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Plasmonic enhancement of electric and magnetic dipole emissions at telecommunication wavelengths on metasurfaces

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Over the last decade, plasmonic metamaterials have been investigated as new artificial nanostructures to exhibit a variety of electromagnetic responses and light-matter interaction, which have not been found in any synthetic material produced in nature. To achieve novel optical properties not attainable so far, realization of artificial magnetic atoms has been an issue in metamaterials [1]. On the other hand, revived attention was paid to the natural trivalent lanthanide ions such as Eu^{3+} and Er^{3+} due to their strong magnetic dipole (MD) transitions at optical wavelengths [2]. As for Eu^{3+} ions, it was reported that enhancement and suppression of the spontaneous visible emissions coming from electric dipole (ED) and MD transitions were controlled by electric local density of states (E-LDOS) and magnetic LDOS (M-LDOS), respectively. It is significant in telecommunication technology to enhance emission intensity in Er^{3+} ions, associate with Purcell effect.

We systematically fabricated luminescent-Er^{3+}-embedded metasurfaces, on which strongly enhanced ED and MD emissions of Er^{3+} were achieved. The metasurfaces include cavity structures that are trenched plasmonic nanocavities [3]. Thin Er^{3+}:SiO_2 layers were set precisely at the positions in the cavities. The enhancement of ED and MD transitions were obtained by controlling the position of the Er^{3+} layer with respect to the maximum of E-LDOS and M-LDOS, respectively.

Figure 1(a) shows a cross section SEM image of a metasurface and Fig. 1(b) shows a 20 nm thick Er^{3+}-doped layer in a plasmonic cavity. Figure 1(c) compares the ED and MD emission components from the metasufaces with the emission from an Er^{3+}-doped film on a SiO_2 substrate. The emission from the plasmonic metasurfaces was strongly enhanced. In the cavities enhancing MD transitions, 14.2-fold-enhanced emission was obtained compared to the simple film sample in term of the number of Er^{3+} ions, and narrower emission spectrum was observed with respect to the conventional bulk Er^{3+} emission.

At the presentation, we report the Er-controlling metasurfaces and the measured emission spectra enhanced by the resonant E-LDOS and M-LDOS in the cavities. We moreover describe electric and magnetic Purcell effects from the temporal measurement of enhanced ED and MD emission.

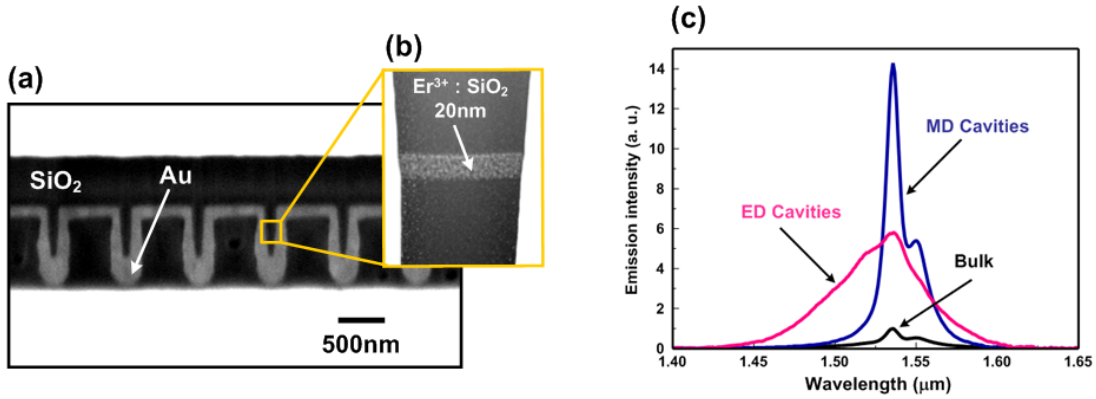

Figure 1. (a) A SEM image of a fabricated plamonic metasurface. (b) A STEM image, enlarging a cavity. (c) Comparison of emission intensities with the different plasmonic nanocavities for a Er^{3+}-doped film.

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