films. Aluminium electrodes of thickness 50 nm and 2.54 cm² were vacuum deposited on one surface (back electrode) of the samples.

The samples were negatively corona charged through the non-metallized surface for 120s at room temperature. The corona voltage was maintained at -8kV and the surface potential was controlled with the help of a grid kept at a negative potential and held \cong 4 mm over the surface of the sample (Fig. 1).

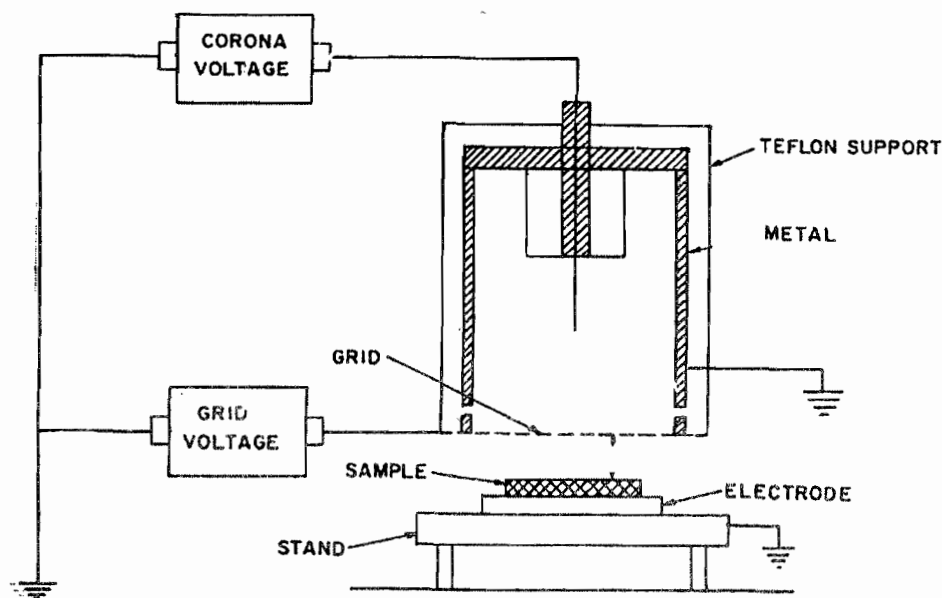


Figure 1: Schematic of corona production

For open circuit TSC measurement, the upper non-contacting electrode was at a distance 4 mm from the sample. TSCD and TSC measurements were carried out in the temperature range 20 to

170°C at a constant heating rate of 3°C/min (Fig. 2(a) and (b)). Using a programmable digital temperature controller (model 1570, Digitech, Roorkee, India). A Monroe 180 probe electrostatic voltmeter model 170-1 with probe was used to measure the surface potential. The TSCD and TSC were recorded on a strip chart recorder. X-ray diffraction scan was obtained with a Philips PW 1710 diffractometer, using Ni filter CuK_α radiation of wavelength 0.154 nm.

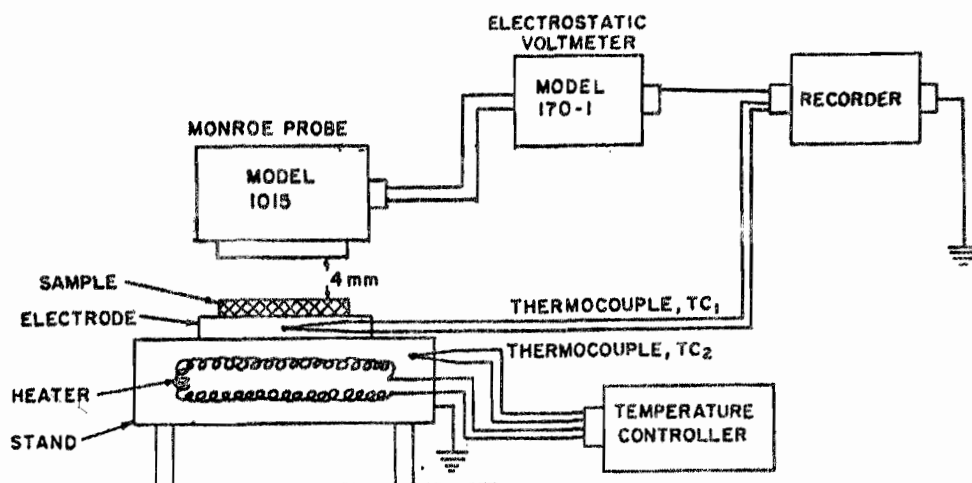


Figure 2 (a): Schematic of Thermally Stimulated Charge Decay (TSCD)

