Novel Functional Nitrile Butadiene Rubber/Magnetite Nano Composites for NTCR Thermistors Application

Salih S. Al-Juaid,[1] E. H. El-Mossalamy,[1] H. M. Arafa,[2] A. A. Al-Ghamdi,[3] A. M. Abdel Daiem,[3,4] Farid El-Tantawy[5]

[1]*Faculty of Science, Department of Chemistry, King Abdulaziz University, Jeddah 21569, Kingdom of Saudi Arabia*
[2]*Faculty of Science, Department of Chemistry, University of Tabuk, Tabuk, Kingdom of Saudi Arabia*
[3]*Faculty of Science, Department of Physics, King Abdulaziz University, Jeddah 21569, Kingdom of Saudi Arabia*
[4]*Faculty of Science, Department of Physics, Zagazig University, Zagazig, Egypt*
[5]*Faculty of Science, Department of Physics, Suez Canal University, Ismailia, Egypt*

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ABSTRACT: A new negative temperature coefficient of resistor (NTCR) thermistors based on nitrile butadiene rubber/magnetite (NBR/Fe_3O_4) nanocomposites were successfully fabricated by conventional roll milling technique. X-ray diffraction and transmission (TEM) analysis showed that the product is mainly magnetite nanoparticles with diameter of 10-13 nm. The microstructure of (NBR/Fe_3O_4) nanocomposites were examined by scanning electron microscopy (SEM) and FTIR spectroscopy. The dispersion of magnetite nanoparticles in the NBR rubber matrix and interfacial bonding between them were rather good. The thermal stability of nanocomposites was also obviously improved with the inclusion of the magnetite nanoparticles. The thermal conductivity, thermal diffusivity and specific heat of nanocomposites were investigated. The electrical conductivity of the NBR/Fe_3O_4 increases with the rise in temperature exhibiting a typical negative temperature coefficient of resistance (NTCR) behavior like a semiconductor. The nature of the temperature variation of electrical conductivity and values of activation and hopping energy, suggest that the transport conduction process is controlled by hopping mechanism. Values of characteristics parameters of the thermistors like thermistor constant, thermistor sensitivity and thermistor stability is quite good for practical application as NTCR devices at high temperature. © 2011 Wiley Periodicals, Inc. J Appl Polym Sci 121: 3604–3612, 2011

Key words: NBR rubber; magnetite nanoparticles; network structure; electrical and thermal properties

INTRODUCTION

Electrically conductive polymer nanocomposites have attracted a great deal of scientific and commercial interest.[1,2] These conductive nanocomposites have been widely used in newer areas and for various applications such as touch control switches,[3] electromagnetic interference shielding,[1,2] floor heating,[4] electrostatic discharge protection,[5] corrosion-protection,[6] PTCR thermistors,[2] temperature sensors,[7] gas sensors,[8] magnetic sensors,[9] piezoresistive sensors,[10] etc. One of the important methods to form a charge carrier path in an insulating polymer matrix is the incorporation of conductive additives like carbon black,[11] carbon fiber,[12] carbon nanotubes,[13] graphite,[14] metal,[15] metal oxide,[16] conducting organic polymer[17–20] and others. Nanometer sized iron oxides such as magnetite (Fe_3O_4) and/or maghemite (Fe_2O_3) posses magnetic, catalytic, conducting and biological properties and are suitable for applications in cell separation, protein purification, targeted drug delivery, environmental and food analyses, organic and biochemical synthesis, and industrial water treatment.[11–16] Magnetic nanoparticles embedded in polymer matrixes have excellent potential for electromagnetic device applications like electromagnetic interference (EMI) noise reduction.[18–21] Recently these conductive composite materials have been very popular due to their low attractive costs, high flexibility, and weather and chemical resistant properties. However, negative temperature coefficient of resistance (NTCR) thermistors are semiconductor materials and are found in an ever-increasing number of electrical and electronic devices since the 1940s in telecommunication circuit compensation.[1,13] An important thermal-sensitive feature of conducting polymer composites, that is, the resistivity decreases with increasing temperature, which is also known as NTCR effect.[14,15] They are widely used in various industrial and domestic applications, for examples, elements for the suppression on in—rush current, for temperature measurement and control,

Correspondence to: F. El-Tantawy (faridtantawy@yahoo.com).