Heat-Sink Solution Through Artificial Nanodielectrics for LED Lighting Application

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Abstract

Light Emitting Diodes (LEDs) are likely to replace other technologies such as incandescent and fluorescent bulbs in signaling, solid state lighting and vehicle headlights because they save energy and extend the light's lifetime. Thermal management of LEDs is a crucial area of research and development [1]. High performance LEDs requires superior thermal management systems. Heat sink mounts that dissipate the heat generated by these high power LEDs are of critical importance for this purpose. The advent of more sophisticated applications of heat-sink materials has led to tremendous interest in alternative methods that can provide access to thermally and electrically stable materials. Composites made with epoxies and polymers mixed with various additives have been developed and are available in the market [2-6]. All these materials lack either in one or more parameters, which are important for optimal properties.Thermally conducting but electrically insulating materials are needed for heat-sink LED lighting applications. Metals are thermally and electrically conductive, so they cannot be used. All polymers are electrically and thermally insulated. Thus, polymers alone cannot be used for this application. However, polymers can be modified by mixing or compounding them with shells, isolated (capped) metal nanoparticles, which are thermally conductive and at the same time electrically insulated (Figure 1). Such nanoparticles with ultrathin shells allow the surface of a particle to be altered while the particle maintains its bulk properties. The solid oxide shell around the Al core prevents agglomeration of Al nanoparticles. This physical barrier overcomes the internal charging creation which in turn improves the dielectric strength of the nanocomposite. In COMSOL Multiphysics, the Heat Transfer Module is selected and both steady and transient analyses were applied to calculate the thermal conductivity of the nanocomposite. Effective Medium Theories (EMT) of Maxwell-Garnett, Bruggeman and Looyenga models were employed to estimate the effective electrical permittivity using In-plane electric currents coupled within the AC/DC Module. Simulation results with 12% $Al\text{-}Al_2O_3$ core-shell nanoparticles loading in a Polyvinylidene fluoride (PVDF) indicates a minimal dielectric loss of the embedded host polymer and at the same time provides a powerful approach for thermal management application for LEDs lighting application. The mean effective thermal conductivity seems to exceed the value of 100W/m·K with an electrical permittivity of 52 at the same fraction of loading. These results are considered outstating but they need to be validated experimentally. It is anticipated that proper loadings of engineered core-shells in selected high dielectric strength thermoplastic polymer will provide high thermal conductivity, thus enhancing the dielectric properties of polymer by mitigating the internal charge creation within polymer host while maintaining electrical insulation to dissipate

the heat with ultrafast response.

Reference

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Figures used in the abstract

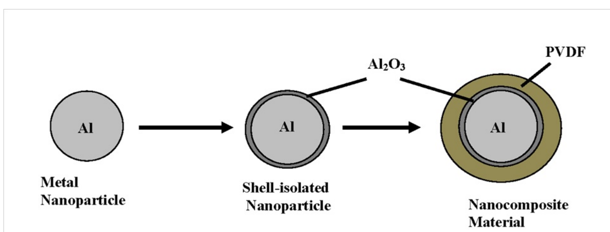

Figure 1: Representative scheme for oxide shell-isolated metal nanoparticle in polymer.