

## Effect of TiO<sub>2</sub> particle incorporation on the electret properties of corona charged polypropylene composite films

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In the present paper the influence of the concentration of TiO<sub>2</sub> particles of average size 500 nm on the electret properties of the polypropylene (PP) composite films were studied. We investigated the PP composite films with different weight concentrations of the TiO<sub>2</sub> particles (0 wt., 2 wt.% and 4 wt.%) and thickness of 200 μm. The samples were charged 1 minute under room temperature by the method of the corona discharge using a point-to-plate three electrode system in a positive or in a negative corona.

The voltage of the corona electrode was ± 5 kV and the one of the grid was ±1 kV with the same polarity. The surface potential of the electrets was measured by the method of the vibrating electrode with compensation. We studied the surface potential decay with reference to both time and storage temperature aiming at determination of the particle influence on the stability of the electret composite films.

The results obtained showed a significant change in the electret behaviour of the composite films after the introduction of particles with different concentration into the PP matrix. It was established that the surface potential decay depended on the corona polarity and the concentration of the particles.

**Keywords:** electrets, composite films, corona discharge

### INTRODUCTION

Electrets have been a field of investigations for many years [1-3]. They have been used in different areas of science, technology and medicine. The surface potential values and the lifetime of electrets are the most important parameters giving rise to the possibility of their practical usage. Hence over the years, considerable interest has been shown in the surface potential decay of corona-charged polyolefin polymers among which polypropylene is the most widely used [4-5]. This is due to their low cost, low density, high thermal stability, resistance to corrosion, low relative weight. Over the last few years, however, together with these materials another relatively new direction has been developed. It is the investigation of different composite electret films with specific features. New structural elements that influence the electrets' properties occur when filling the polymers with dispersive-distributed fillers such as metallic oxide (ZnO, CuO, TiO<sub>2</sub>) [6-7]. In such a way polymer

composite films have attracted wide interest because of changing polymer electrets' properties and extending their applications.

The aim of the present paper is to investigate the influence of the concentration of TiO<sub>2</sub> particles (0 wt., 2 wt.% and 4 wt.%) on the electret properties of the PP composite films.

### EXPERIMENTAL

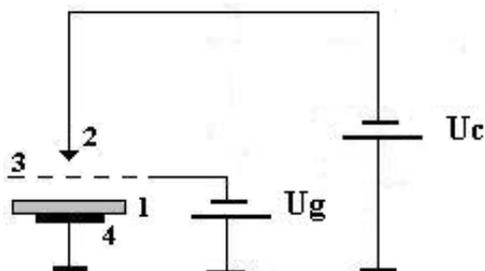
#### *Fabrication of the PP composite films*

Compositions of PP and 500 nm TiO<sub>2</sub> particles were prepared on Brabender® measuring mixer with controlled electrical heating. Mixing occurred for 5 minutes at 190 °C. Polymer composite samples were prepared as 200 μm films on hydraulic press. Molding temperature was 190 ± 5°C. Compositions were heated for 10 minutes, molded for 5 minutes at 140 kg/cm<sup>2</sup> clamping force and then cooled for 5 minutes as long as samples obtained structural stiffness temperature.

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### Corona charging and surface potential measurement

The charging of composite electrets in the corona discharge was carried out by means of a conventional three-electrode system (Fig. 1), consisting of grounded plate electrode, corona electrode and a grid placed between them.



**Fig. 1.** Arrangement of the corona charging set-up. 1 – sample on a metal pad; 2 – corona electrode; 3 – grid; 4 – grounded plate electrode;  $U_g$  – grid voltage power supply;  $U_c$  – corona voltage power supply.

