Ceramic/polymer composites with high thermal conductivity and mechanical strength for electronic packaging

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Abstract

Insulating materials for electronic packaging should ideally have high thermal conductivity and mechanical strength. Ceramic/polymer composite is one of the candidates for such materials. In this work, Al_2O_3/epoxy composites with very high thermal conductivity and flexural strength and were prepared using a new processing technique consisting of the gelcasting, sintering and vacuum infiltration methods. Al_2O_3 green bodies were first formed by gelcasting. After being degreased at 600 ℃, the green bodies were sintered at different temperatures from 1200 ℃ to 1500 ℃, and porous Al_2O_3 ceramic skeletons with readily controlled porosity were resulted. Epoxy was vacuum infiltrated into the porous Al_2O_3 ceramic skeletons to form Al_2O_3/epoxy composites by curing. High Al_2O_3 loadings up to 70 vol.% in the composites were achieved. The flexural strength and thermal conductivity of the Al_2O_3/epoxy composites were found to reach 305 MPa and 13.46 $W\ m^{-1}K^{-1}$, respectively. These results are remarkably higher than those previously reported in the literature. This work provides an effective approach for fabricating high performance ceramic/polymer composites for electronic packaging.

Keywords: Ceramic/polymer composite; Electronic packaging; Thermal conductivity; Mechanical strength; Alumina/epoxy

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Insulating materials for electronic packaging with outstanding properties, such as high thermal conductivity, high reliability, low dielectric constant and more importantly, low cost, are gaining intensive attention in the last decade as high-performance electronic devices are being developed and commercialized at an accelerating pace [1]. In recent years, ceramic/polymer composite materials have been extensively studied because they can be fabricated at relatively low cost and their thermal and mechanical properties can be readily optimized at the design stage [2,3]. In general, as shown in Fig. 1a, the ceramic/polymer composites comprise ceramic particles as fillers which reinforce the polymer matrix [4]. It is well-known that polymers usually have quite poor thermal conduction [5]. Hence, the other major task of the reinforcing ceramic particles in the ceramic/polymer composites is to enhance the thermal conduction of the composites. Many kinds of ceramic particles such as silica [6,7], alumina [8,9], aluminum nitride [10,11], boron nitride [12,13] have been applied to polymer matrices to form ceramic/polymer composites, and their thermal conductivity was found to be higher than the polymer matrices.

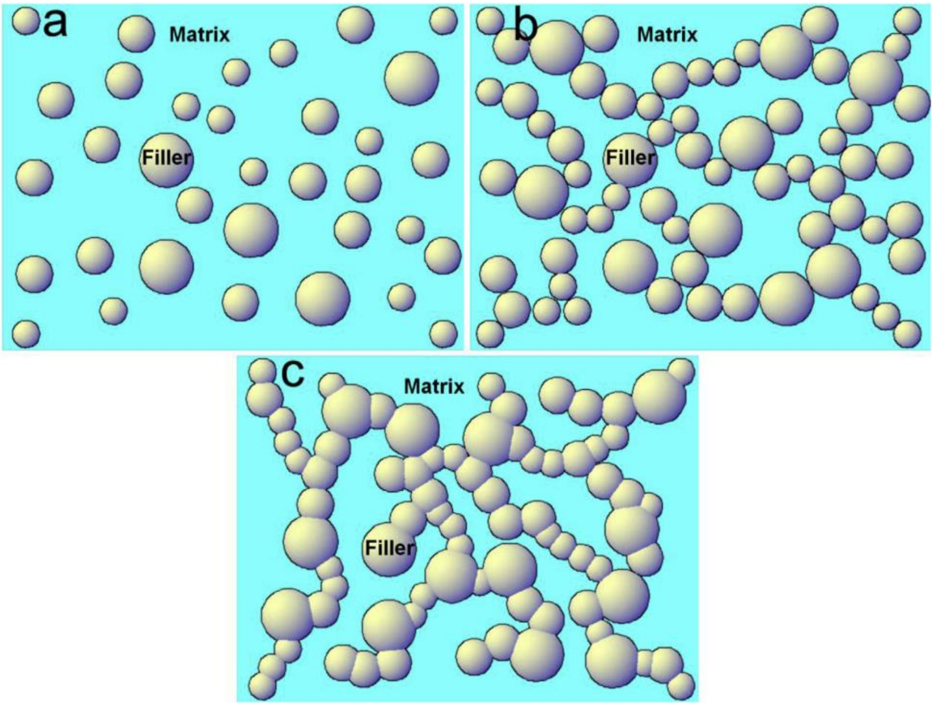

Fig. 1 Three filling configurations of ceramics particles in ceramic/polymer composites: dispersed (a), mechanically contacted (b), and chemically bonded (c) [14].

