Grafting of Polypropylene Fibers. II. Electrokinetic Properties of Grafted Polypropylene Fibers

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Synopsis

Electrokinetic properties of methacrylic acid- and acrylonitrile-grafted polypropylene fibers measured in the presence of cationic dyes are reported. The zeta potential of polypropylene fibers decreases, and the surface charge density along with surface conductivity increases as the concentration of the dyes in the streaming solution increases. The zeta potential at pH 7 decreases as the amount of graft increases in case of both acrylonitrile- and methacrylic acid grafted fibers. Both surface charge density and surface conductivity increase with the increase in dye concentration for both acrylonitrile- and methacrylic acid-grafted fibers. The results are explained on the basis of the cationic dye adsorption on the grafted fiber in the case of methacrylic acid graft. In the case of acrylonitrile-grafted fibers, this could be due to the strong attraction of cationic dye to the nitrile group of the grafted fibers.

INTRODUCTION

The mechanism of interaction between the functional groups of the textile substrate and the dye ions can be understood by the study of electrokinetic properties. Japanese workers studied the electrokinetic properties of polypropylene fibers in presence of γ-rays, surface-active agents, and cationic dye solutions.[1-3] They found that γ-irradiation produces reactive negatively charged dissociating groups in the polymer through peroxidation. Among the halogenated fibers, the fluorinated polypropylene possessed the highest negative zeta potential. We have reported earlier the electrokinetic properties of graft-modified polyester fibers in the presence of dyes and also as a function of pH.[4,5] Here we are presenting some of the electrokinetic properties of methacrylic acid- and acrylonitrile-grafted polypropylene fibers measured in the presence of cationic dyes and the results are discussed.

EXPERIMENTAL

Materials. The process of grafting of polypropylene fibers using γ-irradiation has been reported earlier and the material so obtained was used in these studies.

Dyes. The following purified dyes were used

1. Sandocryl Blue B 3 G (C.I. Basic Blue 3)
2. Sandocryl Red B 6 B (C.I. Basic Violet 16)
3. Sandocryl Orange B G (C.I. Basic Orange 21)

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Measurement of electrokinetic properties. The electrokinetic properties such as zeta potential, surface charge density, and surface conductivity were measured using the procedure adopted in our earlier communication.[4]

RESULTS AND DISCUSSION

The electrokinetic properties of pure polypropylene fibers are shown in Table I.

The plot of zeta potential vs. the precent graft of methacrylic acid onto polypropylene is shown in Figure 1. The plots of zeta potential, surface charge density, and surface conductivity as a function of dye concentration in the

TABLE I
Electrokinetic Properties of Polypropylene Fibers at Different Cationic Dye Concentrations of Streaming Solution

Cationic dye	Concentration of the dye solution ($M \times 10^{-5}$)	Negative zeta potential, (mV)	Surface charge density, (esu/cm^2)	surface conductivity, (ohm^{-1} cm^{-1} $\times 10^{-6}$)
—	—	62.52	16.85	−0.134
Sandocryl Blue	1	38.67	25.31	+0.478
B3G	10	15.71	34.64	−3.270
Sandocryl Red	1	42.89	29.24	−2.298
B6B	10	12.61	40.20	−8.518
Sandocryl Orange	1	39.61	27.02	−0.274
BG	10	16.40	39.91	−0.633