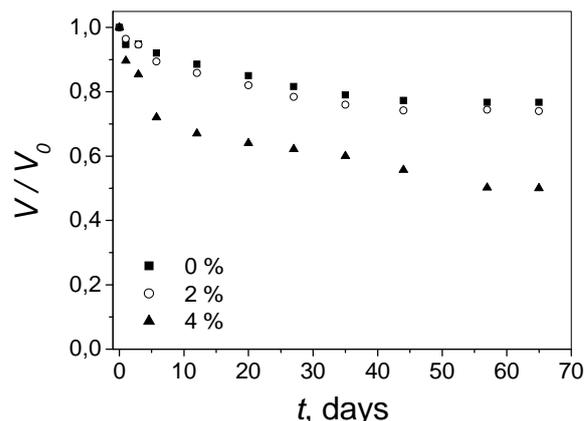
The distance between the corona electrode and the grid was 10 mm and the distance between the grid and the grounded plate electrode was 3 mm. The samples were charged for 1 minute under room conditions. Positive or negative 5 kV voltage was applied to the corona electrode. Voltage of the same polarity as that of the corona electrode was applied to the grid and its value was 1 kV. Electrets surface potential was measured by the method of the vibrating electrode with compensation by which the estimated error was better than 5%.

## RESULTS AND DISCUSSION

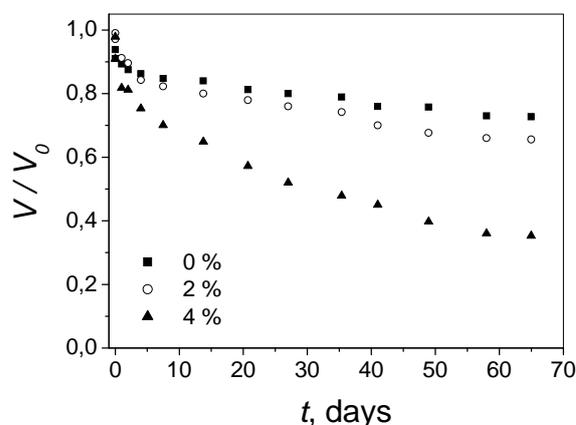
### Influence of time storage on electrets surface potential decay

The dependences of normalized surface potential on the time of storage under room conditions for positively and negatively charged PP composite films with different weight concentrations of the TiO<sub>2</sub> particles (0 wt.%, 2 wt.% and 4 wt.%) have been studied for 70 days. The surface potential was measured once a week except for the first 15 days when it was measured more often because the charge was rapidly decaying. After this period, steady state values of the surface potential were established for all of the samples.

Time dependences of the normalized surface potential for positively and negatively charged PP composite films are presented in Figs. 2 and 3 respectively.



**Fig. 2.** Time dependences of the normalized surface potential for positively charged PP composite films.



**Fig. 3.** Time dependences of the normalized surface potential for negatively charged PP composite films.

The results illustrated in Figs. 2 and 3 demonstrate the following:

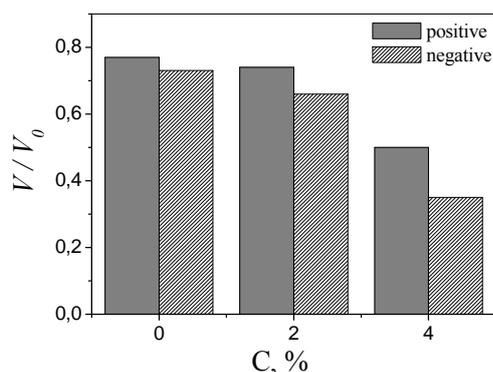
- The final values of the normalized surface potential for the samples charged in a positive corona are higher than those for the samples charged in a negative corona for all concentration of the TiO<sub>2</sub> particles as has been observed earlier [8];
- For all samples investigated the normalized surface potential are initially decaying exponentially for the first 15 days and then are decreasing slowly and are practically stabilized to 70<sup>th</sup> day;
- The normalized surface potential of PP composite films with concentrations of the TiO<sub>2</sub> particles (2 wt.% and 4 wt.%) decays faster than the one of the pure PP films independently of the corona polarity. This might be due to conductivity enhancement with incorporation of the TiO<sub>2</sub> particles into the PP matrix, resulting in easier and faster charge transport in the bulk.

