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Influence of Particulate Fillers on Complex of Dielectric Properties of Rigid and Plasticized PVC Compositions

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Abstract: The article discloses efficiency of modifying the polyvinyl chloride by organic and mineral fillers being the wastes of various industrial productions. Main dielectric properties of rigid and plasticized compositions were examined, for different combinations and ratios of modifying additives. The article displayed how the particulate fillers nature and composition influence on character and intervals of dielectric behavior modification. The results of researches were interpreted with consideration of structural-morphological composition of polyvinyl chloride, of modifying additives' nature, content and ratio.

Key words: Polyvinyl chloride · Modification · Fillers · Structure · Compositions · Dielectric properties

INTRODUCTION

At the present time, polyvinyl chloride (PVC) occupies the second place as for consumption volume of bulk industrial polymers and this material has no equals as for ability to modify its properties and generate great numbers of compositions and products on their basis. The increasing volumes of polyvinyl chloride (PVC) produced and application of compositions on its basis are determined by the following factors: availability and relatively low cost of source raw material, ability to get various grades of polymer and extremely wide range of materials on basis of it, unique ability to be modified and be reprocessed to manufacture goods using traditional methods [1-3]. Composite materials on basis of polyvinyl chloride (PVC) are used being modified, exclusively and represent multi-component systems containing various functional additives to improve their technical properties.

Currently, the crucial task is to solve the problem of polymer raw materials shortage and high cost, decrease of production rough prime cost at the expense of upgrading and optimizing the PVC compositions formulation. One the most effective way of upgrading the PVC compositions properties and cost-cutting them is the introduction of heat stabilizers, fillers, plasticizers and other modifying additives into structures. In process of PVC compositions development, the important task is searching for easy accessible and relatively cheap modifiers incl. fillers, so, wastes of industrial production are of main interest [4].

Technology: For research, the suspension polyvinyl chloride grade C-7059-7058M was selected. As a PVC stabilizer, the mixture of calcium stearate $(C_{17}\text{Í}_{35}\text{CÎÎ})_2\text{Cà}$ and lead silicate $PbSiO_3$ was used (3 mass fractions per 100 mass fractions of polymer). The plasticizer additive was dioctyl phthalate (DOP), the content of which in recipes of plasticized PVC compositions constituted 10, 30, 50 and 80 mass fractions per 100 mass fractions of polymer.

Alkaline sulfate lignine (ASL) and wastewater sludge (WWS) being the non-utilizable wastes in production of cellulose by sulfate method were used as particulate fillers

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of organic nature to generate rigid and plasticized PVC compositions. As mineral filler, the foundry production wastes (FPW) were used, in particular, investment casting wastes comprising the fire-proof fused alumina, the binding agent-hydraulized solution of ethyl silicate and the dusting material in form of quartz sand [4]. The fillers have undergone the preliminary treatment: sieving, drying, refining. The complete dispersion of fillers was proceeded in «Activator 2SL» planetary mill. Dimensions of filler particles were measured on «Analysette 22 Mikro Tec plus» laser analyzer. The content of organic and mineral fillers in recipes of rigid and plasticized PVC compositions constituted: 1, 3, 5, 10, 20 and 30 mass fractions per 100 mass fractions of PVC.

With usage of matrix polymer and selection of modifying additives, the range of recipes for rigid and plasticized compositions was developed. Components included into compositions were preliminarily stirred with certain ratios and combinations in a laboratory mixer to get homogeneous mix. Then, the obtained blends of components were additionally homogenized in double-screw extruder and subjected to thermal plasticization on laboratory friction rollers with optimum mode parameters to get homogeneous films. The plasticized compositions being mixed were subjected to gelatinization at temperature 80-90 °C during the whole day.

Main Description: Composites on basis of rigid and plasticized PVC are widely used in various industrial branches to manufacture technical goods for electric isolation, cable shells and inner infill of electric cables, etc. [5]. In view of this, the necessity arises to investigate the influence of various modifying additives on dielectric behavior of modified PVC compositions.

Modern dielectric spectral analysis allows investigate how the dielectric characteristics change in wide frequency and temperature ranges (from-160 °C to + 400°C) to acquire unique information on relaxation dynamics of samples studied.

There were performed experimental researches to study the influence of modifying additives such as mineral and organic substances on change of main dielectric properties of rigid and plasticized composites on basis of PVC.

Dielectric properties of compositions were determined by measuring the values of dielectric permeability, volume resistivity, dielectric losses of film samples at room temperature and frequency $1{,}1536 \bullet 10^3$ Hz on a «NOVOCONTROL CONCEPT-80» dielectric spectrometer provided with WinDeta and WinFit software for experimental data visualization and treatment.

Numerous studies [4-10] devoted to research of PVC modification efficiency when using modifying additives different in nature and application, including the fillers, revealed extreme change of technical properties complex in zone of low content of modifiers (up to 5-15 mass fractions per 100 mass fractions of polymer). In order to validate such change of properties, the authors of research papers used modern concepts of structural-morphological composition of PVC which was formed in process of polymerization and preserved with further processing through melting.

The Table contains as example the experimental data on change of main dielectric properties complex for rigid and plasticized PVC compositions which contain the mineral and organic fillers as modifying additives.

