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Efficient Heat Transfer Enhancement in Quantum Dots Luminescent Composites by Polymer Fluid Flow-Driven Horizontally Oriented Platelets

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Extended Abstract

Quantum dots (QDs), a kind of nanoscale luminescent particles, have been widely used in optoelectronic fields for its state-of-art characteristics such as size-dependent bandgaps, high luminous efficiency and superior colour purity [1]. These particles are always packaged in low thermal-conductive polymer matrix whose thermal conductivity is lower than 0.2 W m^{-1} K^{-1}. During their operation, heat generates from the light conversion process and results in a temperature rise [2]. Unfortunately, QDs are sensitive to ambient temperature. Their luminous properties sharply drop with the increasing temperature [3]. Therefore, thermal management of QDs is of considerable importance.

Incorporating high thermal-conductive fillers into QDs embedded polymer (QDs-polymer) is frequently adopted. Hexagonal boron nitride (hBN), has been proved to be a suitable option due to its excellent thermal conductivity and negligible light absorption effect [4]. To take full advantage of its high thermal conductivity, researchers proposed to regulate their orientation [5]. However, most of the present strategies for orientation could worsen the optical performance of QDs for the complicated fabrication process. An effective and harmless method is needed for QDs' thermal management.

To tackle this issue, we provided a new strategy to fabricated QDs-polymer with high in-plane thermal conductivity by creating a flow-field in the polymer fluid where the hBN platelets are horizontally oriented. The flow process and polymer fluid are QDs-friendly, and the polymer fluid could continue to be used in QDs' packaging. To furtherly enhance the heat dissipation of QDs, they are bonded to the surface of hBN electrostatically. For the orientation of the hBN, a numerical model of the rotation of hBN in the flow field was constructed. According to this model, hBN platelets periodic rotate in a shear flow field and are approach to a stable state in an elongational flow field. In the shear flow, the normal vector of hBN periodic rotated in the shear rate plane, and vibrated in the plane which is perpendicular to the shear rate plane. There is an equilibrium orientation which takes up most of the time in a period, and when the platelet deviated the equilibrium orientation, they would return to the equilibrium orientation in a very short time. The normal vector of the platelet is in the shear rate plane and perpendicular to the flow direction when it locates in equilibrium orientation. In the elongational flow, when the platelet reaches the stable state, its normal vector is along the elongational direction which is perpendicular to the flow direction. Based on the above investigation, we designed a flow field utilizing spin coating. In the flow field of spin coating, there are both elongational and shearing effect in the upper layer and only shearing effect in the bottom layer. We studied the orientation of particles with different initial angles at different spinning time to optimize the spin coating process and fabricated QDs-polymer with horizontally oriented hBN platelets (QDs-HP) and randomly distributed hBN platelets (QDs-RP). The in-plane thermal conductivity of QDs-HP with 5 wt%, 10wt%, 15wt%, and 20wt% were 0.48, 0.56, 0.60, and 0.92 W m^{-1} K^{-1}, respectively, which is two times larger than that of QDs-RP as 0.21, 0.27, 0.30, and 0.41 W m^{-1} K^{-1}, respectively. The results proved highly efficient heat transfer enhancement ability of QDs-HP and the optical performance comparison of QDs-HP and QDs-polymer indicated that this strategy is harmless to QDs.

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