Chapter 9

Polymer Composite Materials for Microelectronics Packaging Applications: Composites for Microelectronics Packaging

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ABSTRACT

This chapter reports the recent advances in the fabrication methods, properties, and microelectronics packaging applications of various inorganic fillers and reinforced-polymer composites. Recently, inorganic particles, including ceramics and carbon-based material reinforced polymeric matrices, have attracted both academic and industrial interest because they exhibit good thermal and mechanical properties. The low dielectric constant and dielectric loss, the low thermal expansion coefficient, and high thermal conductivity make these kinds of composites suitable for microelectronics packaging. The filler ratio, surface modification, and preparation methods of these composites have a marked effect on the final properties of these materials. Herein, the preparation methods, thermal and dielectric properties, shortcomings, and microelectronics applications of polymers/inorganic composites are summarized and discussed along with detailed examples collected from the extensive scientific literature.

DOI: 10.4018/978-1-5225-5216-1.ch009
INTRODUCTION

In recent years, polymeric thermoplastic, thermoset, and rubber materials have been widely explored and used in many ways to satisfy the needs of industries in the automotive, aerospace, and microelectronics sectors (Fieler, 2000). Such significant interest in the materials derives from various factors, including their ease of processing, light-weight, low cost, high productivity, good corrosion-resistance, low electrical characteristics, a moderate thermal expansion coefficient (CTE), and good customizability for these properties via various structural designs. By some contrast, polymers exhibit inferior thermal conductivity of about 0.2 W/m.K. This makes them useful in microelectronics packaging sector also, particularly as printed circuit boards (PCB), thermal interface materials (TIM), insulation for motor, adhesives for light-emitting diodes (LED), as well as materials for solar cells and phase change applications (Moore & Ashi, 2014).

To satisfy the use conditions of high-performance microelectronic packaging systems, System-in-Package (SiP) technique had been thought as the most efficient packaging method due to its area grid array and flip-chip attach characteristics (Song, Kim, & Lee, 2003). However, this packaging technology has many shortcomings, including difficulty to design and elaborate a high-density multilayer packaging substrate with high I/O density, high working frequencies, and high good thermal stability. The required characteristics for any high-density packaging substrate are: fine-pitch lines (<30 µm), fine via-hole diameters (<30 µm), high operation frequency (>3 GHz), better thermal stability, excellent flip-chip mounting reliability, and low production costs (Shimoto, Baba, & Matsui, 2005).

The use of polymers generally produced conventional packaging substrates exhibiting several serious challenges for a high-density IC packaging system (Mishra, Raj, & Tishler, 2016). This includes the higher cost of building up the multilayers; the deformation of curvature and unevenness of the core laminates at higher temperature; impedance mismatching that resulted form the through-holes drilled in the core laminates, which significantly limited their uses in the high-speed and high-frequency systems (Pleșa, Noțingher, & Schlögl, 2016).

Also, in those applications, the small surface of a substrate exhibits dense thermal energy, which directly influences signal transmission and can even destroy the materials, if the generated heat does not effectively or quickly dissipate (Huang, Jiang, & Tanaka, 2011). To increase the reduced thermal conductivity of polymeric materials, two approaches are available: the molecular design or the filling with thermally-conductive agents (Bigg, 1995). In response, the preparation of some micro- and nanocomposites based these polymeric matrices reinforced with various conductive inorganic particles and fibers are arguably the best means to overcome that serious problem. Along with their high thermal conductivity, the composite
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