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# Effect of moisture content on the triboelectric charging of polymers

Csaba Dani<sup>1</sup>, Thami Zeghloul<sup>2</sup>, Mihai Lungu<sup>1</sup>, Imed-Eddine Achouri<sup>2</sup>,  
Djillali Aouimeur<sup>2</sup>, Lucian Dascalescu<sup>2</sup>

<sup>1</sup>U Department of Physics – West University, Timisoara, Romania

<sup>2</sup>PPRIME Institute, UPR 3346, CNRS-University of Poitiers-ENSMA, France

E-mail: [lucian.dascalescu@univ-poitiers.fr](mailto:lucian.dascalescu@univ-poitiers.fr)

**Abstract.** The triboelectrostatic separation allows the sorting of granular polymers according to their contact charging characteristics. It consists in the appropriate triboelectric charging of particles, followed by their selective sorting in an electrostatic field. Exposed to a humid atmosphere, the polymer granules adsorb water moisture onto their surfaces, which modifies their charging characteristics, by improving the contact between surfaces. The present work was aimed at studying the effect of storage environmental conditions on the triboelectric charging of granular polymers in vibratory-type devices. Four granular different plastic wastes were placed in a climatic chamber and kept for 96 hours under controlled humidity,  $RH = 82\% \pm 4\%$ , at  $19\text{ }^\circ\text{C} \pm 1\text{ }^\circ\text{C}$ . The measurement of the water content of the polymer granules pointed out an increase of at least 10% after 96 h of exposure to high relative humidity ambient conditions. The granules were successively charged by triboelectric effect in a vibratory device equipped with recipients in two different materials, at ambient conditions. The tribocharging efficiency was analyzed by measuring the electric charge of the granules with a Faraday pail connected to an electrometer. The thin water layer formed at the surface of the particle can explain their modified triboelectric behavior. The difference between the triboelectric charging behavior of “humid” and “normal” polymer granules depended also on the nature of the recipient of the tribocharging device.

## 1. Introduction

When two different materials are brought into contact and then separated, they will exchange electric charges of opposite signs where one becomes negative and the other positive [1]. This phenomenon, which is called contact charging or tribocharging, is extremely complex and depends on a number of parameters: contacting time, friction velocity, particles shape, size and surface micro structure, as well as environmental conditions [2] - [4]. It enables the tribo-electrostatic separation of polymer materials according to their contact charging characteristics; by appropriate tribocharging of particles, followed by their selective sorting in an electrostatic field [1].

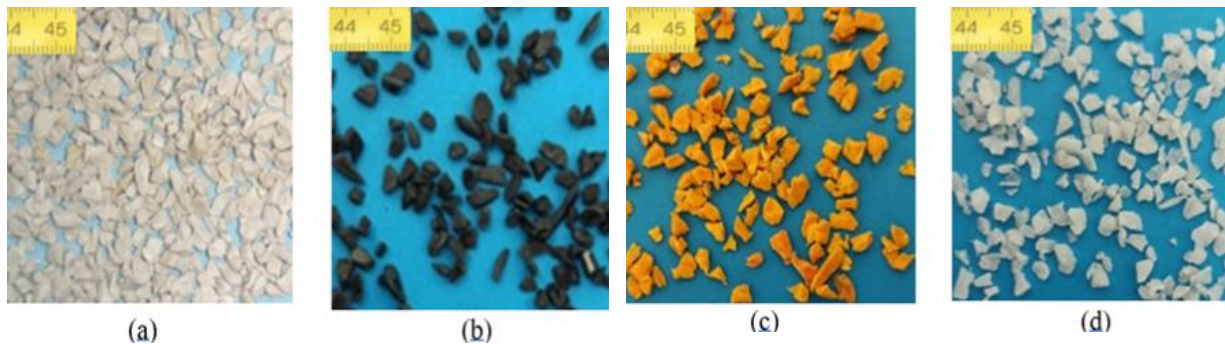
Exposed to a humid atmosphere, the polymer granules adsorb water moisture onto their surfaces [3], a phenomenon that modifies their charging characteristics, as it improves the contact between surfaces. The monolayers of water formed on the surface of allow the diffusion of mobile electric charges between the bodies in contact [3].

The work presented in this paper was aimed at studying the effect of storage environmental conditions on the triboelectric charging of granular polymer waste in vibratory-type devices.



