Narrow-band Thermal Emitters by Spoof Surface Plasmon

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Although incandescent lamps have been the most commonly used light source, they are inefficient light sources. This is because the fraction of infrared (IR) radiation is dominant (more than 90%) in thermal radiation spectra. Since early 2007 almost all OECD governments have announced policies aimed at phasing-out incandescent lighting; more efficient replacement lighting sources such as compact fluorescent lamps or LEDs have been recommended to use. In contrary to our common knowledge above, here we would like to claim that an incandescent lamp is "an efficient emitter" from the viewpoint of energy conversion from electric power to radiation power.

In this presentation, we review recent progress of our study about thermal radiation control by microstructures on metal surface (see Fig.1) and propose new narrow-band efficient thermal emitters. We show experimental results of modification of thermal radiation spectra by various electromagnetic modes in micro-cavity array (MCA) fabricated on tungsten and discuss its applications to thermal emitters. In addition, we propose narrow-band thermal THz emitter using spoof-surface plasmon mode on MCA.

Figure 2(a) shows thermal radiation spectra in mid-IR range from MCA (a=3μm, d=5μm, h=3.7μm) on tungsten heated at 850K. We observed enhancement of radiation at 5.5μm with respect to flat surface. As shown in Fig. 2(b), we observed many peaks (A, B and C) in relative emissivity (emissivity with respect to flat surface). We attribute these peaks to resonant modes of electromagnetic field inside the single open cavity [1]. In order to obtain narrow-band thermal emitter, steeper resonant width is required.

We have calculated absorption spectra for various depths or shapes of cavity by numerical simulation of FDTD method and found that deep rectangular cavity had steeper resonant peak in absorption. In addition, we have also found that a quasi-monochromatic resonant peak was obtained in the case of smaller aperture compared to the period ($a< d/2$). We attribute this very steep peak to the resonance of Spoof-Surface Plasmon (SSP) [2]. Since the dispersion relation of SSP can be controlled by size parameters of MCA, resonant peaks can be designed for desirable frequency. Hence, we have proposed narrow-band thermal emitter using spoof-surface plasmon [3,4]. Figure 3 shows calculated spectra for thermal THz emitter by MCA with smaller aperture (a=40μm, d=100μm, h=100μm). Compared to larger aperture (a=80μm, d=100μm, h=100μm), we have obtained a quasi-monochromatic resonant peak at f=3THz with higher emissivity.

These new kind of thermal emitter can be applied to compact wide range wave sources from THz to mid-IR range.

References

1. F. Kusunoki, J. Takahara and T. Kobayashi, Japanese Journal of Appl. Phys., 43, 8A, 5253 (2004).
2. J.B. Pendry, L. Martin-Moreno, and F.J. Garcia-Vidal, Science 305, 847 (2004).
3. Y. Ueba, J. Takahara and T. Nagatsuma, Opt. Lett. , 36(6), 909 (2011).
4. Y. Ueba, T. Nagatsuma and J. Takahara, Abstracts in SPP5, Busan, MP-63 (2011).

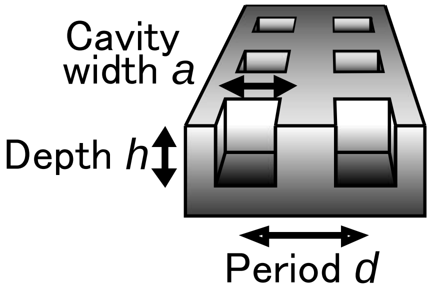

Fig.1 Schematic view of micro-cavity array on metal surface.

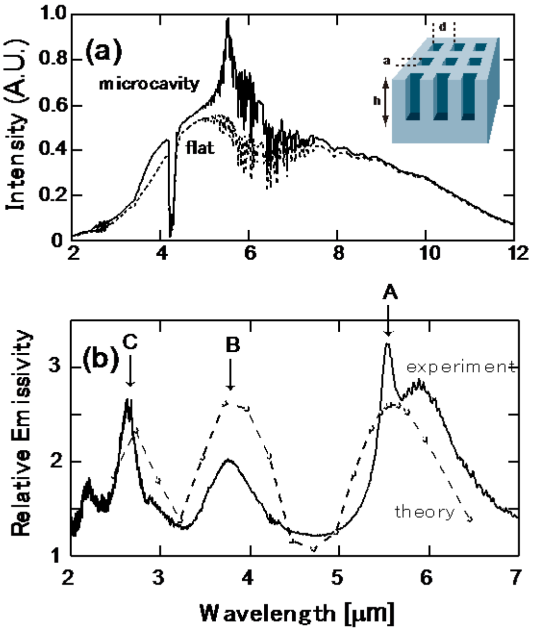

Fig.2 (a) Measured thermal radiation spectra from MCA (*a*=3μm, *d*=5μm, *h*=3.7μm) and flat tungsten surface at 850K, (b) Experimental (solid) and calculated (dashed) relative emissivity.

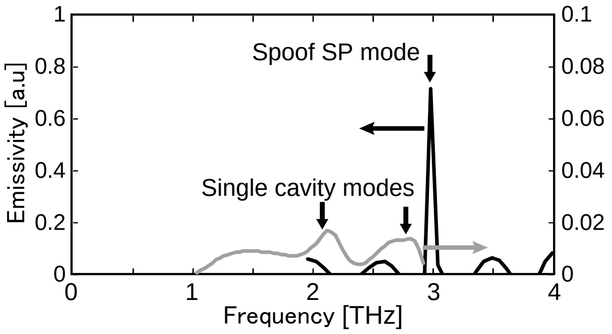

Fig. 3 Emissivity spectra from MCAs: larger aperture (*a*=80μm, *d*=100μm, *h*=100μm) (gray) and smaller aperture (*a*=40μm, *d*=100μm, *h*=100μm) (solid).