19a-C3-5

Visualization of Plasmonic Coupled mode of Gold Curvilinear Nanorods and Straight Nanorods by Photoemission Electron Microscopy

Yukie Yokota[1], Quan Sun[2], Kosei Ueno[2], Yasutaka Matuo[2], Hiroaki Misawa[2], and Takuo Tanaka[1, 2]

[1]Metamaterials Lab., RIKEN, [2]RIES Hokkaido Univ.
E-mail: y-yokota@riken.jp

1. Introduction

We reported that the spectral properties of surface plasmon resonance on the hybrid resonant structure of gold straight and curvilinear structures and demonstrated it showed the electromagnetically induced transparency (EIT)-like phenomenon [1]. At the frequency of EIT, the dark plasmon mode was excited on the gold straight rod, but it could not be observed by optical image due to the nonradiative nature. In this work, we introduced the photoemission electron microscope (PEEM) technique with a near-infrared femtosecond laser to visualize the field distribution of the plasmonic modes excited on the hybrid gold nanostructures.

2. Experimental Details

Hybrid gold nanostructures were fabricated on the ITO substrate using electron beam lithography and lift-off techniques. An element of hybrid gold nanostructures consists of a curvilinear nanostructure and a gold nanorod with 10 nm gap (Fig. 1(a)). The length of gold nanorod corresponds to the arc length (*l*) of the curvilinear structure. Transmittance spectrum of the fabricated nanostructures was measured using a Fourier-transform infrared (FT-IR) spectrometer equipped with a microscope attachment.

We observed PEEM images of the fabricated nanostructures using PEEM system with 10 nm spatial resolution using a NIR femtosecond laser as an excitation light source [2]. The femtosecond laser pulse was perpendicularly irradiated on a substrate under the x-direction polarized as shown in the inset of Fig. 1(a).

3. Results and Discussion

When the linearly polarized light that oscillates x-direction is illuminated on the hybrid nanostructures, transmittance peak is appeared at around 770 nm between two resonant dips as shown in Fig. 1(b). Those resonant peaks overlap with spectrum of the NIR femtosecond laser.

As shown in Fig. 1(c), the photoemission of hybrid nanostructures is highly localized on the curvilinear nanorod excited by femtosecond laser pulses at the center wavelength of 740 nm. The transmittance spectrum of fabricated nanostructures has absorption dip at 740 nm, and these bright spots of PEEM image represent the directly excited bright plasmon mode of the curvilinear nanorod. When the wavelength tuned 770 nm, three bright spots appeared on the straight nanorod as shown in Fig. 1(d). Three bright spots correspond to the second plasmon mode that is dark plasmon mode and it never be excited by the normal plane wave incidence. Therefore, we concluded that dark plasmon mode of straight nanorod was excited through the interaction with the bright plasmon mode of the curvilinear nanorod, and it was visualized using PEEM.

4. Conclusions

We observed the different PEEM images of the hybrid nanostructures by the different excitation wavelength. These results demonstrate that we visualized the field distribution of the interference between the bright and dark plasmon modes of hybrid nanostructures using PEEM.

References

[1] Y. Yokota and T. Tanaka, The 60th Spring Meeting of JSAP (Kanagawa Institute of Tec., March 17, 2013) 27p-A1-7
[2] Q. Sun, K. Ueno, H. Yu, A. Kubo, Y. Matuo, and H. Misawa, Light: Science & Applications **2** (2013) e118.

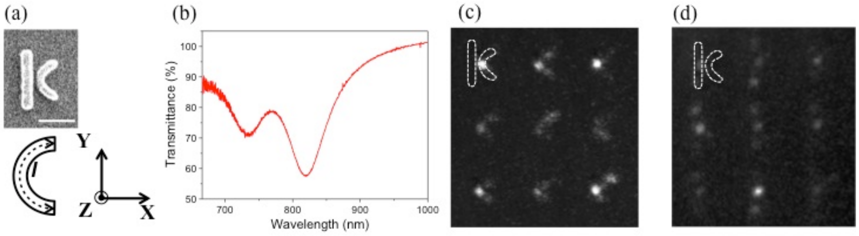

Fig.1 (a) SEM micrograph of hybrid gold nanostructure that consists of curvilinear and straight nanorods with 10 nm gap. The scale bar is 100 nm. The figure shows the layout of curvilinear nanorod and polarization. (b) Transmittance spectrum under the linearly polarized illumination of x-direction. PEEM images of hybrid nanostructures excited using NIR femtosecond laser pulses under the x-direction polarized at the center wavelength of (c) 740 nm and (d) 770 nm.