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Thermal Radiation Control by Plasmonic Resonators: from Microcavity to Metasurface and Metafilament

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1. Introduction

The modification of thermal radiation spectra by micro-structured surface was demonstrated first in 1986 by silicon deep grating [1] and has been studied by utilizing various types of microstructure such as an open-end metallic microcavity [2,3], photonic crystal [4,5] and plasmonic nanocavity [6]. Narrow-band thermal radiation by surface modes such as surface phonon polariton [7] and surface plasmon polariton [8] were also reported. Recent research progress in metamaterial promotes many investigations of a perfect absorber for energy saving applications. According to Kirchhoff's law, it is natural to apply the study of absorbers to emitters. A monochromatic or bandwidth designed thermal emitters by utilizing the concept of two-dimensional metamaterial, i.e. metasurface, have been demonstrated so far [9-11].

In this paper, we review thermal radiation control by plasmonic resonators from microcavity array to metasurface. Then, we report our recent experimental results about metasurface composed of rectangular Sprit-Ring Resonators (SRRs). We discuss about two types of metasurface: electrically isolated SRRs and connected SRRs which we call "metafilament".

2. From microcavity to metasurface

Figure 1 shows various plasmonic resonators for thermal radiation control discussed here. The array of an open-end metallic microcavity shown in Fig. 1(a) is widely used for thermal radiation control, e.g. thermo photovoltaic (TPV) cells. However, a deep trench whose depth is the order of wavelength is needed in this method. Thus, we proposed a new method using metasurface composed of a plasmonic resonator instead of a microcavity [11-13]. Figure 1(b) shows the concept of metasurface where we use a typical plasmonic resonator, i.e. SRR. Since the thickness of metasurface is much thinner than the wavelength, the heat capacity of metasurface is much smaller than that of a microcavity or a conventional ceramics heater.

In order to perform self-heating without using a ceramics heater outside, we propose a new type of metasurface composed of electrically connected SRRs by metallic wire as shown in Fig. 1(c). Such metasurface structure can be self-heated by Ohmic loss as well as frequency conversion. Hence, we call such metasurface metafilament [14,15].

3. Results and discussion

Our recent experiments have shown that the thermal radiation spectra from metafilament had steep resonant peaks due to plasmonic resonant modes of connected SRRs. The spectra are sensitive to the position of connected wires with respect to the arm of a SRR. We discuss the mechanism of observed peaks from numerical simulations. Furthermore, we found the energy conversion efficiency of radiation peaks observed in the metafilament was improved compared to the conventional ceramics heater due to lower heat capacity and the vicinity of heated region. Metafilament can be applied to efficient thermal light source for wide range of the frequency from infrared to visible.

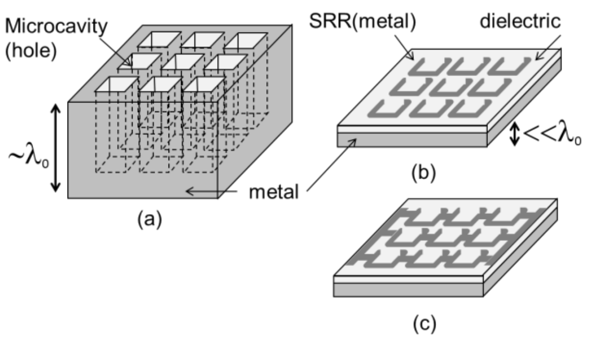

Fig. 1 Plasmonic resonators: (a) microcavity array, (b) metasurface composed of isolated SRRs and (c) metafilament composed of connected SRRs.

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