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Electrical, mechanical and thermal properties of polyvinyl chloride composites filled with aluminum powder

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ABSTRACT

In this work, the electrical, mechanical and thermal properties of polyvinyl chloride (PVC) composites filled with different content of aluminum powder varying from 0 to 40 wt.% have been prepared. The dielectric properties of these composites were investigated in the frequency range 100 Hz–100 kHz at temperature range from 30 to 98 °C. The percolation threshold concentration, which is the concentration after which the conductivity increases many orders of magnitude with very little increase in the filler content for PVC/Al composites depends upon the measuring temperature, whether it is below or above the glass transition of the polymer matrix. The highest value of the electrical conductivity, σ, of the composites was found to be in the order of 10^{-8} S cm^{-1}, this value recommend such composites to be used in electrostatic dissipation applications as the range of conductivity for such application should be in the range of 10^{-5}–10^{-9} S cm^{-1}.

The mechanical strength values decrease with increasing the aluminum content. It was also noticed that, both tensile strength and elongation at break values have been slightly decreased after annealing at 100 °C.

The scanning electron microscope (SEM) micrographs of PVC containing different content of aluminum powder indicate that at the higher aluminum concentration (20 and 30 wt.%) large agglomerates of aluminum particles dispersed within the PVC, yielding a conductive path through the composite.

The thermal stability of the prepared composite samples increases with increasing Al content.

1. Introduction

Conducting polymeric composites based on conductive particles in a polymer matrix were widely used owing to their unique electrical and mechanical properties. Most polymers are typical insulators and conductivity of the composite materials predominantly depends on the content and properties of the filler such as the size and shape of the filler particles in addition to their distribution within polymer matrix, beside the interaction between the filler surface and the polymeric matrix [1–4]. The most general approach for description of charge transport in conducting polymeric composites in relation to the content of conducting particles such as carbon black, carbon fiber, and metals is provided by the percolation theory – in which a continuous network of conductive particles forms.

In such networks there is either direct contact between adjacent particles, or sufficiently small gaps between them, to enable a mechanism of quantum mechanical tunneling conductivity. The percolation threshold is strongly influenced by the geometrical characteristics of the conductive filler, such as aspect ratio and particle size distribution, so that an increase in their value may dramatically drop the filler concentration required to achieve conduction in a given polymeric matrix [5,6].

Also, an interesting phenomenon characteristic to such conductive systems is a non-linear positive temperature coefficient (PTC) effect shown by a sharp resistivity increase upon heating, thus converting the material from electrical conductor to insulator within a narrow temperature range. The PTC feature makes the materials suitable for applications in the electronic industry, such as temperature/current sensors, self-regulating heaters, or as overcurrent protecting devices, with a potential for multiple use, as opposed to conventional fuses [7,8].

Metal–polymer composites exhibit the properties of both metal and polymers and have been the subject of extensive research for the last two decades [9]. They have a wide range of industrial applications because of their low density, high corrosion resistance, ease of fabrication, and low cost [10–13].

The dependence of electrical conductivity of polymer composites containing epoxy resin and two different size fractions of

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