ZENON TARTAKOWSKI
West Pomeranian University of Technology
Institute of Materials Science and Engineering
Al. Piastów 19, 70-310 Szczecin, Poland
e-mail: Zenon.Tartakowski@zut.edu.pl

Electrostatic properties of modified recyclates of polyvinyl chloride cable insulation

RAPID COMMUNICATION

Summary — The characteristics of the electrostatic charge decay in composites produced from recyclates of post-cable insulation of polyvinyl chloride (PVC) and polyethylene (PE) was presented in this paper. The influence of the material composition, technology of composite production and the effect of ageing factors on the electrostatic charge decay time process of the composites were studied. Determination of how composition and methods of composites production influence their electrostatic properties allows to estimate their potential application.

Key words: electrostatic charge decay, recyclate, polyvinyl chloride, polyethylene.

WŁAŚCIWOŚCI ELEKTROSTATYCZNE MODYFIKOWANYCH RECYKLATÓW IZOLACJI KABLOWYCH WYKONANYCH Z POLICHLORKU WINYLU

Streszczenie — Określono charakterystykę zaniku ładunku elektrostatycznego nowych kompozytów materiałowych otrzymanych z recyklatów pokablowych wykonanych z polichlorku winylu (PVC) i polietylenu (PE). Zbadano wpływ składu kompozytów, sposobu ich wytwarzania oraz działania czynników starzeniowych na przebieg krzywej zaniku ładunku elektrostatycznego tych materiałów w funkcji czasu. Określenie wpływu składu i metody wykonania kompozytów na ich właściwości elektrostatyczne pozwala na ocenę możliwości ich potencjalnych zastosowań.

Słowa kluczowe: zanik ładunku elektrostatycznego, recyklat, polichlorek winylu, polietylen.

Due to its good electro insulation, mechanical, and processing properties, and high resistance to physical ageing, polymeric materials are widely used as insulation materials in manufacturing of power cables and leads [1—4]. Main thermoplastic materials used for insulation are polyvinyl chloride (PVC), polyethylene (PE) and polyester (PET). Depending on the purpose of the product (cable, lead) and its "design", other materials including fibers, cellulose (paper) and metals (Al, Cu, Fe) [5, 6] are used as well.

During its lifetime the cables and leads are subjected to damage, thus they have to be periodically replaced. In this case the used insulation products constitute a waste material, which according to the EU Directive should be recycled [7, 8]. Most popular is mechanical recycling, allowing to recover plastic (insulation) and metal parts. The recyclates obtained this way are usually a non-homogenous material, a mixture of different materials. Depending on the degree of required homogeneity of the polymeric material, a multi-stage separation process may be employed, thus the quantity of impurities can be reduced to 5 %. However, every additional reprocessing stage increases the costs of the recyclates. Therefore, one tries to find such applications of recycled polymer, where impurities contained in a recyclate would not reduce its useful properties. The experience so far proves that a huge number of products for technical purposes may be manufactured directly from recyclate materials, instead of the original ones. Consequently, a positive cost effect and the environmental advantages can be achieved this way.

The main indicators of the usefulness of the recycled materials are their physical, mechanical, electrical and processing properties. There are many papers describing properties of recyclates of uniform materials [9, 10]. However, the comprehension of multicomponent recyclates, which number is growing fast, is not sufficient yet. With restricted possibilities of the use of recyclate materials (for example due to hygienic reasons) every additional property can generate new application directions.

In the available literature no information about electrostatic properties of recyclate materials was found.

Since these are crucial properties of products designated for the application in an explosive environment (gas, oil derivate fumes *etc*.) or any other dangerous environment with an extended risk, an attempt was made to evaluate electrostatic properties of composites made from recyclates, based on the time of decomposition of electrostatic charge on the material surface. It is known that the electrification results in generation of an excess of one-sign electric charge, due to external influences (friction or induction) on the material (a dielectric) surface [11, 12]. In the case if a charged system is close to a grounded object, a partial electrostatic discharge can occur (corona discharge, brush discharge) or a disruptive — spark discharge.

The basic parameters characterizing the charge decay rate are following:

— time constant *i.e.* the time after which the voltage [U(t)] takes the value of 0.37 U_0, where U_0 is the voltage of material reached after electrification;

— half-decay time *i.e.* the time after which U(t) takes the value of 0.5 U_0.