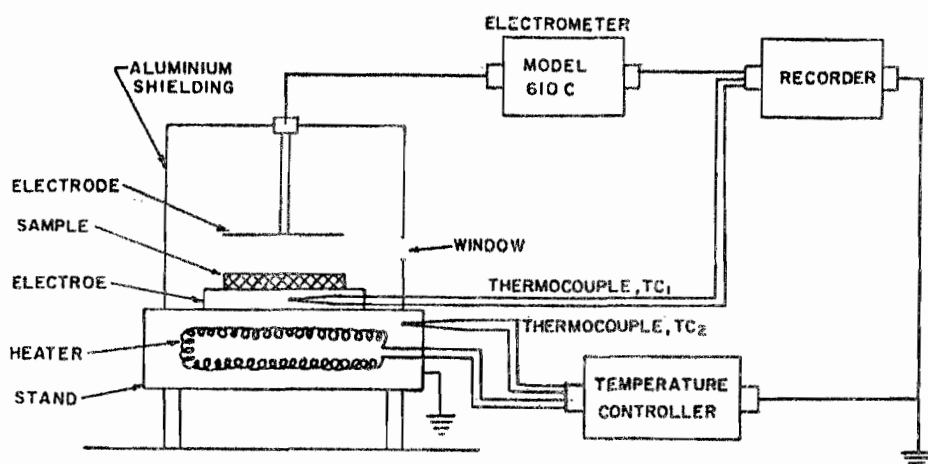


Figure 2 (b): Schematic of open-circuit Thermally Stimulated Charge current (TSC)

3.0 RESULTS AND DISCUSSION

Figure 3 shows X-ray diffraction for pure PS. No peaks are observed and this shows that PS has amorphous phase only. Therefore the crystallinity effects on charge storage can be neglected and the polymer can be used as a matrix for studying dopant traps.

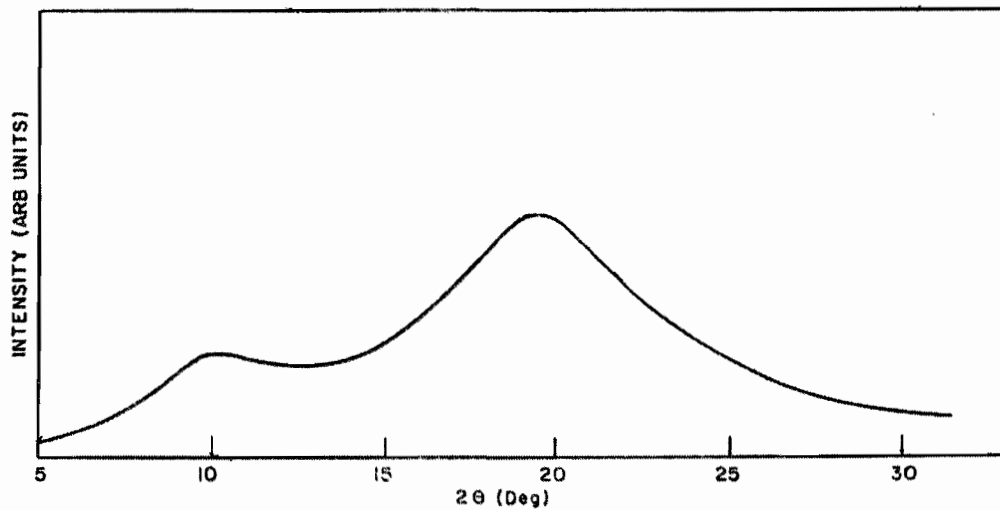


Figure 3. X-ray diffraction scan of Pure Polystyrene (PS)

Fig. 4 shows stimulated charge decay (TSCD) characteristics of pure PS (curve a) and 1, 2, 3, 5 and 10 wt % doped PS (curves (b), (c), (d), (e) and (f) respectively). The films were negatively corona charged to a field of 10^5 V/cm. The arrow in each curve indicates the half-value temperature, $T_{1/2}$ (temperature at which initial surface potential decays to half value) of the respective curve. These half-value temperatures are shown in Fig. 5.

