Properties of a Carbon Filled Cyclic Olefin Copolymer

G. H. MOTLAGH, A. N. HRYMAK, M. R. THOMPSON

MMRI/CAPPA-D, Department of Chemical Engineering, McMaster University, Hamilton, Ontario, Canada L8S 4L7

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ABSTRACT: This article investigates electrical conductivity and rheological aspects of cyclic olefin copolymer (COC) composites containing both carbon fiber (CF) and carbon black (CB) at various concentrations. The different formulations of carbon filled COC were compression molded in such a manner that the formed circular sheets exhibited preferred in-plane filler orientation. Through-plane and in-plane conductivity were measured by 2-probe and 4-probe methods, respectively, while an ARES rheometer in dynamic mode was employed to measure the storage modulus and complex viscosity. It was found that formulations with CF:CB ratios around 3 and where the CB content was close or below its critical percolation concentration resulted in higher electrical conductivity while maintaining the viscosity of the composite at a level acceptable for polymer processing machinery. For those composites containing both fillers, collaborative associations between the CB and CF fillers were found in the established percolating network structure, producing measured conductivities which exceeded the estimated values by the additive rule by up to sixfold. An empirical expression to handle hybrid filler systems is proposed in this work based on the standard percolation model. ©2007 Wiley Periodicals, Inc. J Polym Sci Part B: Polym Phys 45: 1808–1820, 2007
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INTRODUCTION

Polymer composites are an attractive alternative to both metals and graphite for bipolar plates used within fuel cell stack construction because of their relatively low cost, good mechanical, and chemical properties, and most notably, their ease of fabrication into complex geometries.[1] Several efforts are currently underway to manufacture bipolar plates from polymer composites.[2–9] The greatest challenge for this class of materials is their low inherent electrical conductivity, a feature that can be overcome with high loading of conductive additives, though at the expense of processability. Additives shown to improve electrical conductivity in polymers include: carbon fiber (CF),[10–14] nickel-coated CF,[14,15] stainless-steel fibers,[15,16] graphite,[17,18] carbon nanofibers,[19] carbon nanotubes,[20–23] exfoliated graphite,[24–26] and carbon black (CB).[27] With increasing filler content, the electrical conductivity increases, as does the viscosity of the polymer; for example, with 25 wt % CB in polypropylene, it was shown[6] that the electrical conductivity increased from 10^{-17} S/cm (characteristic of the resin) to 0.1 S/cm while the shear viscosity at 100 s^{-1} increased from 70 Pa-s to more than 1000 Pa-s. For mass production of bipolar plates to reach its economic target,[28,29] less than $10 per kg or less than $10 per KW, the polymer composite needs to be able to take advantage of an economically-favorable process like injection molding rather than compression molding. Unfortunately, the high viscos-

Correspondence to: M. R. Thompson (E-mail: mthomps@mcmaster.ca)

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