

Light-Induced Modulation of Contact Electrification with Reactive Polymers

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Abstract— It is currently not possible to exert real-time, dynamic control over the sign and magnitude of contact electrification. This gap in knowledge and capability is an important problem because it limits the effectiveness of technologies such as anti-static materials, and prevents the development of new technologies that could use the large electric fields generated by contact electrification. This talk will present a strategy for controlling contact electrification using a combination of photoreactive acrylic polymers and light. Reversible (isomerization of azobenzene and spiropyran) photoreactions dynamically modulate the rate, and depending on chemical structure, the sign of charge separation by contact electrification.

Introduction

The technologies currently available to control the charging of insulators by contact electrification are limited. Approaches such as increasing conductivity by weaving conductive fibers or topical antistatic treatments can inhibit the accumulation of charge by contact.[1, 2] Materials such as charge-control agents help to ensure that the sign of charging of insulators is consistent and predictable.[3] These methods, however, do not allow for real-time, dynamic control over the rate and/or sign of charging. In addition, irreproducibility of the results of charging remains a major impediment towards establishing structure-activity relationships for the study of the mechanisms of tribocharging.[4] This paper summarizes results in our laboratory that have centered on using photochromic polymers to reversibly change the rate, and depending on chemical structure, the sign of contact electrification.[5]

I. BACKGROUND

Photochromic molecules reversibly change from one chemical structure **A** to another, often isomeric structure **B**, upon irradiation with light.[6] Conditions for reversal from **B** to **A** depend on the particular photochrome being used, but usually are either irradiation with a different wavelength of light, or thermal (including room temperature) equilibra-

tion. The two photochromic isomers often have very different colors—a primary commercial application of them is in color-changing eyewear. In addition to changing color, the structural change induced upon irradiation often gives a molecule with very different hydrophobicity. There have been several literature reports that raise the possibility of a connection between the hydrophobicity of a material and its propensity to develop positive or negative charge during contact electrification—hydrophobic materials apparently tend to charge negatively, while hydrophilic materials tend to charge positively.[7] We therefore reasoned that the interconvertible isomers of photochromic materials might show vastly different contact electrification characteristics.

II. RESULTS AND DISCUSSION

We prepared a series of random acrylic copolymers that contained the same spiropyran moiety, with polymer containing either a different comonomer or a different percentage of spiropyran monomer. Upon isolation by precipitation, we found that each polymer, either in solution or as a spun cast thin film, turned blue or purple upon irradiation with UV light, consistent with the known behavior of spiropyrans to photochemically convert to the more hydrophilic merocyanine. Irradiation with visible light, or treatment at elevated temperatures ($\sim 60\text{ }^{\circ}\text{C}$) for one hour caused the sample to revert to colorless. The advancing and receding water contact angles, also changed reversibly upon irradiation to reflect a more hydrophilic surface.

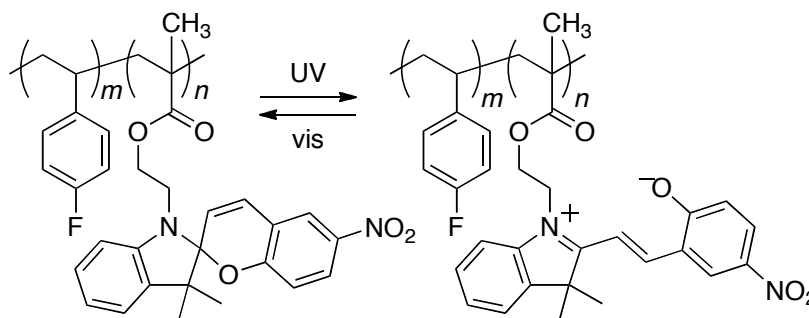


Fig 1. Chemical structure of photochromic polymer that switches sign of charging upon contact electrification with steel.

Upon irradiation with UV light, a steel sphere rolling on a film of a random copolymer of 25 mol% spiropyran and 75 mol %4-fluorostyrene (Figure 1) switched the sign of charge that it developed by contact electrification: before UV irradiation, it charged positively, while it charged negatively after UV irradiation. All the other spiropyran polymers we prepared showed qualitatively similar behavior. Whether the a sphere rolling on them charged positively or negatively before irradiation, the sphere charged negatively after irradiation, with a significantly faster rate of charging after the UV treatment. Figure 2 summarizes the results of initial rate of charging as a function of chemical structure.

Consistent with the known behavior of spiropyran, the switching of charging behavior of these films was reversible: upon irradiation with visible light or heating at $60\text{ }^{\circ}\text{C}$ for ~ 1 hour, steel sphere rolling on the again colorless film showed charging behavior similar

to that before irradiation. This observation confirmed that the change in charging behavior was due to the spiropyran-merocyanine conversion, instead of irreversible photooxidation or other decomposition process. In addition, non-photochromic homopolymers did not show any significant change in charging upon identical conditions of UV irradiation. We also note that the direction of charge switching upon irradiation was consistent with the expected result: the more hydrophilic merocyanine had a greater propensity to charge positively.

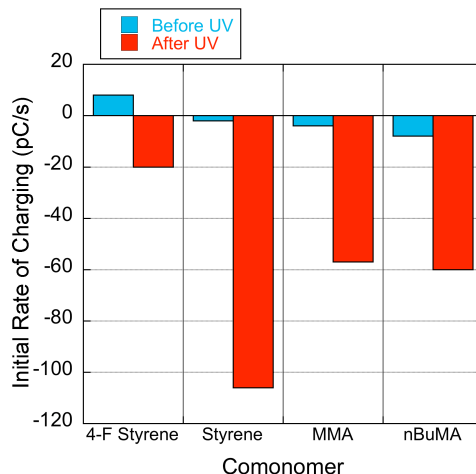


Fig. 2. Initial rate of charging of a steel sphere rolling on different copolymers of spiropyran. Irradiation with UV light to form the more hydrophilic merocyanine causes the steel to increase its rate of negative charging.

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