Parametric study of nanometer-sized pillar array structure for spectrally enhanced near-field radiation transfer

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Near-field thermal radiation transfer has been very attractive in recent years due to its high potential for achieving significantly high heat flux and high energy conversion density. Moreover, it has been shown that near-field radiation could be modulated spectrally using nanometer-sized structure fabricated on the emitter.

In this study, a square pillar array structure is focused on, then contributions of configurations are evaluated numerically. To obtain the radiation flux between emitter and receiver, Maxwell's equation was solved using a three-dimensional finite difference time domain method and electromagnetic fields inside emitter, receiver and in a nanometer-sized vacuum parallel gap between those surfaces made of Al-doped zinc oxide (AZO) [1] are rigorously figured out. Radiation flux passing through the cross sectional area in the vacuum gap was evaluated from Poynting vector at the center of the gap. In order to optimize the spectral radiation flux, the electromagnetic fields were calculated for several configurations of pillar width, pillar height and channel width under the conditions of emitter temperature of 1000 K and receiver temperature of 300 K. Moreover, sinusoidal modulated Gaussian pulse was introduced as a radiation source inside emitter to make a comparison between numerical simulation results with a wide range of frequency.

Even in the case of smooth surfaces which face each other, the radiation flux becomes fifteen times higher than the blackbody surfaces at the frequency of Surface Plasmon Polariton Resonance (SPPR) as shown by $\omega_p/\sqrt{2}$. On the other hand, in the case of pillar array structured surfaces, the radiation flux is enhanced partially compared with blackbody smooth surfaces in a region of smaller frequency than the plasma frequency ω_p. It is considered that the radiation emitted spherically from sources inside emitter produces a surface wave on the side wall of the pillar and the surface wave contributes to the enhancement of radiation flux. Moreover, the radiation flux has the first local maximum around a frequency with a range from 2.5×10^{14} to 5.0×10^{14} rad/s, according to the pillar height. The angular frequency corresponding with local maximum of the radiation flux decreases with increasing height of pillar from 100 nm to 400 nm. And these peak of radiation fluxes become sharp by expanding channel widths. And the radiation flux at the local maximum peak reaches thirty times compared with the blackbody radiation. These results could be supported by classical Fabry-Pèrot interference formula and dispersion relations around a bundle of several thin square pillars.

It is shown that near-field thermal radiation transfer could be enhanced spectrally using pillar array structure.

[1] J. Kim, G. V. Naik, N. K. Emani, U. Guler, and A. Boltasseva, *IEEE Journal of Selected Topics in Quantum Electronics*, Vol. 19, No. 3 (2013), 4601907.