Spectral control of near-field radiation transfer and its application for TPV generation of electricity

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Spectral control of near-field radiation transfer by interference of Surface Plasmon Polaritons (SPPs) in pillar array structured surface made of nickel was investigated using a numerical simulation based on Maxwell's electromagnetic wave theory. The electromagnetic field between two pillar array structured surfaces fixed in face to face with a vacuum gap of several hundred nanometers was obtained using a three dimensional Finite Difference Time Domain (FDTD) method and fluctuational electrodynamics (FED). The near-field radiation flux from a high temperature to a low temperature pillar array structured surfaces was evaluated through the summation of normal components of Poynting vector in any direction at the intermediate of the vacuum gap. Through the numerical simulation, it was clarified that the local maximum and the local minimum of near-field radiation flux were shown periodically with increasing height of pillar under the condition of a fixed vacuum gap, which was regarded as interference between the pillar height and an electromagnetic wave propagating in the channel between pillars. Moreover, the dispersion relation of the electromagnetic wave with an interference in the channel between pillars is quite similar to the SPPs established in two semi-infinite smooth plates with a nanometer vacuum gap. As a result, it was concluded that the spectral control of near-field radiation transfer was achieved by interference of SPPs in the channel between pillars by tuning the height of pillar.

Thermophotovoltaic generation of electricity is enhanced by near-field radiation effect. Using a schottky diode cell as a thermophotovoltaic cell, which consists of an n-type GaSb semiconductor and a 5 nm thickness nickel layer on it, the output power was measured. On the mirror like nickel surface, four silica spacers were made by sputtering: the average height is 265 nm for near-field or 2140 nm for far-field radiation transfer. On the other hand, a tungsten slab was used as an emitter which was heated by an electric heater up to 673 K. In a vacuum chamber, the emitter was directly put on the spacers to setup a parallel gap thickness equal to the spacer height between emitter and cell surfaces, while the cell was mounted on a water cooled copper block using a silver paste to keep the cell temperature at constant around 280 K. As a result, when the gap thickness decreased from 2140 nm to 265 nm, the output power was increased by a factor of 4.8 by near-field radiation effect.

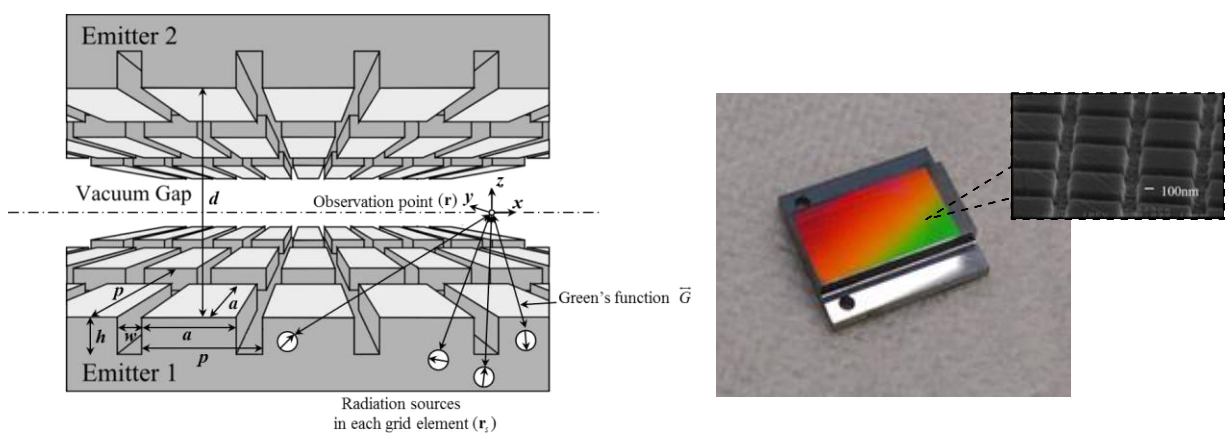

Fig. 1: Pillar array structured surface for spectral control of near-field radiation