Materials Science & Engineering B 225 (2017) 140–149

Contents lists available at ScienceDirect

Materials Science & Engineering B

journal homepage: www.elsevier.com/locate/mseb

Effect of thermal-air ageing treatment on mechanical properties and electromagnetic interference shielding effectiveness of low-cost nano-structured carbon filled chlorinated polyethylene

Subhadip Mondal[a], Sayan Ganguly[a], Poushali Das[b], Poushali Bhawal[a], Tushar Kanti Das[a], Revathy Ravindren[a], Sabyasachi Ghosh[a], Narayan Ch. Das[a,*]

[a] Rubber Technology Centre, Indian Institute of Technology, Kharagpur 721302, India
[b] School of Nanoscience and Technology, Indian Institute of Technology, Kharagpur, India

ARTICLE INFO

Keywords:
Electromagnetic interference shielding
Chlorinated polyethylene
Carbon black
Electrical property
Mechanical properties
Thermal properties

ABSTRACT

Easy fabrication of flexible and high-performance polymeric composites for radiation shielding has been prioritized since the last few decades. But most of the materials have been suffering from lack of durability in environmental exposures. Herein, to develop a new flexible composite with significant mechanical robustness and longtime durability, a low percolating nano carbon clusters reinforced polymer composite has been proposed. The chlorinated polyethylene (CPE) composite showed low percolation threshold (13.7 wt%), and superior electromagnetic interference (EMI) shielding value (42.4 dB) at 40 wt% conductive Vulcan XC-72 (VXC) carbon black loading. It was assessed that CPE composites have excellent serviceability on desired mechanical and EMI shielding properties after thermal-air ageing treatment. Altogether, this work provides an economical way to fabricate flexible CPE composites as serviceable EMI shield material with desired attributes.

1. Introduction

In the last two decades, unwanted electromagnetic pollutant has been increased at a discernible rate due to the large scale development and usage of various electronic devices, portable digital hardware's, communication devices, wireless networks and military instruments [1–10]. The efficiency and lifetime of electronic devices, as well as living environment of the human being are affected by regular long-term exposure of unwanted EM wave [1,11,12]. Moreover, the civic life has been suffered from cancer, leukaemia, asthma, miscarriage, and migraine which can be caused by significant dependency on various electronic gadgets like the cell phone, laptop, smart television, tablet utilizing Wi-Fi and Bluetooth technology [13–18]. To minimize the EMI effect, the most critical demand of researchers is to develop innovative material to overcome the rising radiation pollution and providing a healthier and safer environment. Metal and metal based composites have been widely used as the primary shield material due to their high electrical conductivity [14,19]. However, they have several disadvantages like heavy weight, high cost, difficulty in processing, poor flexibility, corrosion possibility, poor chemical resistance, etc. [20]. Therefore, researchers are now focusing on the development of cost-effective, flexible, lightweight, corrosion resistant, and easy to process carbonaceous filler polymer based EMI shielding materials to overcome the above mentioned difficulties. Most of the research works are available with various conductive nanofillers such as carbon nanofiber (CNF) [1,13], carbon nanotube (CNT) [21], expandable graphite (EG) [22], graphene (G) [23,24], and graphene nanoplatelets (GNP) [25] due to their excellent intrinsic conductivity, heat transfer, and EMI shielding efficiency. Even though these nanofillers can achieve adequate EMI shielding efficiency, but they are still less practiced commercially on account of their quite expensiveness, high processing cost, difficulties in dispersion and distribution. Thus to overcome these drawbacks caused by the complications in the economical point of view, researchers still have the challenge to produce low-cost EMI shield materials with other required optimal properties. The EMI shielding performance and electrical conductivity of polymer composites depend not only on the intrinsic conductivity, concentration of conductive fillers but also on the distribution and dispersion of the conductive filler throughout the matrix. In addition, the development of microstructure and morphological characteristics of filler can also influence the polymer composite properties. To realize morphological characteristics, small angle X-ray scattering (SAXS) is a unique microscopic tool to evaluate the filler microstructure, distribution and dispersion of filler, filler-filler connectivity, and topology of filler network

* Corresponding author.
E-mail address: ncdas@rtc.iitkgp.ernet.in (N.C. Das).

http://dx.doi.org/10.1016/j.mseb.2017.08.024
Received 18 May 2017; Received in revised form 9 August 2017; Accepted 31 August 2017
0921-5107/