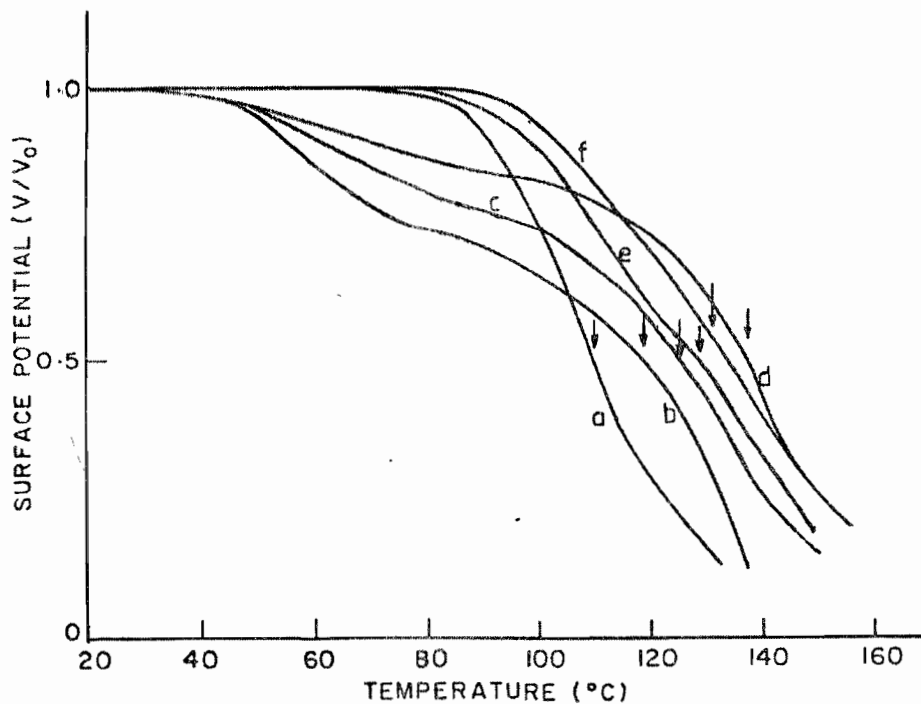


Figure 4. TSCD characteristics of pure PS (curve a), 1, 2, 3, 5, and 10 wt % titanium dioxide doped Polystyrene (curves b, c, d, e and f respectively).

Fig. 5 shows variation in $T_{1/2}$ with doping level. The optimum increase in $T_{1/2}$ (28°C) was obtained at 3 wt % Titanium Dioxide doping level. At high doping levels (above 3 wt %) aggregation of the dopant particles may occur, providing fewer interfaces for deep trapping. More of the charge would then fall into shallow traps yielding lower $T_{1/2}$ values.

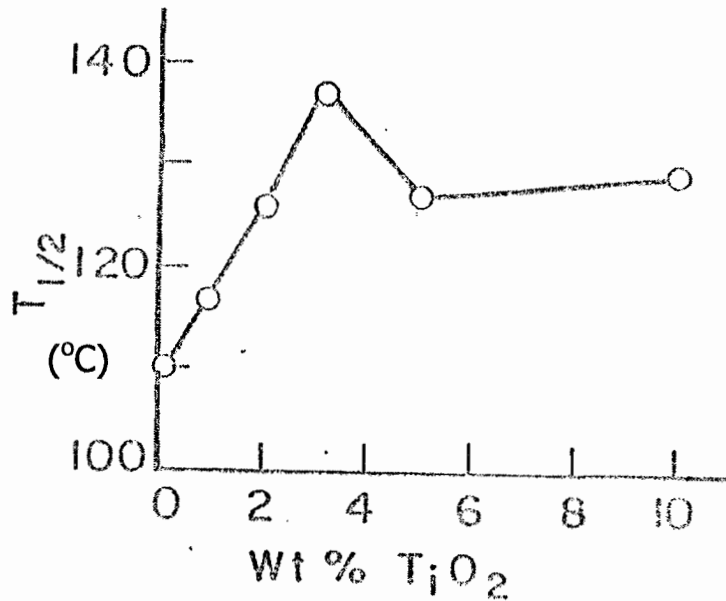


Figure 5. Variation of half-value temperature ($T_{1/2}$) ($^\circ\text{C}$) with level of doping

