

Conducting Polymer Surface Dynamics

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Polymers can be used to treat fibres and films to change their wetting characteristics; poly(ethylene oxide) seems to show an orientational effect on fibres: electrical resistivity, charge decay time constant and contact angles are compared.

The modification of polymer fibres, films and sheets to improve their electrical, adhesion and wetting characteristics is of enormous commercial importance.¹⁻⁷ The adhesion and wetting characteristics of materials are of importance in areas such as polymer composites, biomedical polymers, textile fibres, printing blankets, protective coatings, biocompatibility, porous films, carpet fibres and wood.

The tribological properties of these materials have important implications to static charging and the electrostatic damage to electronic industries is of the order of billions of pounds per year. Photochemical and chemical grafting of hydrophilic polymers such as poly(hydroxyethylmethacrylate) and poly(acrylamide) have been reported to modify the electrostatic charging character of poly(propylene).¹

The wetting characteristics of a surface can be examined by means of a technique called 'dynamic contact angle' (DCA) or more commonly 'Wilhelmy' technique. In this technique, the wetting force at a solid-liquid-vapour interface is recorded using an electromicrobalance as a function of depth of immersion (or time) of a solid sample, typically a flat solid, sheet, film or fibre. While the solid sample is held in a fixed position by the electrobalance, the wetting liquid contained in a beaker scans along the solid at a constant predetermined speed *via* a computer controlled stage. The meniscus formed at the interface is characterised by θ , the dynamic contact angle. Contact angles are measured in two directions, in one direction as the stage moves up, advancing the liquid across the solid surface and in the opposite direction as the stage moves down, receding the liquid across the previously wetted surface denoted by θ_a and θ_r respectively. The difference between these two contact angles ($\theta_a - \theta_r$) is known as contact angle hysteresis and is a unique property of a surface. Modification of surfaces can be studied using the DCA technique.

The surface modification of some Nylon 6 and poly(propylene) fibres with an ionic conductor [poly(ethylene oxide) (PEO) plus iron(III) sulfate], are described along with conductivity, charge decay and contact angle measurements.

The fibres were immersed into a 1% (m/m) aqueous solution of PEO (MW 4000000) for 5 min and then dipped into an iron(III) sulfate aqueous solution [0.5% (m/m)] and dried at 90 °C *in vacuo* for 18 h.

The coated fibres were woven into a mat form and the surface resistivity measured using a ring probe according to BS 2782. The charge decay measurement was carried out by means of the charge decay instrument (JCISS, John Chubb Instrumentation). The dynamic wetting characteristics were determined by means of the Wilhelmy technique (Model DCA 322, Cahn Instruments Inc. 16207, Carmenta Road, USA). The contact angles were measured in distilled water in advancing and receding modes. Table 1 summarises the

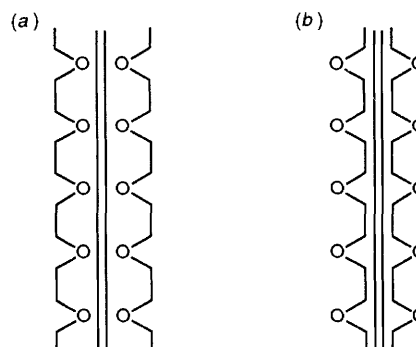


Fig. 1 Orientation of poly(ethylene oxide) in relation to (a) nylon and (b) poly(propylene) fibres

Table 1 Electrical and contact angle data for polymers and modified polymers

Material fibre	Surface resistivity/ Ω	Charge decay time constant/s	Advancing contact angle ($^\circ$)	Receding contact angle ($^\circ$)
Virgin nylon	$(1.0 \pm 0.5) \times 10^{10}$	(1.0 ± 0.1)	71	32
Virgin poly(propylene)	$(1.0 \pm 0.5) \times 10^{11}$	$(3.0 \pm 0.5) \times 10^2$	88	64
PEO-treated nylon	$(5.0 \pm 4.0) \times 10^{12}$	$> 5 \times 10^2$	88	66
PEO-treated poly(propylene)	$(6.0 \pm 3.0) \times 10^9$	$(1.0 \pm 0.5) \times 10^{-1}$	60	51

electrical and wetting characteristics of the materials concerned.

It was surprising to note that the PEO treatment on the nylon fibres makes the fibres hydrophobic and electrically more resistive, whereas the reverse was observed for poly(propylene) fibres. This is explained on the basis of the specific orientation of poly(ethylene oxide) chains around the fibres [see Figs 1(a) and (b)].

It appears that poly(ethylene oxide) orients around the Nylon 6 (polyamide) fibres as shown in Fig. 1(a) because of possible charge transfer interaction or hydrogen bonding with the oxygen atom of PEO and the hydrogen atom on amido group of nylon backbone, thus, exposing the hydrophobic (CH_2)-groups on the surface. On the other hand, poly(propylene), which is hydrophobic interacts with the 'ethylene' moieties thus exposing the hydrophilic-O-group on the surface.

Figs. 1(a) and (b) thus help explain the enhanced hydrophobic properties of PEO-treated nylon fibres (contact angle $\theta_a = 88$ and $\theta_r = 66^\circ$) in comparison to the virgin fibres ($\theta_a = 71$, $\theta_r = 32^\circ$). The dramatic increase in the surface resistivity of PEO-treated nylon can also be explained on the basis that oxygen atoms of the nylon are no longer available (Fig. 1) for interaction with the atmospheric moisture which enhances conduction.

The dramatic decrease in the surface resistivity of PEO-treated poly(propylene) can be best understood with the help of Fig. 1 where the oxygen atoms on the PEO chains are

available for interaction with atmospheric moisture. The PEO-treated poly(propylene) fibres also become more hydrophilic [θ_a (virgin) = 88, θ_a (treated) = 60°] as oxygen atoms are now available for interaction with water possibly via hydrogen bonding.

The surface resistivity data are consistent with the dynamic contact angle data in that the hydrophilicity is important for the conduction in PEO as it is an ionic conductor and the moisture in the atmosphere enhances the conduction.

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