課題番号　　　　　　　　:F-18-HK-0015
利用形態　　　　　　　　:機器利用
利用課題名（日本語）　　:
Program Title (English)　:Near-field properties of one-dimensional gold nanochains
利用者名（日本語）　　　:孫 泉[1,2]，于翰[1]
Username (English)　　　:Quan Sun[1,2], Han Yu[1]
所属名（日本語）　　　　:1) 北海道大学電子研，2) 吉林大学電子科学与工程学院
Affiliation (English)　　:1) RIES, Hokkaido University, 2) School of Electronic Science, Jilin University
キーワード／Keyword　　:Surface Plasmon Resonance, Plasmon Coupling, Near Field, Electron Beam Lithography, リソグラフィ・露光・描画装置

1. 概要（Summary）

We studied the near-field properties of localized surface plasmon resonance (LSPR) in one-dimensional gold (Au) nanochains using photo-emission electron microscopy (PEEM). From the near-field measurements, we provided direct proof of near-field plasmon coupling in Au nanochains. In addition, we explored the energy transport along the gold nanochains under excitation at oblique illumination.

2. 実験（Experimental）

【利用した主な装置】
Electron beam lithography (ELS- F125-U, Elionix); Sputtering system (MPS-4000C1/HC1, ULVAC); FE-SEM (JSM- 6700FT, JEOL); PEEM (Elmitec).

【実験方法】
The applied samples are Au nanochain arrays on Nb-doped TiO_2 (110) substrates, and they were fabricated by standard electron beam lithography technique. The near-field mapping and spectra were obtained by PEEM using a wavelength tunable femtosecond laser as the excitation source.

3. 結果と考察（Results and Discussion）

The SEM image of a typical Au nanochain can be found in Fig. 1(a). Under UV excitation from a Mercury lamp, linear photoemission from the Au structures as can be seen in the PEEM image in Fig. 1(b). The localization of the electromagnetic field in the near-field region was further mapped by PEEM at high spatial resolution using femtosecond laser excitation (Fig. 1 (c, d)), where we could find the local enhancement occurs at the gap positions for the longitudinal excitation with p-polarized light. By tuning the excitation laser wavelength, we can obtain the near-field spectra, from which the energy splitting between longitudinal (L) and transverse (T) plasmon modes of the Au nanochains can be revealed. In particular, the L-mode red shifts and the T-mode blue shifts with increasing chain length. The red shift of the L-mode is highly dependent on the gap distance (Fig. 1 (e)). In contrast, the T-mode almost remains constant within the range of gap distance we investigated. This energy splitting between the L-mode and the T-mode of metallic chains is in good agreement with previous far-field measurements, where it was explained by dipole-dipole near-field coupling. The results experimentally confirm that the coupling of dipole resonance within nanochains from the point of view of near field. As a result of near-field coupling, the energy transport along the nanochains was also demonstrated upon oblique light irradiation. The role of the near-field coupling and subradiant plasmon modes induced by the retardation effect on the energy transport was elucidated with the help of FDTD numerical simulations. The results help to understand the nature of plasmon coupling and energy transport in metallic nanoparticle chains; such understanding will be of importance in future applications, such as plasmonic waveguiding and sensing.

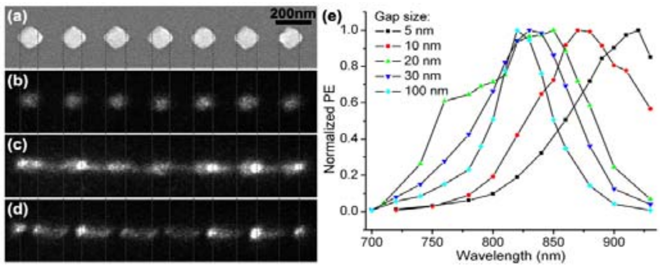

Fig. 1. SEM image (a) of an Au nanochain structure (designed gap size: 100nm); PEEM images of the chain by a mercury lamp only (a), mercury lamp and p-polarized fs laser pulses simultaneously (c), and fs laser pulses only (d), the light was incident from the left side with an incidence angle of 74 º; (e): wavelength dependent PE for different gap size.

4. その他・特記事項（Others）

N/A

5. 論文・学会発表（Publication/Presentation）

1) Q. Sun, H. Yu, K. Ueno, Y. Matsuo, H. Misawa, Opt. Electro. Adv. In press, (2019).
2) Q. Sun *et al.*, The 11th LEEM/PEEM workshop, November 1, 2018, Chongqing, China.
3) Q. Sun *et al.,* Symposium on Surface and Nano Science 2019, January 16, 2019, Shizukuishi, Japan, (invited).

6. 関連特許（Patent）

N/A