

論文 / 著書情報  
Article / Book Information

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Title(English)	Thermal Transport Properties of Silicon Nanocrystals and Polystyrene Nanocomposite Thin Film
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Type(English)	Summary

## 論文要旨

### THESIS SUMMARY

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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words )

As the second most abundant element in the earth's crust, silicon (Si) offer a huge potential to be developed. Having been the main semiconductor material for electronic devices, Si has been developed to meet the technological demand of smaller devices by reducing the Si size down to nano-scale that is called silicon nanocrystals (SiNCs). SiNCs have been observed for the novel size-dependent optical and electrical properties and widely studied and utilized in various devices such as solar cells and light emitting devices. Recently, a number of studies have also been reported on size dependence of thermal transport properties in SiNCs, which allow a controllable thermal transport property of SiNCs, presenting a promising application in various devices, such as thermoelectric and micro-nano thermal management. Therefore, it is essential to understand the intrinsic nature of thermal transport in SiNCs to provide optimum performance of device application. However, direct thermal transport investigation on the single order nano-size particle is technically difficult, due to the limitation of measurement apparatus and precision. Silicon-based nanostructured materials have been extensively studied and developed to utilize and observe the novel properties of SiNCs. Thermal transport investigation on nanostructured materials provides information regarding the intrinsic mechanism of thermal transport in SiNCs.

This dissertation presents the study on the thermal transport properties of SiNCs and polystyrene (PS) nanocomposite thin films. The nanocomposite samples were fabricated through solution processing in a low-temperature environment, which is preserving the original SiNCs size and narrow size distribution. Preserving the nano size during the process is essential in order to observe the intrinsic properties of SiNCs and their behavior in the bulk nanostructure. Thermal transport property is represented by thermal conductivity, which is determined through the measurements of mass density, specific heat, and thermal diffusivity. The thermal diffusivity of nanocomposite was measured by temperature wave analysis (TWA) method, based on the phase shift of temperature wave along the cross-plane direction. Thermal transport mechanism in nanocomposite structure is extensively analyzed, including the interfacial interaction between SiNCs and polystyrene through experimental measurement and comparison with theoretical thermal conductivity model calculations.

Chapter 1 provides an introduction to SiNCs, including synthesis methods and their thermal transport properties and mechanism. Thermal transport analysis on SiNCs is also described, as well as the motivation of analyzing the thermal transport in nanocomposite materials.

Chapter 2 describes the nanocomposite fabrication process and thermal transport properties measurement methods. Thermal properties measurements were validated by measurement of bulk polystyrene as a well-known polymer. The result shows a significant effect of SiNCs in determining thermal transport in nanocomposite with a decreasing trend, despite the conductive properties of SiNCs compared with polystyrene. Extensive material characterizations were investigated to analyze the effect of SiNCs in thermal conductivity of nanocomposite.

Chapter 3 describes a further investigation of nanocomposite thermal transport by comparing crystalline and amorphous silicon nanoparticles (SiNPs). The result showed insignificant discrepancy due to the lattice structure, indicating that the thermal transport at the material interface is the main factor of thermal conductivity. The experimental results are compared with thermal conductivity models for nanocomposite to help determine the contribution of thermal boundary resistance at the material interface. Phonon confinement effect may be neglected, and phonon scattering at SiNPs/PS boundary plays a major role in determining thermal transport at room temperature. The thermal transport mechanism at the material interface was further investigated by thermal annealing treatment, which showed an increase of thermal conductivity values due to the molecular structure change of stress release or restructuration, resulting in thermal transport enhancement at the interfacial region. Large interfacial area of nanocomposite amplifies the minor change in the molecular structure at the interfacial region, significantly determining the thermal transport properties of the nanocomposite.

Chapter 4 highlights the interfacial region developed at the material interface and its effect in determining the thermal transport of nanocomposite. Polymer is a soft material with properties that are highly dependent on their morphology. Interfacial interaction between SiNCs and PS at material boundaries was observed to affect the PS morphology near the material interface, called interfacial region. It was found that the thermal conductivity model has a deviation with the experimental result and can be improved by considering the effect of interfacial region on nanocomposite thermal transport.

Chapter 5 provides conclusions and recommendations for future work. The possible future works from this research are interfacial molecular interaction control at filler/matrix interfaces, which can be applied in any device employing nanostructure such as solar cells, thermoelectrics, etc. Thermal transport analysis on interfacial region formed in polymer-based nanocomposite may also lead to an analogous effect on electrical and optical properties for broad application of nanocomposite device.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note: Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1 copy of 800 Words (English).

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