- The decay of the normalized surface potential becomes faster with increasing the concentration of the TiO<sub>2</sub> particles. When the concentration of the TiO<sub>2</sub> particles is higher (4 wt. %), the normalized surface potential of the composite film decays very fast and reaches a stable state value depending on the polarity of the corona as shown in Figs. 2 and 3. This behavior may be attributed to the fact that the partial injection of the deposited charges depends on the level of concentration of the TiO<sub>2</sub> particles.

Therefore, the incorporation of TiO<sub>2</sub> particles with a greater concentration in a matrix of PP leads to a decrease of the electrets surface potential value.

*Influence of different concentration of the filler on electrets surface potential decay*

The dependences of the steady state value of the normalized surface potential on the different concentration of the TiO<sub>2</sub> particles for positively and negatively charged PP composite films were presented in Fig. 4.



**Fig. 4.** The dependences of the steady state value of the normalized surface potential on the different concentration of the TiO<sub>2</sub> particles for positively and negatively charged PP composite films.

The results illustrated in Fig. 4 show that:

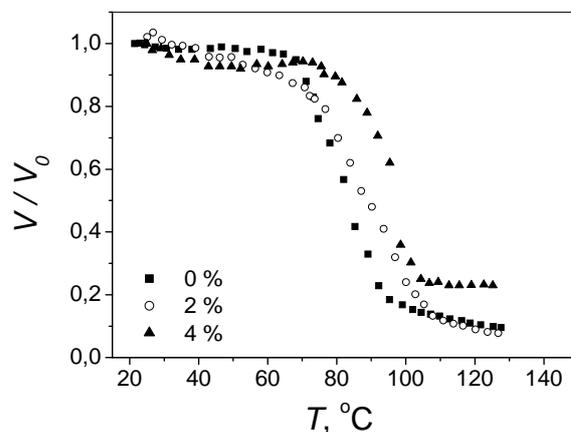
- The stable state values of the surface potential decrease with increasing concentration independently of the corona polarity;
- The stable state values of the surface potential for positively charged PP composites are higher than those for negatively charged irrespectively of the concentration of TiO<sub>2</sub> particles.

*Influence of the temperature on electrets surface potential decay*

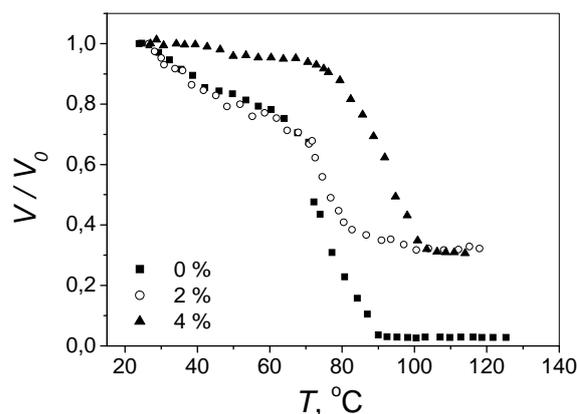
The dependence of the normalized surface potential on the temperature for positively and negatively charged PP composite films with different weight concentrations of the TiO<sub>2</sub> particles (0 wt.%, 2 wt.% and 4 wt.%) was investigated. The surface potential measurements were performed by

means of the surface potential measurement set-up at elevated temperatures. The surface potential was measured every two minutes for 1 hour at a constant temperature increase.

The dependences of normalized surface potential on the temperature for positively and negatively charged PP composite films are presented in Figs. 5 and 6 respectively.



**Fig. 5.** Temperature surface potential decay curves for PP composite films after positive corona charge.



**Fig. 6.** Temperature surface potential decay curves for PP composite films after negative corona charge.

The experimental results (Fig. 6) show that the curves of the PP composites are shifted slightly to higher temperatures with the increase of the particle concentrations. Probably the introduction of TiO<sub>2</sub> particles with different concentration leads to the creation of new charge traps that require higher energies for charges release and leads to the curves shift toward higher temperatures. When the temperature increases, the transport processes through the bulk will play a determinant role because of the increase of both the injection of the carriers from the surface into the bulk and the generating of the carriers in the bulk as well as the increase of their mobility.

