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

Science and Engineering (Engineering)

# Title of Project : Infrared Energy Harvester by Artificially Structured Heterojunction

Tadaaki Nagao
(National Institute for Materials Science, International Center for Materials Nanoarchitectonics, Group Leader)

Research Project Number : 16H06364 Researcher Number : 40267456
Research Area : Materials Engineering
Keyword : Infrared Light, Thermal Radiation, Physical Properties, Optical Nanomaterials

## 【Purpose and Background of the Research】

All the objects on earth have thermal energy and thus emit or absorb infrared light to exchange mutually their thermal energy. If the spectrum of thermal radiation and absorption is flexibly controlled by adopting artificial surface nanostructures, many devices for the energy application will be realized. For example, single-band infrared light emitters, material-specific infrared sensors, and energy harvesting device that collect thermal radiation from the environment as well as waste heat in industry and houses will be realized and contribute to the developments of sensors, energy conservation and low carbon emission.

In this project, we focus ourselves on the phenomena related to the thermal properties of matter such as phonons, localized infrared plasmons, as well as low-energy electronic excitations to clarify the energy transfer among them and establish the guiding principles for developing the heterojunctions or infrared resonators with artificially enhanced energy conversion efficiency. For example, we will develop the methodology for designing and fabricating metal-semiconductor heterojunction combined with polaritonic resonator with optimized energy conversion efficiency between the phonon excitation and electronic excitation, which will enable us to collect or emit infrared light with high efficiency and further convert it to other types of energies. By appropriately designing and combining semiconductors with elemental or compound materials with excellent infrared absorption, optimization of energy transfer between infrared plasmon polariton, low-energy electronic excitations and phonons will be achieved.

## 【Research Methods】

By designing appropriately the nanoscale and mesoscale structures, thermal absorption and emission of the objects can be modified largely from those of the blackbody. We will characterize the generation, absorption, propagation, and damping of these artificial structures by our spectroscopic techniques such as photoluminescence spectroscopy, ultrafast spectroscopy, infrared microscopy, and scanning near-field microscopy. The knowledge will be adopted for establishing the methodology for realizing the high-efficiency transduction of infrared radiation to the electrical or near-infrared energy and thus leading to the development of high-sensitivity sensors and energy harvesting system.

## 【Expected Research Achievements and Scientific Significance】

The understanding for the mechanism of the energy conversion between electricity, heat, and thermal radiation at the surface/interface of materials will be deepened and new knowledge will be accumulated. The methodology for artificially controlling these energy conversion processes will be established, and will lead us to the realization of environmental energy harvesting devices and self-powered sensor networks.

## 【Publications Relevant to the Project】


- S. Ishii, S.R. Pasupathi, T. Nagao, “Titanium Nitride Nanoparticle as Plasmonic Solar Heat Transducers,” J. Phys. Chem. C **120**[4], 2343-2348 (2016).
- T. Dao, K. Chen, S. Ishii, A. Ohi, T. Nabatame, M. Kitajima, and T. Nagao, “Infrared perfect absorbers fabricated by colloidal mask etching of Al-Al2O3-Al trilayers,” ACS Photonics **2**, 964-970 (2015).
- K. Chen, T. Dao, S. Ishii, M. Aono, and T. Nagao, “Infrared aluminum metamaterial perfect absorbers for plasmon-enhanced infrared spectroscopy,” Advanced Functional Materials **42**, 6637-6643(2015)


**【Term of Project】** FY2016-2020

**【Budget Allocation】** 141,400 Thousand Yen

**【Homepage Address and Other Contact Information】**

http://samurai.nims.go.jp/NAGAO_Tadaaki-j.html
NAGAO.Tadaaki@nims.go.jp