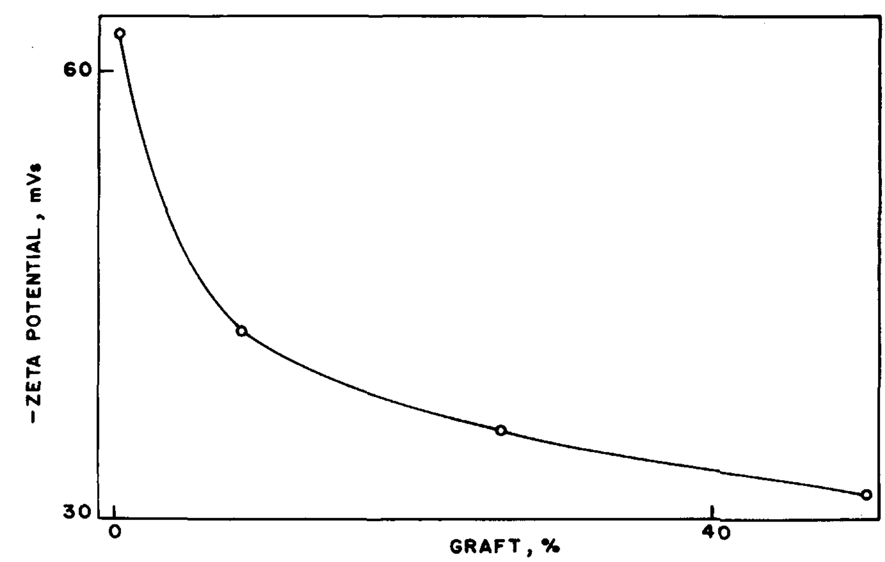

Fig. 1

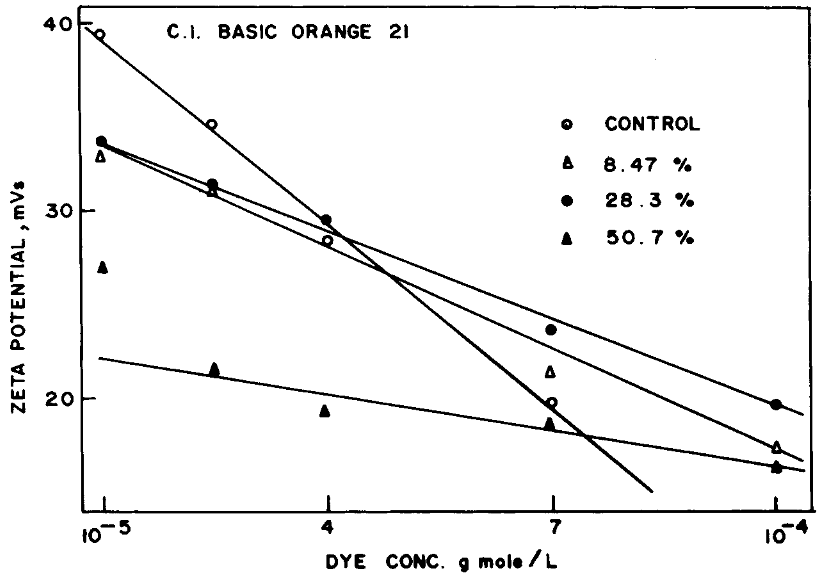
C.I. BASIC ORANGE 21
CONTROL
8.47 %
28.3 %
50.7 %
ZETA POTENTIAL, mVs
40
30
20
10^{-5}
4
7
10^{-4}
DYE CONC. g mole / L

Fig. 2

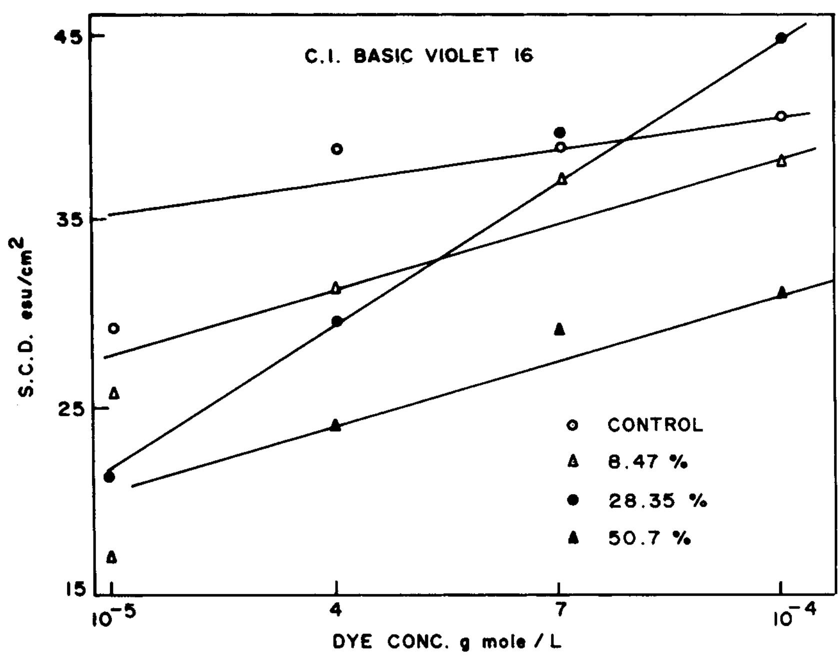
C.I. BASIC VIOLET 16
CONTROL
8.47 %
28.35 %
50.7 %
S.C.D. esu/cm²
45
35
25
15
10^{-5}
4
7
10^{-4}
DYE CONC. g mole / L

