Characterization of plasmonic nano-antennas by cathodoluminescence

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1. Introduction

Plasmonic nano-antennas have recently attracted much attention owing to their preferable optical properties [1]. They are composed of metallic nano-structures and have the ability to receive and emit light ranging from infrared to ultraviolet. Besides size scale, other significant differences from common RF antennas are that plasmonic nano-antennas can strongly confine light within sub-wavelength regions and realize extraordinary field enhancement by orders of magnitude. This is attributed to the coupling of the electromagnetic wave and the collective movement of free electrons at the metal surface, leading to the excitation of surface plasmon from which the word "plasmonic" derives.

In the present study, we have investigated the optical characteristics of surface plasmons excited in plasmonic nano-antennas by using a cathodoluminescence (CL) imaging method.

2. General Instructions

Experimental method

We observed surface plasmon induced light emission from plasmonic nano-antennas which are fabricated by electron beam lithography and composed of single or two gold triangles as shown in Fig. 1(a). In this experiment, a 80-kV scanning transmission electron microscope equipped with a light detection system was employed, which allows us to obtain nanometer-scale localized optical information on the sample due to an electron-beam spot size of as small as 1 nm in diameter [2]. By moving a focused electron beam with a constant spacing over the sample and simultaneously collecting an emission spectrum at each point, a photon map was obtained as shown in Fig. 1(b), which reflects an electric field distribution of a localized surface plasmon (LSP) around the sample.

Results and Discussion

In the photon map of a triangle structure, the emission intensity is seen to be strong around its apexes, which indicates that the electric field by the excited LSP on the structure largely concentrates in these areas. When the size of the structure becomes larger, the emission spectra from the side edges begin to show several peaks corresponding to the different LSP resonance modes. The spatial distribution of each resonant mode can be visualized in a monochromatic photon map taken by the beam scan spectral imaging using a CCD detector.

When two triangle structures make a bow-tie structure, LSPs in the two triangles hybridize to form distinct modes

with different resonant energies. One is called a bright mode, which was excited by an electron beam located at the outer side edges of the bow-tie structure, and couples strongly with light emission due to an asymmetric charge distribution on the structure. Another is called a dark mode which was excited by an electron beam at the gap region, having a symmetric charge distribution that contributes to weak emission. Strong emission appears at the outer side edges in the bright mode, whereas weak emission appears at the gap region in the dark mode.



Fig. 1 (a)Schematic diagrams and SEM images of a triangle and a bow-tie plasmonic nano-antenna, and (b)corresponding photon maps.

3. Conclusions

We have investigated the LSPs excited in plasmonic nano-antennas at sub-wavelength scale by cathodoluminescence. Cathodoluminescence imaging technique realized the visualization of an electric field by a LSP around a plasmonic nano-antenna as well as its resonant mode energy. Therefore, this technique is very useful for locally characterizing the optical properties of plasmonic nano-antennas, paving the way to various applications.

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References

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