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Program Title (English)　:Near field enhancement effects on stacked nanogap metallic structures pursued by photoemission electron microscopy
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1. 概要（Summary）

We investigated the near-field properties of stacked nanogap gold structures composed of metal/insulator/metal (MIM) nanostructure both in experiments and simulations. Dark state of quadrupole plasmon mode was excited by the near field interaction between upper and lower gold nanostructures separated by an alumina layer with a thickness of 15 nm, and appeared as a Fano dip in the far-field reflection spectrum as the result of interference between dipole and quadrupole plasmon modes. Near field spectral properties were elucidated by multi-photon photoemission electron microscopy (PEEM) as well as numerical simulations based on finite-difference time-domain (FDTD) methods.

2. 実験（Experimental）

【利用した主な装置】

原子層堆積装置

【実験方法】

Ordered array of stacked nanogap metallic structures was fabricated by electron beam lithography and dry etching processes on a niobium doped titanium dioxide (0.05wt% Nb-TiO2) single crystal substrate with a thickness of 0.5 mm. Three layers composed of gold (40 nm) / alumina (15 nm) / gold (40 nm) were deposited by sputtering for Au and atomic layer deposition for Al2O3 on the Nb-TiO2 substrate. Near field enhancement effect on stacked nanogap gold structures was explored by multi-photon photoemission electron microscopy (MP-PEEM) using femtosecond laser pulses as an excitation source.

3. 結果と考察（Results and Discussion）

In the far field, the spectrum dip indicates one possibility that the Fano resonance is induced due to interference between bright state of dipole plasmon mode and dark state of quadrupole plasmon mode which can be induced by the near filed interaction between upper and lower gold nanostructures. FDTD simulation was performed to verify the excitation of quadrupole plasmon mode with the strong near field enhancement at the nanogap on the basis of the suppression of scattering loss and localization of near-field between upper and lower gold nanostructures. Furthermore, the near-field photoemission intensity spectra also show the peak of the dark state near the Fano dip. In the time domain, the longer dephasing time in dark state of quadrupole mode can be measured by the time-resolved photoemission electron microscopy. The photoemission intensities as a function of the delay time between pump and probe pulses reveal the dephasing time of gold nanoblock structures (4 fs) and stacked nanogap gold structures (7fs). Therefore, it was experimentally verified that near-field enhancement induced in the stacked nanogap gold structures is ascribed not only to the localization of electromagnetic field at nanogap but also to the relatively longer dephasing time in the dark state of quadrupole plasmon mode.

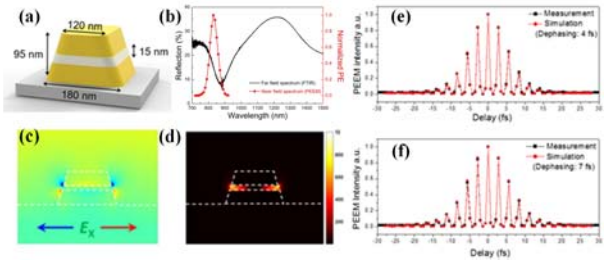

Figure 1. (a) Sketch of stacked nanogap gold structure. (b) Far-field and near-field spectrum. (c) and (d) Electric field distributions simulated by FDTD. (e) and (f) Time-resolved PEEM measurements with the nanoblock and the stacked nanogap gold structure.

4. その他・特記事項（Others）

Collaborators: Kosei Ueno, Quan Sun, Yu Han, and Hiroaki Misawa

5. 論文・学会発表（Publication/Presentation）

K. Ueno and J. Yang et al., CSJ 2017 annual meeting, 2017.03.16, Keio University, Yokohama, Japan

6. 関連特許（Patent）

N/A