Fig. 3

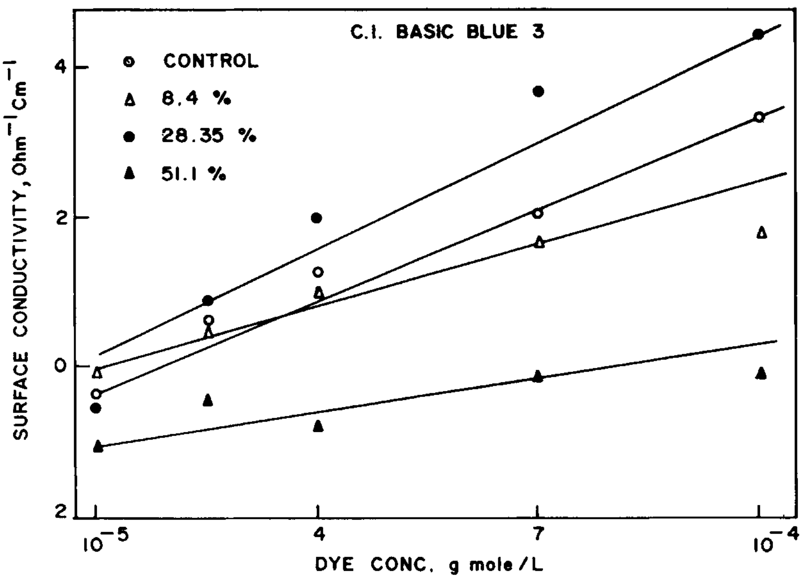

Fig. 4

streaming solutions are shown in Figures 2 to 4 for methacrylic acid-grafted polypropylene and Figures 5 to 7 for acrylonitrile-grafted fibers. Figures 8 and 9 show a linear relationship between surface charge density and zeta potential for the two monomers grafted onto polypropylene.

The mechanism of interaction between the functional groups of the substrate and the dye ions can be understood by the study of electrokinetic

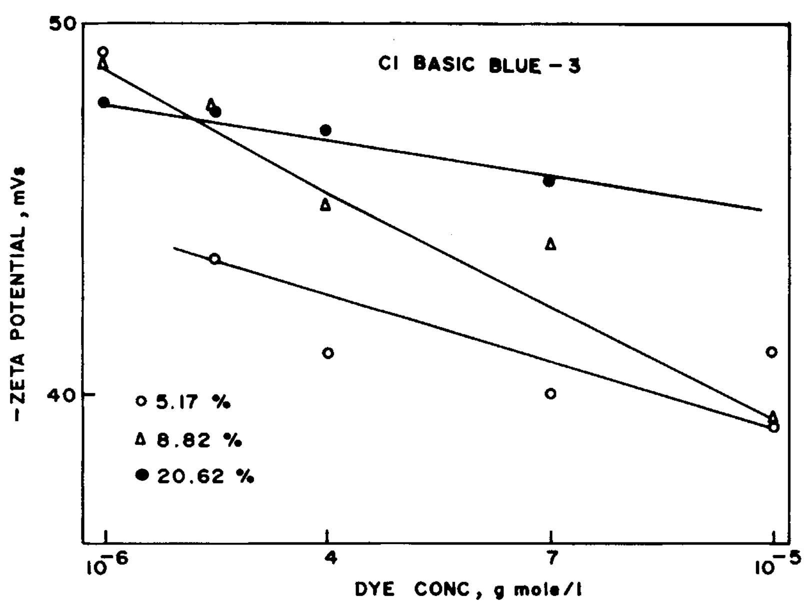

Fig. 5

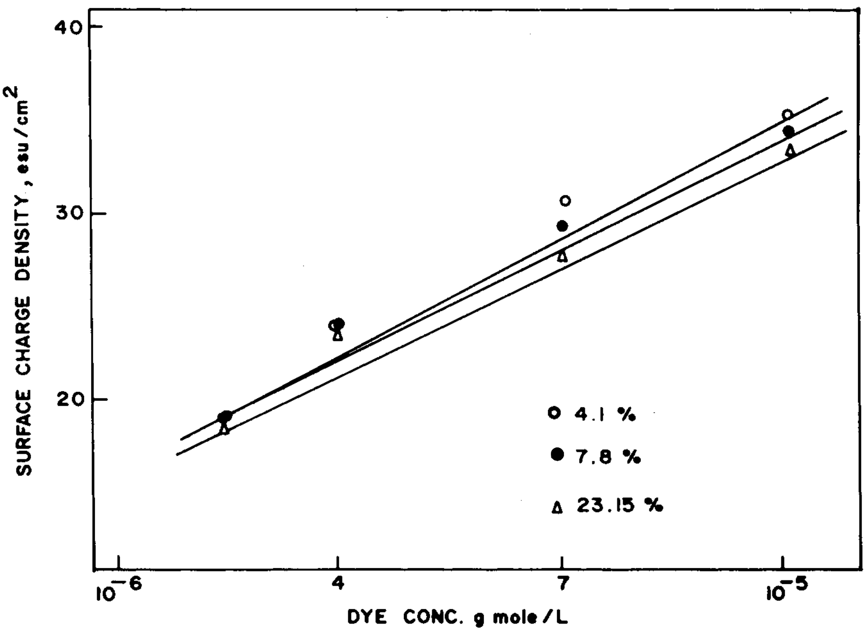
40
30
20
SURFACE CHARGE DENSITY, esu/cm²
4.1 %
7.8 %
23.15 %
10⁻⁶
4
7
10⁻⁵
DYE CONC. g mole/L