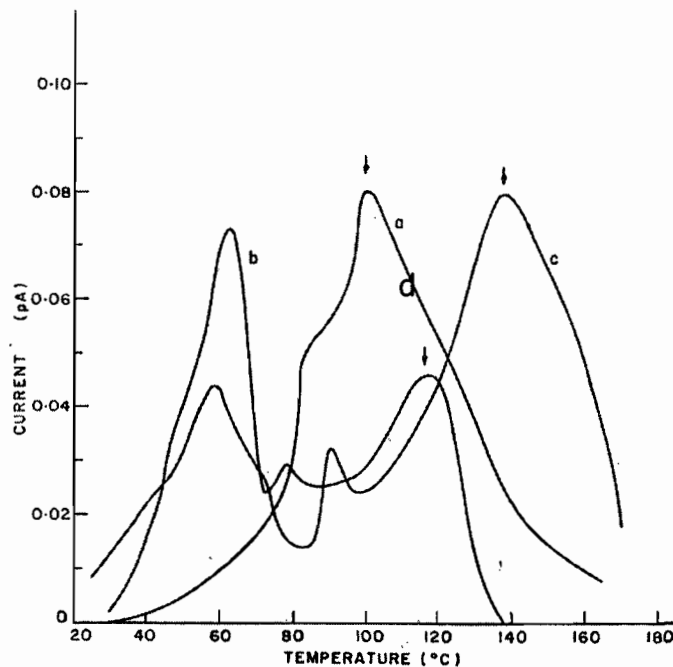


Figure 6. Open circuit TSCs of pure PS (curve a) and 1 and 3 wt % titanium dioxide doped PS (curves b and c respectively).

Fig. 6 shows comparison of open circuit TSCs of pure PS (curve a) and 1 and 3 wt % titanium dioxide doped PS (curves (b) and (c) respectively). The samples were corona charged to initial field 10^5 V/cm at room temperature. The TSC of pure sample (curve a) showed a shoulder at 80°C and a peak position at 100°C . Similar peaks have been observed by others (Singh and Datt, 1985) at nearly the same temperature. The shoulder at 80°C has been attributed to shallow charge trapping (Singh and Datt, 1985; Eve, 1985) while the peak at 100°C is attributed to relaxation related to glass transition (Perlman and Haridoss, 1987; Singh and Datt, 1985; Eve, 1985). In the TSCs of TiO_2 doped PS (Fig. 6 curves (b) and (c)) the shift in the 100°C peak of pure PS towards higher temperature is observed (120°C for (b) and 140°C for (c)). Other observed peaks in the TSCs of the doped PS (fig. 6 curve (b), peak at 80°C and curve (c), peaks at 60°C and 90°C) have been explained in terms of shallow charge trapping and relaxation related to glass transition temperature (T_g) (Perlman and Haridoss, 1987; Singh and Datt, 1985; Eve, 1985). The T_g of PS is 95°C (Hall, 1989). A qualitative examination of TSCs (Fig. 6) shows that the area under the high temperature peak (140°C) of 3 % TiO_2 doped sample is more compared to that of curve (b). This implies that charge trapping predominantly occurs at deep traps in 3 % TiO_2 doped sample. The temperature peak in the latter can be due to either pigment-matrix boundaries and/or the titanium dioxide itself can provide deep traps (Nath and Perlman, 1989).

5.0 CONCLUSION

Thermally stimulated current (TSC) and thermally stimulated charge decay (TSCD) studies were done on pure and Titanium Dioxide doped polystyrene show that, polystyrene can be made good charge storer by doping with 3 % TiO_2 and that dopant-matrix boundaries and/or the dopant itself can provide deep traps.

Consequently Titanium Dioxide enhances the charge storage capabilities of polystyrene.

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