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Triboelectrification of granular insulating materials as affected by dielectric barrier discharge (DBD) treatment

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ABSTRACT

The aim of this paper is to point out the influence of dielectric barrier discharge treatment on tribocharging of granular insulating materials. Particles of Polyvinyl Chloride (PVC) and Polypropylene (PP) were subjected to an AC dielectric barrier discharge (DBD) plasma treatment in ambient airprior to tribocharging in a vibratory device. The charge to mass ratio was measured for treated and untreated materials. Electrostatic separation of a mixture of granular materials (PVC and PP) to measure the effectiveness of DBD treatment was evaluated by processing treated and untreated PVC/PP granular mixtures in a free-fall electrostatic separator. The obtained results clearly indicate that DBD has the capability to influence surface charging proprieties of polymer granular materials. In case of short treatment time, typically less than 3 s, a marked increase in the charge to mass ratios was observed for both PVC (about 35%) and PP (roughly 45%). In the same way, the quantity of DBD-treated materials, recovered after electrostatic separation, was increased by about 104% and 30% for PVC and PP, respectively, as compared to untreated case. The DBD treatment time is a key factor to increase the tribo electric effect.

1. Introduction

Triboelectricity is one of the earliest observed, but also less understood electrostatic phenomena [1–3]. Until recently, triboelectrification of insulating materials was perceived mainly as a source of electrostatic hazard [4–6]. Nowadays, the triboelectric effect is more and more employed as a charging mechanism in several electrostatic applications, such as: separation of polymer materials [7–9], energy harvesting [10,11], triboelectric based sensors [12,13]…etc. In such applications, the charge acquired by the materials has a major influence on the outcome of the process. Therefore, it is very important to enhance the tribocharging capability of the processed materials.

Tribocharging occurs when two different materials are separated after having exchanged electric charges during their contact [14]. In the process, one material acquires positive and the other negative charges. Despite the important number of studies devoted to triboelectricity, the mechanism of charging by contact (and friction) between insulators seems to be still unclear. Indeed, several issues are still poorly understood, like the nature of the charge carriers exchanged during contact, the role of friction, of contact pressure, of ambient conditions and so on. In this day, triboelectrification of insulators is tentatively explained by three mechanisms: electron transfer [15], ion transfer [16] and transfer of charged material between the bodies in contact [17]. Understanding these mechanisms would help to improve, or inversely eliminate, the triboelectric effect.

The electrostatic separation of granular insulating mixtures is the result of the combined action of mechanical and electric forces [18]. Therefore, the triboelectric charge carried by the granules should be as high as possible so that the electric Coulomb force could overcome the mechanical and gravitational forces and consequently better separate the constituents of the mixture. Previous carried studies on electrostatic separators have already tried to improve the tribocharging devices and optimize their operation. One solution, for instance, is to increase the charging time and air speed in the case of fluidized bed devices [19–23]. However, the possibilities offered by the adjustment of such parameters are

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limited: a too long charging time would reduce the hourly quantities of treated material and a too high air speed would increase the energy consumption at levels unacceptable for industry application.

Several research groups have used plasmas to modify the tribocharging properties of polymers [24,25]. Most plasma systems require a pump and a specific gas to operate. DBD might be a better option, as it can be conveniently generated in atmospheric air, using very simple electrode geometries.

The present paper is aimed at evaluating the influence that exposure of granular insulating materials to a dielectric barrier discharge (DBD) might have on the triboelectric charging process. Thus, two granular polymers, PVC and PP, were submitted to an AC DBD before being tribocharged in a vibratory device. The tribocharged materials were later introduced in a free fall electrostatic separator to evaluate the effect of DBD treatment on the selective sorting of the two constituents of the granular mixture.

2. Experimental procedure

2.1. Materials

The experiments were performed on two granular insulators, Polyvinyl Chloride (PVC) and Polypropylene (PP). The materials used in this study were provided by RECYMAP, a French company specialized in plastic recycling. The aspect of the used PVC and PP granular materials is shown in Fig. 1. The mixture used in the separation experiments was composed of 50% PVC and 50% PP.