Fig. 6

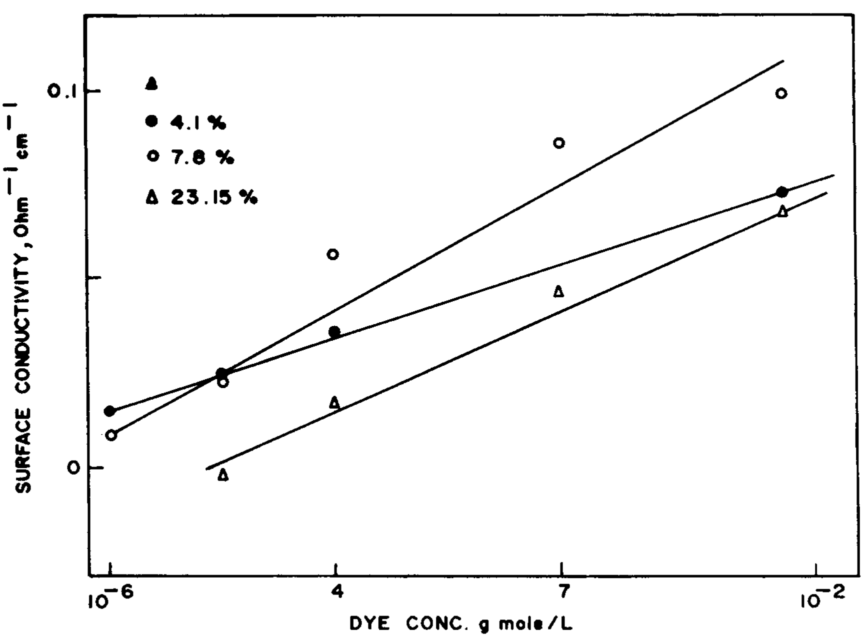
0.1
0
SURFACE CONDUCTIVITY, Ohm⁻¹ cm⁻¹
4.1 %
7.8 %
23.15 %
10⁻⁶
4
7
10⁻²
DYE CONC. g mole/L

Fig. 7

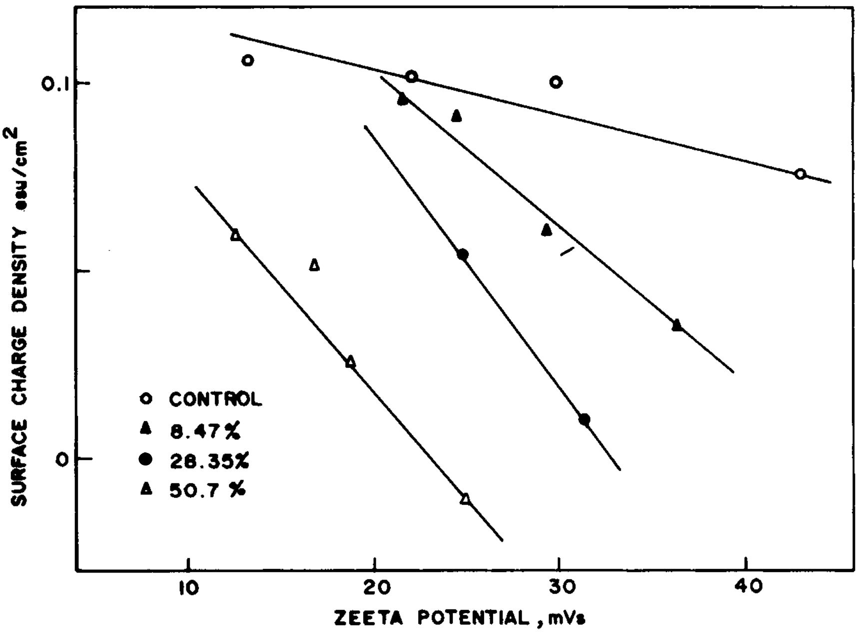

Fig. 8

properties. The adsorption of dye at the grafted groups can also be understood by the study of these properties.