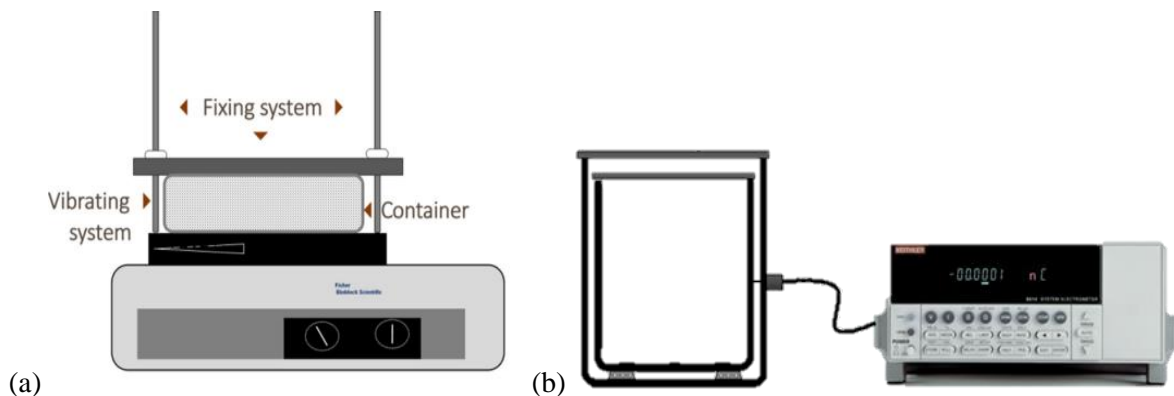
## 2. Materials and Method

Four granular plastic wastes, ABS (Acrylonitrile butadiene styrene), PS (Polystyrene), PE (Polyethylene), PP (Polypropylene) (figure 1) were placed in a climatic chamber and kept 96 hours under controlled humidity,  $RH = 82\% \pm 4\%$ , at a temperature  $T = 19\text{ }^\circ\text{C} \pm 1\text{ }^\circ\text{C}$ . The granules stored under these conditions will be referred to as being “humid”, while the “normal” granules were kept at ambient humidity  $RH = 48\% \pm 3\%$ , at a temperature  $T = 17\text{ }^\circ\text{C} \pm 1\text{ }^\circ\text{C}$ . Their water content of both “humid” and “normal” granules was measured with a thermal balance.



**Figure 1.** Aspect and size of the particles: (a) ABS; (c) PS; (c) PP; (d) PE

The “humid” and “normal” granules were successively charged by triboelectric effect in a vibratory device equipped with recipients in PLA, PE and ABS (figure 2). Each experiment was carried out at ambient conditions and triplicated. The tribocharging efficiency was analyzed by measuring the charge of the granules, with a Faraday pail connected to an electrometer (Keithley Instruments, model 6514), and their mass, using an electronic scale.



**Figure 2.** (a) Vibratory-type tribocharging device; (b) Faraday pail connected to an electrometer for measuring the charge of the granules.

## 3. Results and Discussion

The measurement of the water content of each of the four types of polymer granules pointed an increase by at least 10% (in the case of PE particles) after 96 h of exposure to the high relative humidity ambient conditions (Table 1). For the ABS particles, the increase was of roughly 40%, while for the PS and PP it attained 75%. The thin water layer formed at the surface of the particle can explain their modified triboelectric behaviour. The difference between the triboelectric charging behaviour of “humid” and “normal” polymer granules depended also on the nature of the recipient with which the vibratory device was equipped

**Table 1.** Variation of the humidity content of polymer granules as a function of the storage duration at elevated relative humidity  $RH = 82\% \pm 4\%$  and at stable temperature  $T = 19\text{ }^\circ\text{C} \pm 1\text{ }^\circ\text{C}$ .

Time [h]	Water content [%]							
	ABS		PS		PE		PP	
	Average	Range	Average	Range	Average	Range	Average	Range
0	0.24	0.04	0.25	0.06	0.17	0.02	0.12	0.04
24	0.26	0.05	0.30	0.05	0.16	0.04	0.16	0.03
48	0.27	0.05	0.29	0.03	0.16	0.02	0.16	0.06
72	0.30	0.07	0.36	0.07	0.16	0.02	0.19	0.02
96	0.34	0.06	0.44	0.09	0.19	0.03	0.21	0.02

The charge/mass values given in Table 2 were obtained as averages of three or more samples stored for 96 h either at “normal” ( $RH = 48\% \pm 3\%$ ,  $T = 17\text{ }^\circ\text{C} \pm 1\text{ }^\circ\text{C}$ ) or “humid” ( $RH = 82\% \pm 4\%$ ,  $T = 19\text{ }^\circ\text{C} \pm 1\text{ }^\circ\text{C}$ ) ambient conditions. The range of the values measured for similar samples did not exceed 20 %.

**Table 2.** Charge/mass ratios of polymer particles stored for 96 h either at “normal” ( $RH = 48\% \pm 3\%$ ,  $T = 17\text{ }^\circ\text{C} \pm 1\text{ }^\circ\text{C}$ ) or “humid” ( $RH = 82\% \pm 4\%$ ,  $T = 19\text{ }^\circ\text{C} \pm 1\text{ }^\circ\text{C}$ ) ambient conditions.

Polymer	State	$Q/m$ [nC/g]	
		Inox	PLA
ABS	normal	-8.67	0.85
	humid	-3.22	0.37
PS	normal	-2.60	-4.31
	humid	-1.44	-3.46
PE	normal	-4.67	-5.29
	humid	-3.87	-4,37
PP	normal	-2.61	-3.48
	humid	-1.87	-2,39

The ABS particles, either “normal” or “humid” charged negatively in the Inox recipient and positively in the PLA one. The other three polymers charged negatively in both types of recipients of the vibratory device.

As expected, the increase of the water content of the particles due to their exposure to high levels of relative humidity of the ambient air had an adverse effect on their tribocharging. The results suggest that the diminution of the charge/mass ratio is more significant in the case of the polymers the water content of which was more affected by the relative humidity of the ambient air.

#### 4. Conclusions

The results of the experimental study that made the object of the present paper authorize the following conclusions:

- 1) Depending on their nature, when polymer granules are stored at high levels of relative humidity of the ambient air, their water content can increase by up to 75% with respect to their initial state.
- 2) The adsorption of water moisture onto the surfaces of polymer granules stored in a humid atmosphere affect their tribo-electric charging properties. In all the polymers that were studied, the absolute value of the charge/mass ratio of “humid” granules was roughly 50% to 70% of that recorded under normal conditions.
- 3) Further studies are needed to evaluate the effect of the water content on the triboelectric charging and electrostatic separation of granular plastic mixtures and correlate the outcome of the process with the hydrophobic or hydrophilic nature of the polymers.

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