The data presented show that dielectric characteristics of rigid PVC compositions improve slightly with increase of chemically inactive mineral filler content, with filler content 10-20 mass fractions. As for rigid PVC compositions filled with organic substance, slight worsening of dielectric characteristics was observed as compared to pure polymer. Evidently, it is explained by peculiar chemical composition of organic fillers which are natural polymers with complex group and chemical compositions, i.e. various functional groups are available (methoxy, carbonyl, carboxyl). Plasticized compositions reveal appropriate increase of dielectric permeability, dielectric loss tangent and decrease of volume resistivity with increase of organic filler and plasticizer content. It should be noted that dielectric parameters for rigid as well as plasticized PVC compositions containing mineral and organic fillers are within permissible interval of their change.

Afterword: The complex analysis of modification of rigid and plasticized PVC compositions by organic and mineral particulate fillers has revealed how the complex of dielectric characteristics changes. The effect of abnormal modification of compositions' dielectric properties was revealed in zone of low content of mineral filler. The maximum effect of modification of PVC compositions dielectric characteristics is revealed when they are filled with organic additives which is explained by peculiarities of their chemical composition and structure, i.e. by content of various functional groups.

Table 1: Dielectric properties of rigid and plasticized PVC compositions

Compositions recipes, mass fractions (per 100 mass fractions of PVC)	Dielectric permeability, ε	Dielectric loss tangent, tg δ	Volume resistivity, C_v, ohm•cm
PVC	2,12	$7{,}93\ 10^{-3}$	$1{,}07\cdot10^{11}$
PVC+1 FPW	2,12	$7{,}93\ 10^{-3}$	$1{,}07\cdot10^{11}$
PVC+3 FPW	2,10	$7{,}86\ 10^{-3}$	$1{,}13\cdot10^{11}$
PVC+5 FPW	2,10	$7{,}77\ 10^{-3}$	$1{,}13\cdot10^{11}$
PVC+10 FPW	2,04	$7{,}59\cdot10^{-3}$	$1{,}23\cdot10^{11}$
PVC+20 FPW	2,10	$7{,}58\cdot10^{-3}$	$1{,}11\cdot10^{11}$
PVC+30 FPW	2,22	$7{,}82\cdot10^{-3}$	$1{,}00\cdot10^{11}$
PVC+1 ASL	2,13	$7{,}95\ 10^{-3}$	$1{,}01\cdot10^{11}$
PVC +3 ASL	2,16	$8{,}43\ 10^{-3}$	$9{,}00\cdot10^{10}$
PVC +5 ASL	2,18	$9{,}45\ 10^{-3}$	$8{,}81\cdot10^{10}$
PVC +10 ASL	2,22	$1{,}23\cdot10^{-2}$	$8{,}63\cdot10^{10}$
PVC +20 ASL	2,39	$1{,}77\cdot10^{-2}$	$7{,}61\cdot10^{10}$
PVC +30 ASL	2,73	$2{,}13\cdot10^{-2}$	$7{,}18\cdot10^{10}$
PVC+3 WWS +10 DOP	2,62	$7{,}63\ 10^{-3}$	$1{,}07\cdot10^{11}$
PVC+3 WWS +30 DOP	2,80	$8{,}46\ 10^{-2}$	$9{,}01\cdot10^{10}$
PVC+3 WWS +50 DOP	3,86	$9{,}31\cdot10^{-2}$	$8{,}15\cdot10^{10}$
PVC+3 WWS +80 DOP	3,99	$9{,}94\cdot10^{-2}$	$7{,}88\cdot10^{10}$
PVC+10 WWS +10 DOP	2,74	$8{,}14\cdot10^{-3}$	$8{,}43\cdot10^{10}$
PVC+10 WWS +30 DOP	2,97	$8{,}54\cdot10^{-2}$	$8{,}03\cdot10^{9}$
PVC+10 WWS +50 DOP	3,68	$8{,}82\cdot10^{-2}$	$7{,}61\cdot10^{9}$
PVC+10 WWS +80 DOP	3,88	$9{,}08\cdot10^{-2}$	$7{,}06\cdot10^{9}$
PVC+30 WWS +10 DOP	2,98	$8{,}62\cdot10^{-3}$	$8{,}06\cdot10^{10}$
PVC+30 WWS +30 DOP	3,30	$9{,}24\cdot10^{-2}$	$7{,}79\cdot10^{9}$
PVC+30 WWS +50 DOP	3,99	$9{,}45\cdot10^{-2}$	$7{,}39\cdot10^{9}$
PVC+30 WWS +80 DOP	4,28	$9{,}98\cdot10^{-2}$	$7{,}00\cdot10^{9}$

CONCLUSIONS

The research results for rigid and plasticized compositions by method of dielectric spectroscopy proved that introduction of modifying additives in form of fillers and plasticizers causes modification of dielectric behavior. It was found that direction and intervals of modification of PVC compositions' dielectric properties complex depend upon nature, quantity and ratio of modifying additives. The revealed peculiarities of dielectric behavior modification for filled compositions enable to suggest formulating technique with optimum dielectric values.

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