Iran Polym J (2013) 22:61–73
DOI 10.1007/s13726-012-0104-4

ORIGINAL PAPER

Thermal and electrical properties of epoxy composites at high alumina loadings and various temperatures

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Received: 9 July 2012 / Accepted: 29 October 2012 / Published online: 13 November 2012

Abstract Epoxy microcomposites with high loading micro alumina (Al_2O_3, 100–400 phr) were prepared by casting method and their thermal and electrical properties were studied at temperatures from 25 to 150 °C. The electric resistance device and the dielectric electrode device were designed to measure the electrical properties of the composites. Thermogravimetric analysis (TGA) and scanning electron microscopic proves the homodispersion of Al_2O_3 microparticles in epoxy. TGA indicates that the temperature of 5 % weight loss of epoxy/Al_2O_3 (100 phr) composite is 366 °C, 34 °C higher than that of pure epoxy. Differential scanning calorimetry shows that the glass transition temperature of epoxy/Al_2O_3 composite (400 phr) increases to 114.7 °C, 9.2 °C higher than that of pure epoxy. Thermal conductivity test demonstrated that with increasing Al_2O_3 content at 25 °C, thermal conductivity of epoxy/Al_2O_3 composites increased to 1.382 W/(m K) which is 5.62 times that of pure epoxy. Electrical tests demonstrate that by increasing of Al_2O_3 content and temperature, the electric resistance and dielectric properties of the composites show great dependencies on them. Resistivities of all the specimens decreased with the increasing of temperature owing to the increasing molecular mobility in the higher temperature. Resistivity of pure epoxy at 25 °C is about 9.56×10^{16} Ω cm, about one order of magnitude higher than that of pure epoxy at 125 °C and two orders of magnitude higher than that of pure epoxy at 150 °C. These results can give some advice to design formulations for practical applications in power apparatus.

Keywords Epoxy · Alumina · Thermal stability · Thermal conductivity · Dielectric property

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Introduction

Epoxy resins as thermosetting materials have been used in a variety of industrial applications, such as inks, coatings, paints, vacuum pressure, impregnation of coils, encapsulation of electronic circuit elements and printed circuit board coatings because of their excellent heat and chemical resistance, superior mechanical and electrical properties, as well as easy processability [1–3].

Despite many advantages of epoxy resin, the modifications of epoxy resin aiming at improving the thermal stabilities and electrical performances are quite necessary to prolong the service life and increase the operating reliability of power apparatus [4]. Earlier reports and our previous studies all show that the addition of inorganic nanoparticles such as graphite [5], SiC [6], clay [7, 8], CNT [9], MWCNT [10], BN [11, 12], graphene and graphene oxide [13, 14], silica [15, 16], AlN [17], SiAlON [18], etc. into epoxy matrix due to formation of nanocomposites has been proved to be an efficient way to enhance thermal stabilities and electrical performances. Al_2O_3 is often chosen as fillers because of its high electrical resistivity (>10^{14} Ω cm), low dielectric constant (9.8 at 1 kHz), low dielectric loss (0.0002 at 1 kHz) and low cost [19–21].