From Figure 1, one can see that, with respect to methacrylic acid, the zeta potential decreases initially at a faster rate followed by a slow rate with the increase in the amount of graft in the fiber. In case of acrylonitrile-grafted

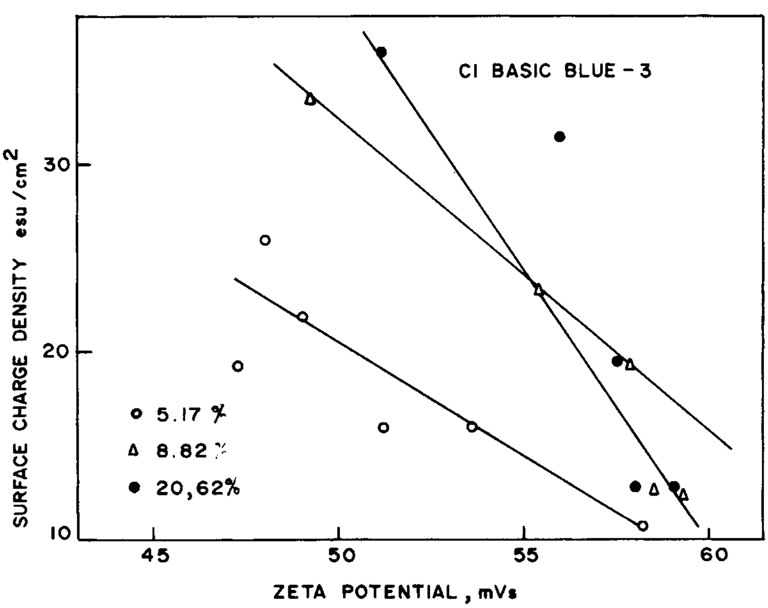

Fig. 9

fibers, an almost linear decrease in the negative value of zeta potential was observed with the increase in the amount of graft.

In general, the grafting of vinyl monomers induces opening of the structure of the fibers, as well as hydrophilicity, especially in case of the methacrylic acid-grafted polypropylene fibers. The combined effect is perhaps seen in the decrease in the amount of negative zeta potential of these fibers. It can also be seen that for the methacrylic acid-grafted polypropylene fibers, the decrease in the negative value of zeta potential is greater compared to acrylonitrile-grafted polypropylene fibers when the dye solutions were streamed through. The decrease in the negative value of zeta potential may be attributed to the specific adsorption of the dye cation at methacrylic acid groups in the fibers, thereby reducing the negative value of zeta potential. The dye absorption will be higher at higher amounts of graft as shown in Figure 2.

Figure 3 shows the relationship between surface charge density and dye concentration for methacrylic acid graft. The surface charge density increases with the increase in the amount of the dye in the solution which shows that fiber surface is made more and more charged as more and more cations are taken by the fiber at the methacrylic acid sites. Surface conductivity showed similar behavior for grafted polypropylene fibers (Fig. 4). It can seen from Figure 8 that a good correlation exists between surface charge density and zeta potential.

Even with acrylonitrile-grafted fibers, the negative value of zeta potential decreases with the increase in the concentration of the dye in the streaming solution (Fig. 5). The negative zeta potential is higher for higher amounts of graft. The nitrile group of acrylonitrile possesses strong attraction for cationic dye, and therefore, the zeta potential decreases.

Surface charge density vs. dye concentration plot is shown for a typical case in Figure 6 and a positive slope is observed. Similar behavior is also seen with respect to surface conductivity and dye concentration as shown in Figure 7. The introduction of nitrile group in the fiber structure increases the adsorption of the dye cations, and in turn, increases the surface charge density and surface conductivity. Surface charge density and zeta potential have shown a linear relationship in the case of acrylonitrile (Fig. 9).

CONCLUSION

In conclusion, both the surface charge density and surface conductivity increases, while the negative value of the zeta potential decreases with increase concentration of the dye in the streaming solution for both acrylonitrile- and methacrylic acid-grafted polypropylene fibers. This is explained as being due to strong adsorption of the cationic dye onto methacrylic acid-grafted fiber, however, it could be due to strong attraction between the dye and the nitrile group of acrylonitrile-grafted fibers.

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