Research Article

Received: 1 January 2019 Revised: 23 February 2019 Accepted article published: 14 March 2019 Published online in Wiley Online Library: 2 April 2019

(wileyonlinelibrary.com) DOI 10.1002/pi.5812

Electromagnetic interference shielding effectiveness and skin depth of poly(viny 1/10 fluoride)/particulate nano-carbon filler composites: prediction of electrical conductivity and percolation threshold

Ranvijai Ram,[a,b*] Dipak Khastgir[a] and Mostafizur Rahaman[c]

Abstract

The addition of various particulate nano-carbon (PNC) fillers to heat-resistant poly(vinylidene fluoride) (PVDF) was carried out to prepare conductive composites for use in electromagnetic interference (EMI) shielding application. Three different PNC fillers, namely N472 (Vulcan XC-72), N550 (Fast Extruding Furnace) and N774 (Semi-Reinforcing Furnace), were used in various concentrations to prepare composite systems PVDF/N472, PVDF/N550 and PVDF/N774 by solution casting followed by a moulding technique. These PNC fillers have a particle size at the nanometre level, but they have an aggregating tendency; both these characteristics influence the properties of composites to which such fillers are added. The percolation threshold of the PVDF/PNC composites was theoretically determined using the sigmoidal Boltzmann model and classical theory and compared. Theoretical models were also used to predict composition-dependent electrical conductivity. The electrical conductivity is correlated to that of EMI shielding effectiveness at ambient temperature.

Keywords: polymer composites; electrical modelling; skin depth; EMI shielding

INTRODUCTION

Polymeric materials are often preferred to other materials because of their low weight and ease of processing and fabrication so that prototyping of complicated components can be done most economically.[1,2] Properties of a base polymer can be modified as per requirements through the addition of appropriate filler. Electrostatic dissipation and electromagnetic interference (EMI) shielding materials are in demand for technical applications.[3–12] Polymers, in general, are insulating in nature; however, they can be made conductive intrinsically as well as extrinsically.[13] Extrinsically conductive polymer composites are produced through the incorporation of an appropriate conductive additive within the insulating polymer matrix.[14] Such polymer composites include a wide variety of materials.[14,15]

The addition of conductive additives to an insulating polymer matrix increases the conductivity of the composite.[16–22] However, at and beyond a critical concentration of conductive filler (percolation threshold), a system becomes adequately conductive so that such composites may be used for various purposes.[23–28] Different conductive additives can be added to an insulating polymer, like metal powder, metal wire, metal flakes, carbon fibres, carbon nanotubes, particulate carbon black, etc.[29–35] Carbon fillers are better than metal fillers because they make a system adequately conducting at low filler loading. Moreover, metal fillers suffer from some demerits such as corrosiveness, high density, incompatibility with polymers, chain scission, prone to oxidation, etc. By the use of carbon fillers, the flexibility and low weight characteristics of polymer matrices can be retained to a great extent.[30,31,36–38] Among carbon fillers, particulate carbon fillers are often preferred mainly due to their low cost, ease of mixing and better dispersion in polymer matrices compared to other forms of carbon fillers.[39–43] Further, particulate carbon filler up to a certain level of concentration reinforces a polymer matrix.[43–46]

In the work presented here, poly(vinylidene fluoride) (PVDF) and three types of carbon blacks were used as base polymer matrix and conductive additives, respectively. PVDF is a semi-crystalline specialty thermoplastic, having strong piezoelectricity, toughness and resistance to chemicals. The three types of carbon blacks differ in their particle size and structure. Studies of PVDF/carbon black or multiphase hybrid composites have been carried out in the last few years.[47–51] In short, it can be mentioned that in those studies,

* Correspondence to: R Ram, Rubber Technology Centre, Indian Institute of Technology Kharagpur, Kharagpur, India. E-mail: ranvijai.chemistry@gmail.com

a Rubber Technology Centre, Indian Institute of Technology Kharagpur, Kharagpur, India

b Department of Chemistry, Maharaja Agrasen College, University of Delhi, New Delhi, India

c Department of Chemistry, College of Science, King Saud University, Riyadh, Saudi Arabia