Therefore, the problem presented and discussed in this paper is the capability of a material to keep its electric charge, and the process of electric discharges on the surface of a product. The knowledge of the discharging processes may deliver information how to modify recycled materials in order to provide them with antistatic properties.

The main objective of this study was to determine the decay time of the electrostatic charge of a group of polymeric materials made from recyclates, depending on their composition, manufacturing technology and ageing history.

EXPERIMENTAL

Material

Two kind of recyclate materials were studied. First of them was a recyclate of the power cable insulation (PVC_{rec}) containing 90 wt. % of PVC, 7 wt. % of PE and 3 wt. % of solid impurities (polyester foil, paper, metal particles). The mean dimension of recycled particles was 5 mm, and they had an irregular shape (Fig. 1). The second one was polyethylene cable insulation recyclate (PE_{rec}) containing up to 5 wt. % of solid impurities in a form of fibers, paper, and polyester foil. The mean size of recyclate particles was 10 mm, and they had an irregular shape. This recyclate did not contain metal particles (Fig. 2).

Fig. 1. PVC recyclate (PVC_{rec})

Fig. 2. PE recyclate (PE_{rec})

Preparation of new composites

From these two kinds of recyclate materials new composites with six different compositions were produced, listed in Table 1. Three processing techniques were used.

T a b l e 1. Composition of tested recycled polymeric materials

Symbol of composite sample	Content, wt. %	
	PVC_{rec}	PE_{rec}
K100	100	0
K80	80	20
K60	60	40
K40	40	60
K20	20	80
K0	0	100

Process type A — injection molding. Pre-prepared components were mixed in a drum mixer, followed by injection molding (screw injection molding machine MonoMat 80) using the following parameters: temperature T = 160—190 °C along the barrel, filling pressure p = 110 MPa, cycle time 35 s and molding temperature T_m= 25 °C. A single-seat mould was used.

Process type B — extrusion and compression molding. Homogenization of materials was done with a screw extruder T32 (Metalchem, Gliwice). Extrusion parameters were selected experimentally (T = 160—200 °C). The obtained extruded product was subjected to compression molding in a single-seat mold (temperature of the mold T= 60 °C, pressure p = 90 MPa). This technology is used for large dimension products.

Process type C — homogenization with a BRABENDER mixer. Prepared material was introduced into a heated chamber of the mixer with two rotors, followed by plasticizing and homogenization procedures. The process was conducted at 180 °C (homogenization time $t = 180$ s). The molten polymeric material was formed by compression molding in a single-seat mold.

Methods

In order to determine the electrostatic charge decay time a method of a rotating sample was used [13]. Device MRS-04 (PPHU "METRA" Wrocław), which scheme is presented on Fig. 3, was applied for the tests. The tested sample in a form of a round plate 120 mm in diameter, is placed on a rotating disc driven by an electric motor. This rotating sample moves above a discharge and a measuring electrode. The discharge electrode is powered from a high constant voltage source *via* a switching-off system. The alternating voltage on the electrode induced by the charge on samples is measured by a voltmeter.

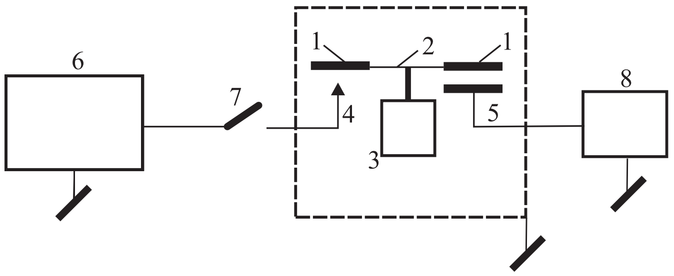

Fig. 3. MRS-04 measuring system: 1 — tested sample in the form of a round plate, 2 — rotating disc, 3 — electric motor, 4 — discharge electrode, 5 — measuring electrode, 6 — high voltage DC source, 7 — switching-off system, 8 — voltmeter

By recording of the voltage as a function of time $U(t)$ the characteristics of the decay of a charge on the sample surface was obtained. The discharge electrode supply voltage adopted for tests was 4 kV and the electrification time — $t_u = 60$ s.

