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論 文 要 旨

THESIS SUMMARY

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学生氏名： Student's Name	谷口　祐司	指導教員（主）： Academic Supervisor(main)	花村　克悟
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Near-field radiation transfer from a metal-insulator-metal (MIM)-structured emitter to a receiver was investigated through numerical simulation using a finite difference time domain (FDTD) method. In addition, the improvement of the nano-gap thermophotovoltaic (TPV) power generation systems was numerically confirmed using a MIM-structured emitter and a metal-semiconductor-metal (MSM)-structured cell, aiming for a strong power density with high efficiency by spectrally tuning the near-field radiation between the emitter and cell. Furthermore, by using a pseudo blackbody surface, the evaluation method of TPV cell made of Gallium Antimonide (GaSb) was proposed to measure a technical features of TPV generation system quantitatively.

Firstly, the MIM-structured emitter and receiver consist of a squared-island-type metal array made of nickel (Ni), an insulator layer made of silicon dioxide (SiO_2), and a metal substrate made of nickel (Ni) were set up with a vacuum gap of a few hundred nanometers and the radiation flux between the emitter and receiver was simulated at various sizes of Ni islands, vacuum gaps and etc. Based on the radiation flux for each model, it was confirmed that the near-filed radiation between the MIM- structured emitter and receiver was

spectrally enhanced and the maximum ratio was by a factor of about four compared with that between blackbody surfaces. Simultaneously, the enhancement was spectrally controlled over a wavelength range of 0.9 to 2.1 μm depending on the size of the squared island. In addition, the magnetic field in both the emitter and receiver clarified that the spectrally enhanced radiation flux is caused by the magnetic resonance condition generated in the insulator between the squared-island metal and the substrate metal when the frequency of the magnetic resonance is coincident with that of the near-field radiation. Furthermore, the resonance mode between the frequencies of the magnetic resonance and the angular frequency at the maximum radiation flux are predicted with a good agreement with that obtained by numerical simulation by an impedance model that considers the capacitance between the islands in the emitter and receiver, in addition to the conventional circuit model of a MIM structure.

Secondly, near-field radiation transfer from a MIM-structured emitter made of Ni and SiO_2 to a metal-semiconductor-metal (MSM)-structured cell made of gold (Au) and Gallium Antimonide (GaSb) was studied to demonstrate the performance of spectral tuning between the structured emitter and cell considering a practical TPV generation system. Here, a metal-semiconductor-metal structured cell consisting of a fishnet Au electrode and a thin GaSb semiconductor layer on an Au substrate was introduced as the structure of MSM-structured cell. Here, the in-suite condition of magnetic field shows that the near-field radiation transfer was spectrally enhanced when magnetic resonance condition was strongly generated in the thin SiO_2 layer between the top Ni island and the Ni substrate in the MIM emitter. Simultaneously, a strong constrained magnetic resonance was also generated in the GaSb layer separated by the fishnet electrode at the same angular frequency, which is almost the same frequency for the bandgap of GaSb, and that brings high spectral selectivity compared with a thin semiconductor-Au substrate (SM) cell. As a result, with decreasing aperture size of fishnet grid, sharper spectrally enhanced near-field radiation transfer is achieved around the bandgap frequency of GaSb. Consequently, the radiation flux from the MIM emitter to the MSM cell becomes about 2.3 times higher than that between blackbody surfaces at the emitter temperature of 1000 K and the cell temperature at 300 K. Therefore, by adjusting the structure of the MIM emitter and the MSM cell, the Nano-gap TPV power generation system is expected to exhibit strong power density when its emitter produces the enhanced near-field radiation; in addition, simultaneous higher efficiency can be attributed to the spectral tuning.

Lastly, a quantitative evaluation method using a pseudo blackbody surface consisting of a wave guide aperture was proposed experimentally to measure the electrical characteristics of a TPV cell. Here, a GaSb semiconductor cell were manufactured using molecular beam epitaxial growth method and each cell was exposed by infrared radiation from a pseudo blackbody surface at some fixed temperature for TPV generation. As a result, it was shown that the evaluation of TPV cell is feasible using this system and the generation feature showed good accordance with the semiconductor theory. In the end, the maximum output power was measured at 18mW/cm^2 at the source temperature of 668 degree Celsius. In addition, the conversion efficiency reached approximately 4 % in the range of wavelength shorter than 1.8 μm.

Consequently, through numerical simulation using a FDTD method, the mechanism of near-field radiation transfer from a MIM-structured emitter to a receiver was disclosed and showed the adjustability of peak radiation flux ratio for the spectral radiation flux. In addition, the improvement of power density and efficiency of the nano-gap TPV power generation systems by spectrally tuning the near-field radiation between the emitter and cell was confirmed using a MIM-structured and a MSM-structured cell which provides huge potential for the flexible design of Nano-gap TPV generation system. Furthermore, a proposed evaluation method, quantitative measurement method by using a pseudo blackbody surface, of TPV cell was confirmed using a manufactured GaSb cell by a molecular beam epitaxial growth method.