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Title(English)	Study on Enhancement Mechanism of Thermal Conductivity in Main Main -Chain Liquid Crystalline Polyesters and their Composites
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種別(和文)	論文要旨
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（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	有機・高分子物質　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（工学）
学籍番号： Student ID Number		指導教員（主）： Academic Advisor(main)	渡辺　順次
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

This thesis consists of six chapters and is written in English.

Chapter 1. General Introduction for Thermally Conductive Polymers

In Chapter 1, the related studies so far reported are surveyed and the objects to perform this study are described. Thermally conductive, electrically insulating materials have attracted attention as useful substances for heat dissipation in electronic devices. Polymers are lightweight electrical insulators; however, their thermal conductivity (TC) is typically very low (0.1–0.5 W m^{-1} K^{-1}). Even with large concentrations of thermally conductive fillers, it is difficult to enhance the polymer composite TC. Moreover, a high filler content leads to undesirable weight gain and poor processability. A possible solution to solve these issues is to enhance the polymer matrix TC according to Bruggeman's theory. The TC of polymer composites can be significantly increased when the polymer matrices serve as good heat conductors between the filler particles. However, no such thermoplastic matrices have been reported so far. Here, I report that a main-chain smectic liquid crystalline (LC) PB-10 polyester acts as an effective thermally conductive matrix in a composite with thermally conductive filler particles. PB-*n*, where *n* is the even number of methylene units in the spacer moiety, has been widely studied by our group and forms a highly ordered smectic LC phase along with a lamellar structure in both smectic and crystalline phases.

Chapter 2. Identifying Smectic I Phase of Main-Chain PB-10 Polyester Consisting of 4,4'-Biphenol and 1,10-Dodecanoic acid by Fibre X-ray Diffraction

In Chapter 2, the type of mesophase formed by PB-10 is identified as smectic I using spinnable PB-10 polyester, which was obtained for the first time by solid state polymerization. Polymer chains are packed laterally in a 2D hexagonal lattice and lie along the *c*-axis and pass diagonally across the smectic layers. SAXS and SEM clarify lamellae stacking regularly along the fibre axis with a spacing of 41 nm, which is approximately 20 times the smectic layer thickness. The lamellar normal is thus parallel to the chain axis and tilted to the smectic layer normal.

Chapter 3. Enhanced Thermal Conductivity of Thermoplastics by Lamellar Crystal Alignment of Polymer Matrices

In Chapter 3, TC enhancement of PB-*n* by lamellar crystal alignment is discussed. PB-*n* shows a parallel

orientation of LC lamellae by shear flow during injection molding, in which polymer chains are aligned in normal direction (ND) with respect to the molding surface, thus leading to high TC (1.2 W m^{-1} K^{-1}) in this direction. Furthermore, the composites containing plate-shaped hexagonal boron nitride (h-BN) particles exhibit a dramatic enhancement of TC in not only the ND but also the in-plane direction, indicating that polymer chains align in the ND served as effective heat paths between h-BN particles.

Chapter 4. Influence of Molecular Orientation Direction on the In-plane Thermal Conductivity of Polymer/Hexagonal Boron Nitride Composites

In Chapter 4, the effect of the molecular orientation direction of a polymer matrix on the in-plane TC of injection-molded polymer/h-BN composites is discussed. In this system, the h-BN platelets align in the in-plane direction owing to injection shear flow. Three molecular orientations (perpendicular, random, and parallel to the h-BN plane) are achieved using liquid crystalline polyesters and the in-plane TCs are compared. Although a parallel orientation of the polymer chains provides the highest TC of the matrix in the injection direction, the TC of the composites is the lowest of the three systems for this orientation. The highest in-plane TC is found in the perpendicularly oriented system, irrespective of the in-plane direction. These results reveal that perpendicularly oriented molecular chains serve as effective heat paths between h-BN platelets that are arranged one above the other, and consequently, a continuous thermal network is created in the in-plane direction.

Chapter 5. Main-Chain Smectic Liquid Crystalline Polymer Exhibiting Unusually High Thermal Conductivity in an Isotropic Composite

In Chapter 5, the TC of an isotropic composite comprising of a main-chain smectic liquid crystalline PB-10 polyester and 50-μm-sized roughly spherical magnesium oxide (MgO) particles is discussed. The increase in the composite TC with higher MgO fractions is steeper than that expected by Bruggeman's theory for the TC of a polydomain PB-10 polyester (0.52 W m^{-1} K^{-1}). When the filler content is larger than 30 vol%, the composite TC approaches a value that can be explained only if the polyester functions as a thermally conductive matrix with 1.0 W m^{-1} K^{-1}, which is 5 times as high as those of isotropic common polymers (0.2 W m^{-1} K^{-1}). Such an unusually high TC for a polymer matrix is attributed to some polymer lamellae that lie parallel to the particle surface and are stacked toward neighboring particles. As an appendix, the TC of biomass based PB-8/MgO composites is measured, indicating that the PB-8 polyester also functions as thermally conductive polymer matrix like PB-10.

Chapter 6. General Conclusion

In Chapter 6, contents from chapter 2 to 5 are summarized, demonstrating that main-chain liquid crystalline polyesters will be commercially useful as the high TC matrices. Finally, the thesis concludes with future recommendations.