A study of the influence of water on the materials was also carried out. The experiments have been performed for 9 weeks, and the measurements were taken weekly at the temperature of 25 ± 2 °C.

RESULTS AND DISCUSSION

The kinetics of the decay of the electric charge on the surface of a material depends on the composition of a given material, manufacturing technology and ageing time in the water (water absorption). Figure 4 presents the charge decay course for materials containing different amounts of PVC. Various charge decay characteristics may be observed depending on the PE_{rec} content. For the materials made of 100 wt. % recycled PVC (K100) the charge decreases faster, compared to composites containing PE_{rec}. An addition of 20 wt. % of PE_{rec} (K80) to a composite causes a significant increase of the discharge voltage compared to the unmodified material. By comparing the charge decay kinetics for several investigated materials it may be seen that with decrease of PVC_{rec} contents the time of charge decay on the composite surface increases similarly as for pure PE_{rec} (K0).

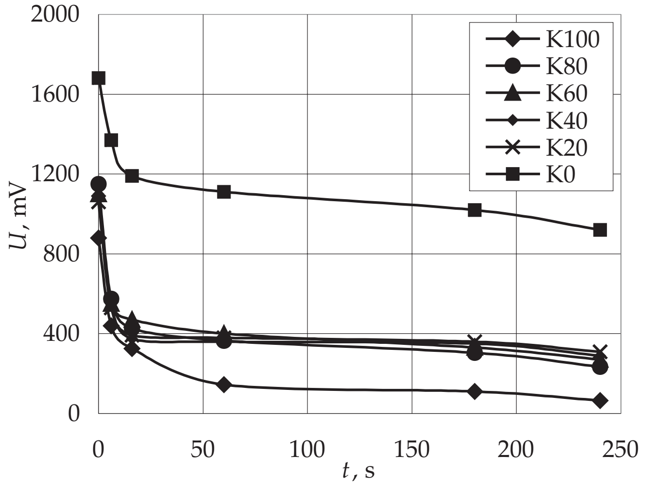

Fig. 4. Effect of the PVC content on the kinetics of the electric charge decay on the surface of PVC/PE composites (process type A)

The influence of the processing method of the PVC recyclate on the charge decay process is presented on Fig. 5. It may be seen, that a charge recedes fastest for composite manufactured by injection molding (process type A). For products made by extrusion and compression molding (process type B) and by the Brabender mixer (process type C) the kinetics of charge decay process is similar.

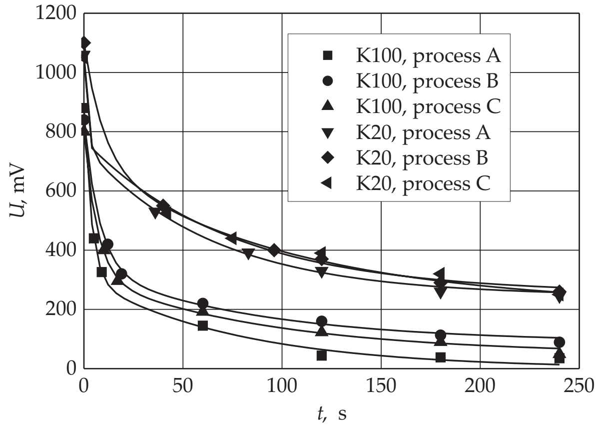

Fig. 5. Influence of processing method of PVC recyclate (K100) and composite with 20 wt. % of PVC (K20) on the electric charge decay kinetics

Comparing the processing technology of composite materials with various content of individual components it may be noted that with a growing content of the PE_{rec} in a composite, the difference of the run of decreasing electrostatic level between various materials used in these experiments became smaller.

Analysis of the decay of electrical charge after periods of 50 s and 100 s for the manufactured composites showed that differences in voltage depend on processing techniques used. The voltage after 50 s for the K100 sample made in processes type B and C was higher than the voltage of injection-molded (process type A) sample by about 26—43 %, but after 100 s even by about 61—96 %. For the sample K20 these differences are about 7—8 % after 50 s and 10—12 % after 100 s.

