Visualization of Thermal Extraction Achieved by Metasurface Absorber

Wakana KUBO*
Tokyo University of Agriculture and Technology, 5-208, 2-24-16, Naka-cho, Koganei-shi, Tokyo 184-8588, Japan
**E-mail:w-kubo@cc.tuat.ac.jp*

Thermal absorption achieved by metasurface absorber is typically evaluated using far-field spectroscopy. In its absorption process, the metasurface absorber extracts heat from the surrounding air;[1-4] however, this phenomenon cannot be directly measured by conventional far-field spectroscopic methods, and has not been visualized previously.

In this study, we successfully visualized the cooling phenomenon induced by thermal absorption of a metasurface absorber using an infrared (IR) camera. We fabricated a metamaterial thermoelectric device by attaching a metasurface-fabricated electrode to one side of a thermoelectric element (Fig. 1(a-c)). Cu plates were placed on top of the electrodes of both the metasurface device and a control device, and both were heated using a heater.

Figure 1(d) shows the time-dependent output voltages generated by the metasurface and control thermoelectric devices. Figure 1(e) displays the voltage difference of the metasurface and control devices after 320 s, demonstrating that the metasurface device exhibited a higher output voltage. The corresponding temperature difference between the Cu plates on the metasurface and control devices is shown as red plots in Fig. 1(e), indicating that the Cu plate on the metasurface device experienced greater cooling. Figure 1(f) presents the infrared camera images of the Cu plates on the metasurface and control devices. At 10 s after heating stopped, the temperature of the Cu substrate placed on the metasurface device was visually confirmed to be lower than that on the control device, indicating that the metasurface extracted heat from the Cu plate. This trend is also supported by the output voltage difference profile. These findings directly demonstrate that a metasurface absorber can extract thermal energy from surrounding objects in real time.

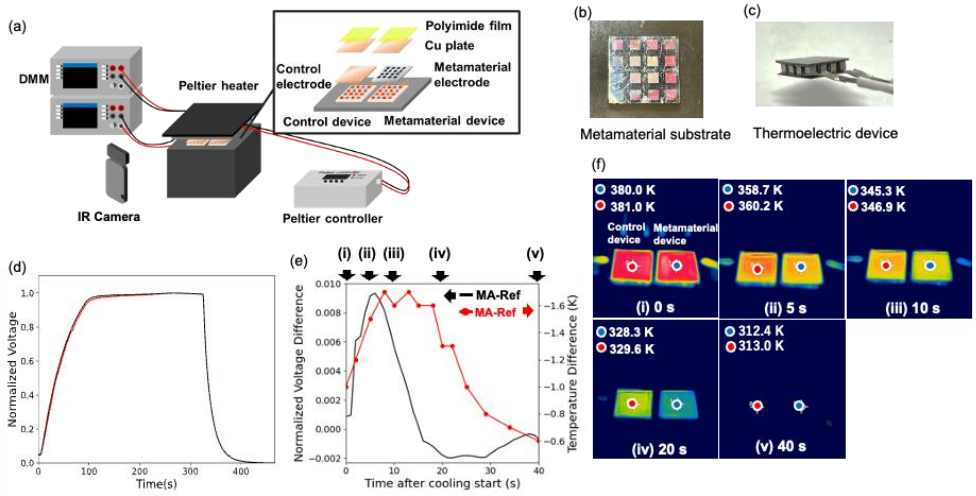

Figure 1. (a) Schematic of experimental setup. Photographs of (b) the metamaterial substrate and (c) a thermoelectric device. (d) Output voltage profile of the metamaterial (red line) and control (black line) thermoelectric devices. Heating was stopped at a time of 320 s. (e) Comparison of the voltage differences of the metamaterial and control devices, and the absolute value of temperature difference between the Cu plates on the metamaterial and control devices. (f) IR camera photographs of the Cu plates placed on the MA and control devices at (i) 0 s, (ii) 6 s, (iii) 16 s, (iv) 20 s, and (v) 30 s, respectively.

References

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