Application of Non-radiative Cooling to Electronic Device Thermal Management

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Radiative cooling is a key technology that reduces the temperature of sky-facing objects through radiative energy transfer between the objects and outer space at 4 K. However, this technology is not applicable when cooling objects and spaces surrounded by opaque absorbers. Here, we report a non-radiative cooling technology that can reduce the temperature of space surrounded by an opaque container. When a metamaterial-loaded thermoelectric device is placed in an opaque and sealed container, the metamaterial absorber absorbs the thermal radiation inside the container, and the thermoelectric element converts the thermal energy to electric current (Fig. 1(a, b)).[1-3] The generated current flows to the resistor placed outside the container, releasing thermal energy to free space as Joule heating. To the best of our knowledge, there is no literature reporting the cooling technology combined with the thermal gathering acquired by the MA and thermoelectric conversion. In this study, we demonstrate non-radiative cooling realized by metamaterial thermoelectric conversion and examine whether the non-radiative cooling occurs in an opaque and sealed container.

We used a MA consisting of a Ag film and Ag disk sandwiching a thin layer of calcium fluoride. Figure 1(c) shows the absorption spectra of the MA and control electrodes, and the blackbody radiation spectrum calculated at 311 K. The unbalanced absorptivity difference between the MA and control electrodes can induce an additional thermal gradient across the thermoelectric element, driving the thermoelectric conversion in an environment with uniform thermal radiation. Figure 1(d) shows the time dependence of the environmental temperature difference of the containers loaded with MA or control devices. The container with the MA device showed a faster reduction in the environmental temperature than the container with the control device, indicating that the non-radiative cooling is demonstrated.[4]

We are currently attempting to cool highly integrated electronic devices using this non-radiative cooling technique. In this presentation, we will report on the extent of temperature reduction achievable through metasurface non-radiative cooling.

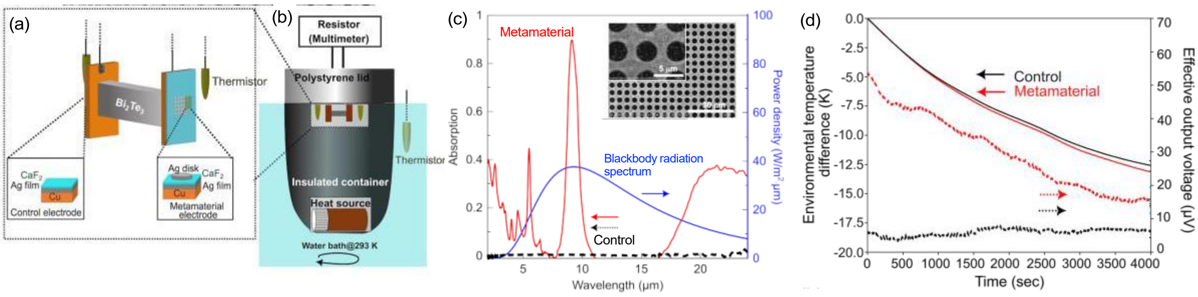

Figure 1 (a) Depiction of metamaterial thermoelectric device and (b) schematic of a container soaked in a water bath at 293 K. (c) Comparison of absorption spectra of the metamaterial absorber (red line), a control electrode (dashed black line), and the blackbody radiation calculated at 311 K (blue line). The inset shows SEM images of the metamaterial absorber. The scale bars are 5 μm and 30 μm, respectively. (d) Time dependence of the environmental temperature difference within an opaque and sealed container loaded with the MA or control devices and the corresponding effective output voltages generated on the MA or control thermoelectric devices.

References

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