【Grant-in-Aid for Scientific Research (S)】

Science and Engineering (Interdisciplinary Science and Engineering)

Title of Project : Spectral control of near-field thermal radiation for highly efficient thermo-photovoltaic power generation

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Research Project Number : 17H06125 Researcher Number : 10208358
Research Area : Photonics
Keyword : Photonic crystal

【Purpose and Background of the Research】

Thermal radiation from heated objects to free space generally exhibits a broad spectrum and its peak intensity is limited to that of a blackbody at the same temperature. To overcome these limitations, in this project, we investigate the spectral control of thermal radiation using photonic crystals and near-field effects, and demonstrate narrowband near-field thermal radiation beyond the blackbody limit for highly efficient thermo-photovoltaic (T-PV) power generation.

【Research Methods】

Recently, we proposed a novel strategy for thermal emission control by simultaneously manipulating photonic states with photonic crystals and material absorption, and experimentally demonstrated highly efficient narrowband thermal emission to free space. In this project, we combine the above strategy and a near-field enhancement effect of thermal emission to realize frequency-selective thermal radiation beyond the blackbody limit between thermal emitters and PV cells placed in close proximity to each other. Specific research topics in the project are listed below:

(I) Theoretical study on the control of near-field thermal radiation spectra using photonic crystals: We will elucidate the role of photonic crystals (photonic bandgap, band folding, low group velocity effect, etc.) in the control of near-field thermal radiation spectra by developing a new simulation method based on the fluctuation-dissipation theorem and rigorous coupled wave analysis, and design the near-field TPV system shown in Fig. 1.

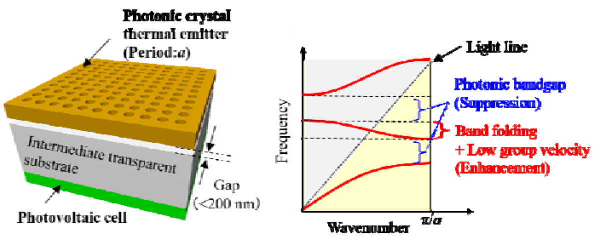

Figure 1. Thermal radiation control using photonic crystals and near-field effects.

(II) Experimental realization of near-field coupling between emitters and PV cells: By using semiconductor nano-processing technologies including wafer bonding, we will develop a method to realize close positioning (<200 nm) of photonic crystal thermal emitters and PV cells including the intermediate transparent substrate.

(III) Demonstration of narrowband near-field thermal radiation for T-PV applications: Using the system developed in (II), we will experimentally demonstrate near-field enhancement of thermal radiation as well as reveal the effect of photonic crystals. Furthermore, we will perform the experiment of T-PV and quantitatively evaluate the efficiency of energy transfer.

【Expected Research Achievements and Scientific Significance】

We believe that our research will provide a new systematic theory for the control of thermal radiation using photonic crystals and near-field effects. We also believe that the experimental technologies developed in this project will contribute to the realization of fundamental technologies for highly efficient T-PV power generation systems.

【Publications Relevant to the Project】

- T. Asano, M. Suemitsu, K. Hashimoto, M. D. Zoysa, T. Shibahara, T. Tsutsumi, and S. Noda, “"Near-infrared-to-visible highly selective thermal emitters based on an intrinsic semiconductor,” **Science Advances**, vol. 2, e1600499 (2016).
- T. Inoue, T. Asano, and S. Noda, “Near-field thermal radiation transfer between semiconductors based on thickness control and introduction of photonic crystals,” **Physical Review B**, vol. 95, 125307 (2017).

【Term of Project】 FY2017-2021

【Budget Allocation】 154,900 Thousand Yen

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