Enhancement of Thermal Diffusivity in Phase-separated Polyimide Blend Films Containing Needle-Shaped ZnO Particles

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Polyimides (PIs) are a typical super engineering plastics obtained by dehydration reaction of poly (amic acids) (PAAs). PIs have been widely used as alignment layer of liquid crystal displays or flexible printed circuit board due to their excellent heat resistance, mechanical properties and electric insulation. Very recently, enhancement of thermal conductivity is strongly demanded for PI insulating layers associated with speeding up and miniaturization of power-ICs. In this study, thermal diffusivity of phase-separated polyimide (PI) blend films containing needle-shaped ZnO (n-ZnO) nanoparticles was investigated. The PI blend films were prepared by blending n-ZnO and precursors of a sulfur- (SD) and a fluorine-containing PI (TF), followed by curing at 350 °C. Phase-separated structures with vertical double percolation (VDP) morphology was observed by SEM, in which each PI phase was oriented along the out-of-plane direction. In addition, n-ZnO particles were selectively confined in TF phase due to the affinity to fluorine. To investigate the effects of thermal conductivity enhancement of VDP morphology and anisotropic shapes of n-ZnO, thermal diffusivity of the composite films was evaluated by temperature wave analysis (TWA). Comparing with a mono-phase PI with dispersed pyramidal-shaped ZnO (p-ZnO), mono-phase PI containing n-ZnO showed higher thermal diffusivity based on the formation of effective heat conduction paths owing to the improvement of mutual contact probability. In addition, the PI blend films containing n-ZnO demonstrated more enhanced thermal diffusivity than the PI blend films containing p-ZnO. From these results, n-ZnO has higher probability for orienting to the out-of-plane direction due to the confinement of n-ZnO particles in tight space formed in the VDP morphology.