In general, as shown in Fig. 1, there are three types of filling configurations of ceramic particles in ceramic/polymer composites [14]: dispersed (a), mechanically contacted (b), and chemically bonded (c). In Fig. 1a, the ceramic particles are isolated in the composite, so their thermal conductivity can only be moderately enhanced. As shown in Fig. 1b, the thermal conductivity of ceramic/polymer composites could also be enhanced to a certain extent by dispersing high loadings (up to 70 vol.%) [15,16,17] of ceramic particulate fillers using the polymer molding technique [18,19]. In Fig. 1b, the ceramic particles mechanically contact one another. However, the interface between neighboring particles (Fig. 1b) has much lower thermal conduction than the bulk particles. Thus, the enhancement in the thermal conductivity of such high loading ceramic/polymer composites is expected to be rather modest [16,17]. With regards to their mechanical properties, such high loadings, however, will result in inferior mechanical properties (e.g., susceptible to thermal cracking and challenging to process) to the composites [20].

Herein, we prepared ceramic/polymer composites by building both the ceramic and polymer matrices which are interwoven as shown in Fig. 1c. The ceramic matrix is sintered so that the neighboring ceramic particles form chemically bonded interfaces, which are expected to have similar thermal conductivity as the bulk ceramic particles. In addition, such ceramic matrix also possesses good mechanical properties. Considering Al_2O_3 has relatively good thermal conductivity and is of much lower cost than AlN and BN, we selected Al_2O_3 to prepare Al_2O_3/epoxy composites in this work. High loadings of Al_2O_3 in Al_2O_3/epoxy composites were achieved using the new process combining the gelcasting, sintering and vacuum infiltration techniques. A significant enhancement in the thermal conductivity of the

Al_2O_3/epoxy composites was observed, and in the meantime high mechanical properties were achieved. This work demonstrates an effective processing method for fabricating ceramic/polymer composites with very high thermal conductivity, mechanical properties and good reliability.

As shown in Fig. 2, high Al_2O_3 loading up to 70 vol.% in the composites was achieved [14]. Effects of the Al_2O_3 content or the sintering temperature on the flexural strength, thermal conductivity, and dielectric constant of the Al_2O_3/epoxy composites were studied and discussed. The flexural strength and thermal conductivity of the Al_2O_3/epoxy composites were found to reach 305 MPa and 13.46 $W \cdot m^{-1}K^{-1}$ [14], respectively. These results are remarkably higher than those previously reported in the literature. This work provides a promising approach for fabricating high performance ceramic/polymer composites for electronic packaging.

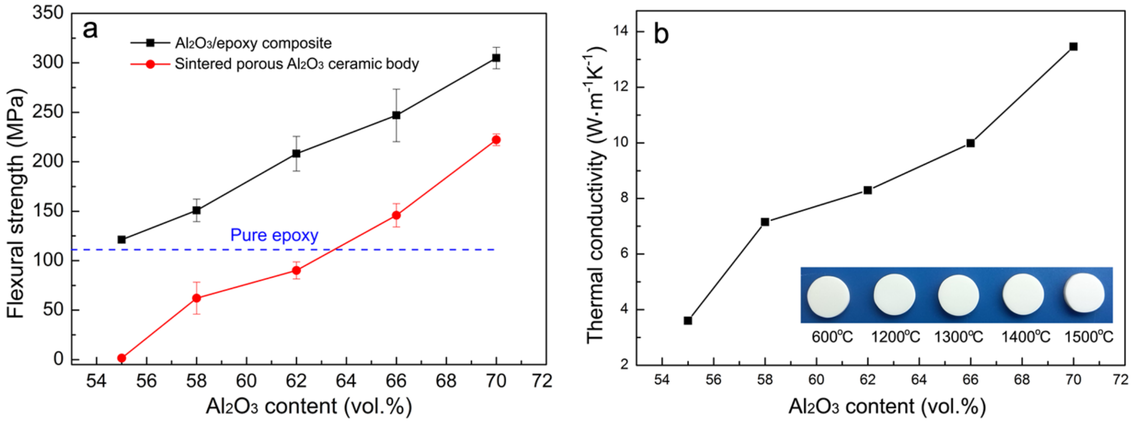

Fig. 2 Flexural strength and thermal conductivity of the Al_2O_3/epoxy composites as a function of the Al_2O_3 content [14].

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