## CONCLUSION

The surface potential decays of polypropylene composite films with different concentration of the TiO<sub>2</sub> particles (0 wt., 2 wt.% and 4 wt.%) were investigated. It was established that there was a significant change in the electret behavior of the composite films after the incorporation of particles with different concentration into the PP matrix. The normalized surface potential of PP composite films with concentrations of the TiO<sub>2</sub> particles decayed faster than that of pure PP films and the stable state values of the surface potential decreased with the increasing concentration independently of the corona polarity. Therefore, the incorporation of TiO<sub>2</sub> particles with a greater concentration in a matrix of PP led to a decrease of the electrets surface potential value. This might be due to conductivity enhancement with incorporation of the TiO<sub>2</sub> particles into the PP matrix, resulting in an easier and faster charge transport in the bulk.

## REFERENCES

1. G. Sessler, R. Gerhard-Multhaupt, *Electrets* 3rd Ed., Laplacian: Press Morgan Hill, California, 1999.
2. H. S. Nalwa, *Ferroelectric polymers*, Marcel Dekker Inc., New York, 1995.
3. B. Hilczler, J. Malecki, *Electrets*, Elsevier, Amsterdam, 1986.
4. J. Hillenbrand, N. Behrendt, V. Altstädt, H-W. Schmidt, G. M. Sessler, *J. Phys. D: Appl. Phys.*, **39**, 535 (2006).
5. G. F. Leal Ferreira, M. T. Figueiredo, *IEEE Trans. Electr. Ins.*, **27**, 719 (1992).
6. Sh. Chen, R. Huang, Z. Peng, X. Wang, X. Cheng. (Proc. of Int. Conf. on Solid Dielectrics, Potsdam, Germany, 2010).
7. M. Galikhanov, A. Borisova, R. Deberdeev, *Russ. J. Appl. Chem.*, **78**, 820 (2005).
8. T. Yovcheva, M. Marudova, A. Viraneva, E. Gencheva, N. Balabanov, G. Mekishev, *J. Appl. Polymer Sci.*, DOI: 10.1002/APP.38140, 1 (2012).

## ВЛИЯНИЕ НА КОНЦЕНТРАЦИЯТА НА TiO<sub>2</sub> ЧАСТИЦИ ВЪРХУ ЕЛЕКТРЕТНИТЕ СВОЙСТВА НА КОРОНО ЗАРЕДЕНИ ПОЛИПРОПИЛЕНОВИ КОМПОЗИТНИ ФИЛМИ

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### (Резюме)

В настоящата работа беше изследвано влиянието на концентрацията на частици от TiO<sub>2</sub> със среден размер 500 nm върху електретните свойства на полипропиленови (ПП) композитни филми. Бяха изследвани ПП композитни филми с различно тегловно съдържание на частици от TiO<sub>2</sub> (0 wt., 2 wt.% and 4 wt.%) и дебелина 200 μm. Образците бяха зареждани по метода на коронния разряд с помощта на триелектродна система в положителна и отрицателна корона за една минута при стайна температура. На корониращия електрод беше подавано напрежение ± 5 kV, а на решетката ±1 kV със същата полярност. Повърхностният потенциал на получените електрети беше измерен по метода на вибриращия електрод с компенсация. За определяне на влиянието на частиците върху стабилността на електретните композитни филми беше изследвано спадането на повърхностния потенциал с времето и температурата на съхранение. Получените резултати показват значително изменение в електретното поведение на композитите след вкарването на частици с различна концентрация в матрица от ПП. Беше установено, че спадането на повърхностния потенциал зависи от полярността на короната и концентрацията на частиците.