

Enhancement of the Out-of-Plane Thermal Diffusivity in Micro-phase Separated Polyimide Films Containing Silver Nanoparticles

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Polyimide (PI) films are promising as interlayer dielectrics in fast integrated circuits and optical waveguides because of their outstanding chemical and physical properties for microelectronics, though the thermal conductivity of PIs is not enough as well as other polymeric materials. Recently, polymer films containing homogeneously dispersed inorganic fillers have been widely studied to enhance their thermal properties. However, the improvement in thermal conductivity is still limited due to the small amount of fillers in order to maintain their insulation property and flexibility. In this study, we proposed a new strategic material design for effective increase in thermal conductivity in spite of small amount of fillers based on the selective precipitation technique of silver nanoparticles (Ag-NP) in PI blend. Two types of PI, sulfur-containing PI and fluorine-containing PI, were blended with silver nitrate as the precursor of Ag-NP. Then, the films, on the order of 20-40 μm in thickness, were prepared by spin coating method. Under optimized conditions, the films showed the “double percolation” structures orienting along the out-of-plane direction, while the films exhibited variety of micro phase-separated structures according to the blend ratios and process conditions. XRD measurements showed the formation of Ag-NP (ca. 10 nm) by spontaneous reduction of silver nitrate, and FE-SEM/EDS analysis revealed the segregation of Ag-NP in the sulfur-containing PI region that has a higher affinity to silver ions. To evaluate the thermal conductivity of the films, we measured thermal diffusivity along the out-of-plane direction using the temperature wave analysis [1]. Comparing with the mono-phase PI films with homogeneously dispersed Ag-NP, the blended PI films having the double percolation structures with selectively dispersed Ag-NP exhibited significantly higher thermal diffusivity. These results indicate the “double percolation structures” which were spontaneously formed in the PI blend system, function as the effective thermal conduction pathways.

[1] J. Morikawa et.al, *J. Appl. Phys.*, **103**, 063522 (2008).