2.2. Dielectric barrier discharge-DBD plasma system

Surface treatment using a dielectric barrier discharge was carried out in a plasma reactor composed of two circular aluminum plate electrodes (diameter: 70 mm, thickness: 12 mm) each of them covered by 3-mm thick glass plate (150 mm × 150 mm); the air gap between the two glass plates: 5 mm. The samples were placed on the lower glass plate. The electrode configuration is supplied by a high voltage amplifier (model Trek 30/20A) (Fig. 2).

2.3. Vertically-vibrated bed device

The charging of untreated and treated insulating particles was carried out in a stainless-steel box connected to the vibratory device (Fig. 3). The amplitude of the vertical oscillations was 1 mm, at a frequency of 50 Hz. In the metallic box, charge transfer is due to particle-particle and particle-wall collisions.

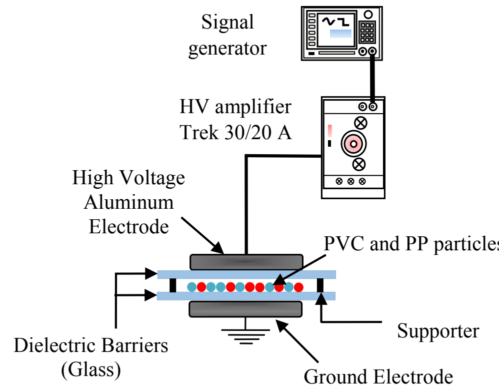

Fig. 2. Dielectric barrier discharge plasma system.

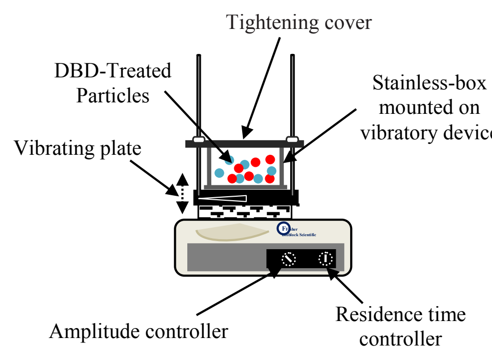

Fig. 3. Vibratory tribocharging device.

2.4. Free-fall electrostatic separator

The charged binary mixtures (either untreated or treated PVC and PP particles) were processed in a standard free-fall electrostatic separator under the action of the high intensity electric field generated by two vertical aluminum plate electrodes of opposite polarities connected at ± 30 kV, as shown in Fig. 4. The products were collected in three boxes placed at the lower end of the separator: two, adjacent to the electrodes, for recovering PVC and PP products, and one in the center, for middling.

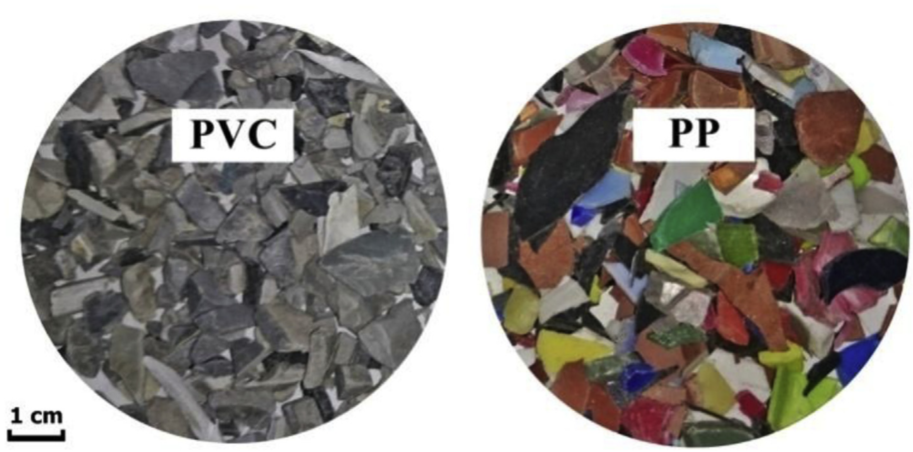

Fig. 1. Aspect of PVC and PP plastic particles.