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論 文 要 旨

THESIS SUMMARY

専攻： Department of	機械制御システム　　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	(Engineering)
学生氏名： Student's Name	Naphatsorn VONGSOASUP	指導教員（主）： Academic Supervisor(main)		Professor Katsunori HANAMURA
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

A thermophotovoltaic (TPV) system is an energy conversion system consisting of two main components, i.e. an emitter and a receiver (a TPV cell). The emitter is heated by thermal energy and radiates. Photons reach to the TPV cell and are directly converted to electricity if their energy is higher than the energy bandgap of TPV cell. The system has high versatility of energy inputs, very low pollution, carbon-free, quiet operation and low maintenance. Hence, it has attracted attention of developers and researchers. Since the TPV system generates electricity from thermal emission from the emitter, the wavelength in consideration is mainly in near-infrared range. Hence, low bandgap semiconductors are preferable for high energy conversion. In addition, the spectrum of emitter should match the bandgap of TPV cell to maximize the conversion. Generally, the emitter temperature is expected to be high, i.e. 1000-2000 K, to match the bandgap of III-V semiconductors that are widely used as the TPV cell. Furthermore, a temperature of TPV cell should be kept around the room temperature as a performance of TPV cell was reported to be significantly temperature dependent. All these requirements and restrictions prevent the TPV system from being competitive with other energy conversion devices. The recent power output and conversion efficiency of TPV system are still considered low. To improve the TPV system, several ideas have been proposed such as using reflectors, a spectral selection, near-field radiation and hyperbolic modes, etc. The TPV system that utilizes the near-field radiation is called a near-field thermophotovoltaic (NTPV) system in this study. As of now, the NTPV system has not yet been commercialized due to several issues that need to be overcome. In addition to the restrictions of TPV system, the NTPV system has critical concern regarding setting up the micro- or a nano-scale parallel gap between the emitter and the TPV cell due to surface curvature and unavoidable large-scale particles. NTPV related studies are mostly conducted through numerical or theoretical perspective due to several difficulties in setting up the TPV system in nano- or micro-scale as previously mentioned. In addition, there is still a room to explore regarding a configuration that can further enhance NTPV performance such as the NTPV system that utilizes the surface waves and the hyperbolic modes. Hence, the author is motivated to design the NTPV system that has high performance and practical. The improvement of performance is expected to come from the evanescent wave effect and the hyperbolic modes. The NTPV performance is evaluated both numerically and experimentally in this study. A pillar-array structured emitter is proposed as a hyperbolic metamaterial (HMM) emitter that supports type I hyperbolic modes.

In summary, three general conclusions are made as follows:

1. The evanescent wave effect is detected in both a numerical simulation and an electricity generation experiment. Good agreement is found between experimental and numerical results.
2. The occurrence of hyperbolic modes is confirmed and elucidated through the numerical simulation. The hyperbolic modes are shown to noticeably improve the NTPV performance and the improvement is quantified. In the electricity generation experiment, the hyperbolic modes are shown to enhance the power output compared to the case when a flat emitter is applied in the majority of all experimental cases. Nevertheless, there exists the case that the pillar-array structured emitter is outperformed by the flat emitter. This reduction of power output is suspected to come imperfections of experimental setup and the pillar-array structured emitter. More experimental cases are required to confirm this hypothesis.
3. This study shows that the practical NTPV system is feasible. Despite some discrepancies between the numerical and experimental results, the trend between the numerical and experimental results is arguably similar especially in the flat emitter case indicating that setting up the NTPV experimental setup in nano-scale is possible. In addition, the fact that large temperature difference between the emitter and the TPV cell is maintained (i.e. 484-489 ℃) in every experimental case proves that difficulty in thermal management mentioned can be overcome.

In addition, suggestions for further study are given in two perspectives as follows:

1. Numerical aspect
Despite the fact that Finite-Difference Time-Domain (FDTD) can be simply applied in case of schottky diodes to compute the radiative heat transfer when the pillar-array structured emitter is used, the FDTD encounters incompatibility problem in case of p-n junction semiconductors. The problem comes from different discretization and computational space. The revised discretization, the enlarged computational space and information of absorbed flux per grid will solve this problem and an integration of FDTD to a photocurrent calculation model will be achieved.
2. Experimental aspect
The quality of TPV cell is an important key to achieve high power output. P-n junction semiconductors obtained from the outsource show more consistent and higher quality compared to self-manufactured schottky diodes. As a result, the power output obtained from the p-n junction semiconductors are higher than the schottky diodes by one order of magnitude.