Simultaneously it was found that the decrease of the electric charge at the period between 50 s and 100 s, for materials obtained in process type A, is about 47 % for K100 sample and 26 % for K20 sample. For the products made by process type B decrease during the same period was about 27 % for K100 sample and 23 % for K20 sample. For samples K100 and K20 produced in process type C the corresponding values reached 32 % and 25 %, respectively.

The exposure of recycling samples to water under the conditions specified results in a certain water absorption. Due to non-homogenous structure of these materials, *i.e.* existence of a number of microcracks, penetration and migration of water into the material were observed. Depending on the processing method (injection molding, extrusion and compression molding) the voids existing in the composites allow water particles to adhere to the product surface. The kinetics of the electrostatic charge decay on the surface of the PVC recyclate samples (K100), after the period of 3, 6 and 9 weeks of water exposure is shown on Fig. 6, and for the K20 composite on Fig. 7, respectively.

According to Fig. 6 a higher ageing time leads to a decrease of the electrostatic charge decay time, compared to the sample not exposed to water (curve 1). It may be also observed, that the charge quantity developed on tested samples after 60 s of electrification decreases with increasing ageing time.

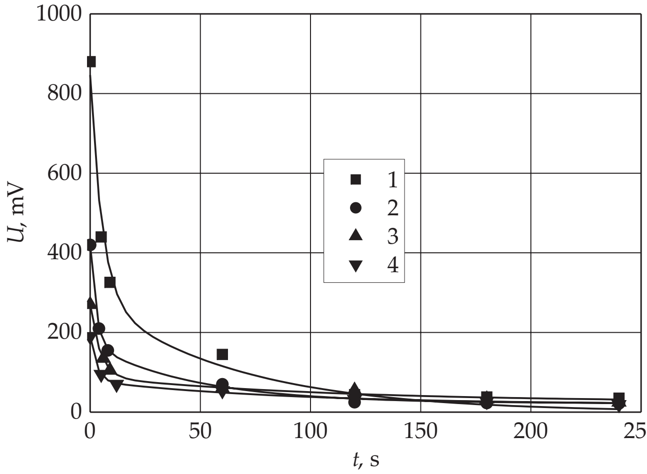

Fig. 6. The electric charge decay kinetics for PVC recyclate (K100, process type A) — influence of the exposure time to water (in weeks): 1 — 0, 2 — 3, 3 — 6, 4 — 9 (process type A)

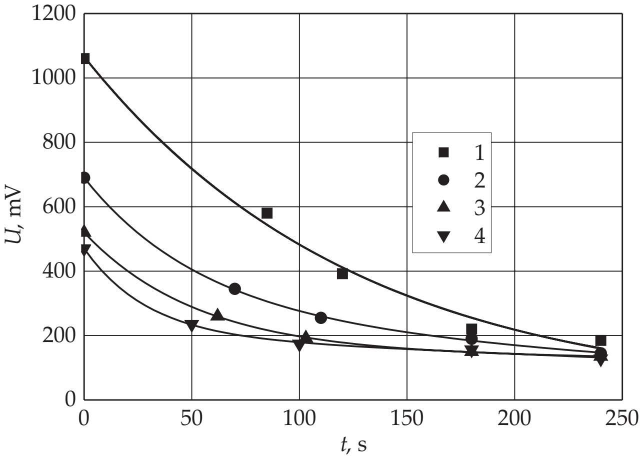

Fig. 7. The electric charge decay kinetics for composite K20 (process type A) — influence of the exposure time to water (in weeks); description of curves as in Fig. 6

A similar course of the charge decay was found for recyclate composites containing PE_{rec} (K20). As it may be seen on Fig. 7, the longer is the exposure time, the shorter is the time when the charge is maintained (a charge decays faster).

Similar relationships were found for all examined materials (K20—K80). The only differences observed was the voltage after electrification of samples.

CONCLUSIONS

Based on the experiments it was found that the decay of charge on the surface of recyclate materials depends on their composition, manufacturing technology and ageing factors.

Modification of composites with PE_{rec} increases the charge decay time. Processing by injection molding has positive influence on the decrease of electrostatic charge decay time, the effect which may be related to improved homogeneity of the composite material. For products manufactured from recycled materials by compression molding the decay time is longer than for products made by injection molding.

The exposure of recycled materials to water leads to faster decay of its electrostatic charge.

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Received 17 XI 2009.

Rapid Communications

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