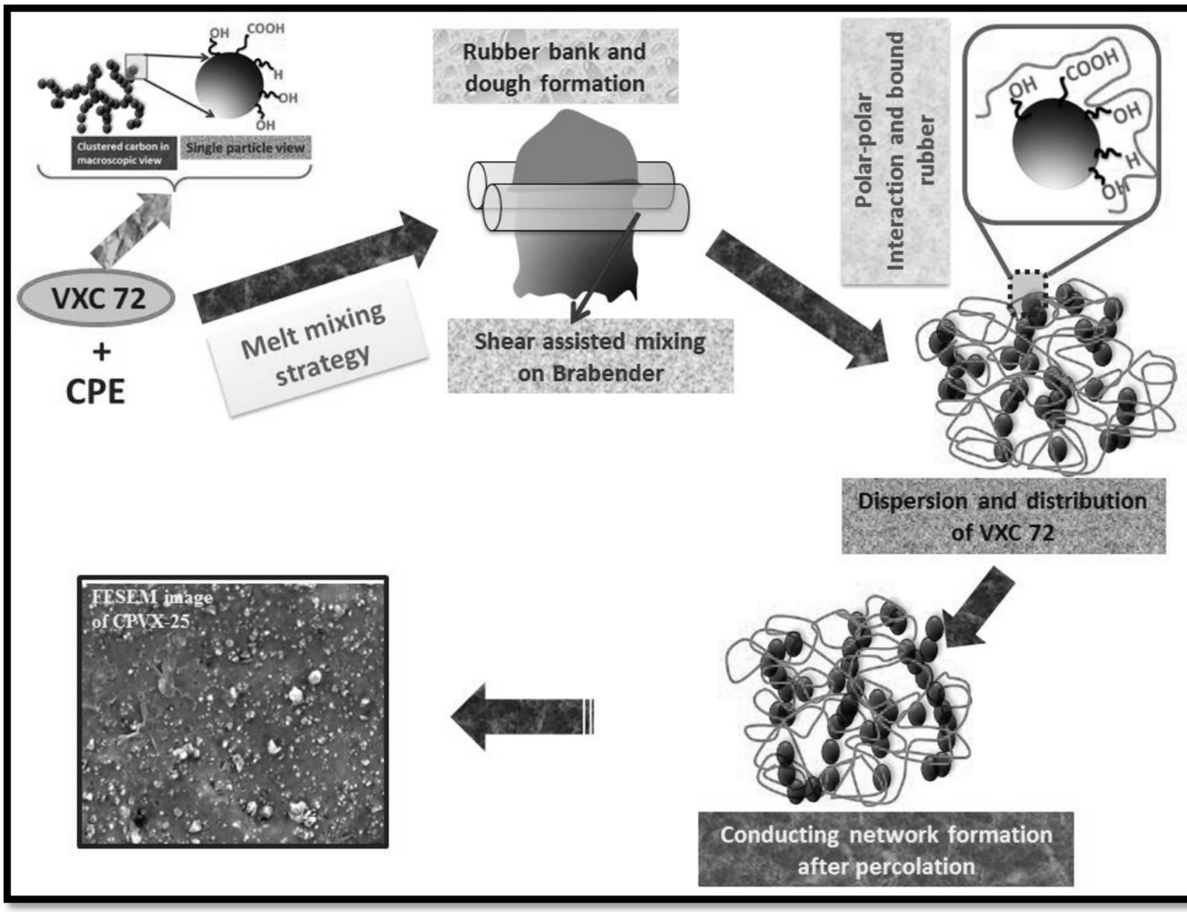

Fig. 1. Melt mixing strategy of CPE/VXC composites with distribution of nano-structured carbon particles.

structure and also correlate with mechanical, electrical and rheological properties [26].

In this study, CPE and VXC (conductive carbon black) are used as the polymer matrix and conductive filler respectively which are fabricated by melt mixing method with different VXC loading via the externally applied shear action. Curing or vulcanization is a process by virtue of which gum polymer (especially rubber) can be spatially crosslinked in order to achieve modulus. There are various types of vulcanization systems. Among them peroxides are exploited to crosslink polymer chains because of the peroxide's versatility against unsaturated and saturated elastomers. The most desirable outcome has seen when a coagent is applied with peroxide [27]. Coagents synergistically help peroxides by boosting the cure properties during curing reaction in mold. Triallyl cyanurate (TAC) is a widely accepted coagent which has the provision of simultaneous cyclopolymerizations as well as vinylic grafting in rubber backbone. Basically it (here TAC) forms semi-interpenetrating polymeric network which is phase inseparable in character without hampering the polymer microstructure and properties [27]. Thus CPE/VXC composites are cured by peroxide with TAC coagent. For, techno-commercial applications of polymer composites, melt mixing strategy is simple and scalable industrial technique to fabricate polymer composites without the usage of solvents as compared to other methods [28]. Most of the reported works are focused on electrical properties of melt mixed polymer composites. To the best of our knowledge, only two previous works focused on CPE polymer composites as EMI shield material reported.

In this contribution, we report on the flexible and industrially viable melt-processed CPE/VXC composites with enhanced EMI shielding efficiency and tuned electrical conductivity. The influence of VXC loading on the morphology, polymer-filler interaction, mechanical, electrical, thermal, and EMI shielding efficiency of CPE/VXC composites were extensively examined. The effect of thermal-air ageing treatment on mechanical and EMI shielding efficiency of CPE composites was also studied. The enhanced EMI shielding efficiency of the composites allows the easy fabrication with proper distribution and dispersion of VXC in CPE matrix. It is expected that the CPE/VXC composites would exhibit good morphology, improved electrical conductivity, good mechanical properties, tunable thermal stability, and enhanced EMI shielding efficiency which may offer great promise to flexible, lightweight EMI shield materials for academic and industrial purposes.

2. Experimental procedure

2.1. Materials and chemicals

Chlorinated polyethylene (CPE-360) was supplied by Nicco Corporation Limited, India. VXC-72 conductive carbon black (BET surface area: 240 m^2/g, the particle size: 50–60 nm) was purchased from Cabot Corporation, India. Dicumyl peroxide (DCP), curing agent and triallyl cyanurate (TAC), co-agent were procured from Hercules, India, and Fluka, AG, Germany, respectively. Magnesium oxide (MgO), acid scavenger and heat stabilizer dibutyltin dilaurate (DBTDL) were obtained from Sigma-Aldrich, USA.

2.2. Preparation methodology

CPE and VXC were dried in vacuum oven for 12 h at 60 °C before melt mixing to minimize the effects of moisture. CPE, VXC, and other ingredients were added in a Brabender Plasticorder PLE-330 at 120 °C for 13 min with 60 rpm. At first, CPE was melt mixed at a same