Metamaterial absorbers and their applications

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Recent advances in metamaterials enable us to create unprecedented optical materials, and as a example of such materials, perfect absorptive material surfaces within a certain frequency range were demonstrated. Since the metamaterial absorber offers a unique surface condition with tailored absorption properties, a wide variety of potential applications have been proposed.

As an application of metamaterial absorber in IR region, we demonstrate high sensitive background-suppressed surface enhanced IR absorption (SEIRA) of molecules adsorbed on the metamaterial [1]. Figure 1(a) shows a unit cell cross-section of a metamaterial IR absorber and Fig.1(b) shows a photograph of the fabricated metamaterial absorber and its SEM image. Since the metamaterial absorber offers not only strong plasmonic enhancement but also significant background suppression, this unique surface environment improves the sensitivity of the conventional SIERA. Figure 2 shows the measured reflection spectrum of the 16-MHDA SAM from the metamaterial absorber. When the molecules were in the vicinity of the surface structure, their vibrational modes resonantly coupled with the plasmonic modes of the metamaterial. This in turn produced distinct Fano-like anti-resonant peaks within a broad absorption of the metamaterial. Using the SAM packing density of 21.4 Å^2/molecule, we estimated the amount of the molecules with the diffraction limited IR beam spot to be ~1.8 attomoles (1.8×10^{-18} mole).

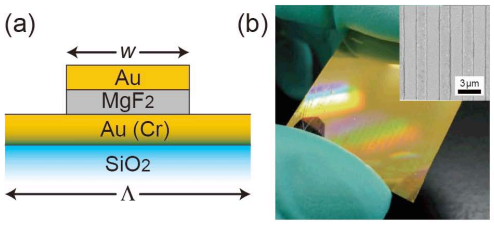

Figure 1 Metamterial IR absorber.

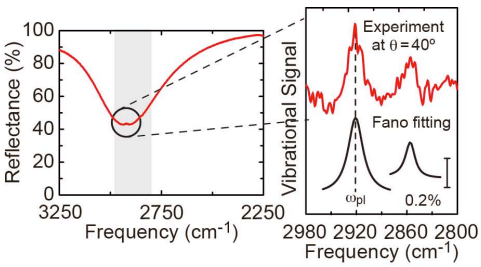

Figure 2 Background suppressed SEIRA.

When we make the size of unit cell of metamaterial absorber down to several hundreds nanometers, the absorption bands move to the visible light region. We present a simple yet efficient approach for ink-free color printing employing sub-micrometer scale plasmonic pixels of aluminum structure [2]. The dependence of plasmonic resonances on two different parameters of the same pixel enables controllable color attributes such as hue, brightness and saturation across the visible spectrum. Figure 3 shows the experimental results; Fig. 3(a) is RIKEN's logo observed by optical microscope and (b) is its structure observed by SEM. Fig. 3(c) shows a full color palette made by controlling the size of unit cell of the metamaterial.

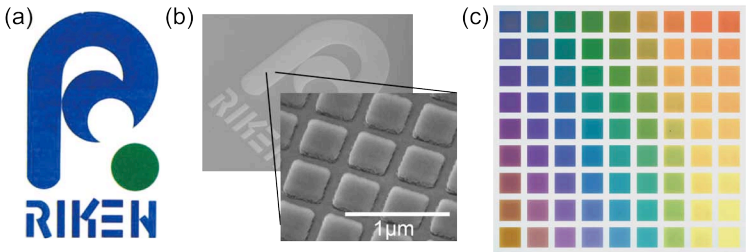

Figure 3 Full color printing by metamaterial absorber.

[1] Scientific Reports **5**, 12570 (2015). [2] Scientific Reports **7**, 1199 (2017).