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金属ロッド配列ナノレンズによるサブ波長像拡大

Nanolens made of metallic rods array for magnified subwavelength images

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Metallic nanostructured materials exhibit interesting optical applications such as imaging, field enhancement, optoelectronic devices, and biosensors. In particular, the early research by other scientists was aimed to achieve super-resolution imaging by using metallic subwavelength structures with distinct shapes and arrangement. Although such structures act as a lens with super-resolution, they still have two major restrictions. The first restriction is that they can only work at one particular resonant wavelength. The second is that the image can only be transferred for a short distance within the limits of the near field and is therefore undetectable in the far field. Recently, our group has proposed a lens made of stacked metallic nanorods array tapered at a certain angle for magnification [1]. This nanolens realizes the subwavelength super-resolution color imaging in visible range. The image is magnified and plasmonically transferred through metallic nanorods arrays, until it is detectable in far field.

These properties of nanolens to transfer and magnify images require proper stacking of nanorods, such as long chains placed at tapered angles in a fan-like shape. Hence, we first fabricate the arranged nanorods chain, and we will make tapered configuration of those nanorods chain for magnification of subwavelength images. Such metallic nanorods chains are fabricated with combination of lithography and self-assembly method, known as the template-assisted self-assembly (TASA) method [2].

We assembled chemically synthesized gold (Au) nanorods in trench templates, which was patterned by focused-ion beam (FIB) lithography on a poly-methyl methacrylate (PMMA) coated glass substrate. The diameter and length of nanorods were ~15 nm and ~50 nm, respectively, and the trench width was ~25 nm for precise alignment of Au nanorods. After arranging the nanorods into the trenches, we removed the PMMA layer with acetone to clean the surface outside the trenches (Fig. 1). A bilayer of CTAB surfactant, which is used in chemical synthesizing process of Au nanorods, was coated on the surface of Au nanorods to create a 10 nm gap between the rods. The hydrophilic CTAB bilayer and hydrophobic PMMA layer helped to control capillary force and to efficiently align Au nanorods into hydrophilic trenches.

In a finite-difference time-domain (FDTD) calculation, we found some peaks of surface plasmon resonance in visible range, and the strongest peak appeared at a wavelength of 727 nm (Fig. 2). These results show that the combination of lithography and self-assembly has the potential to realize plasmonic nanolens made of Au nanorods.

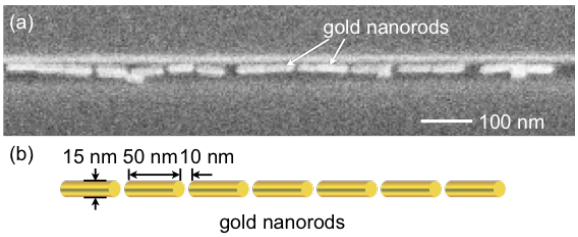

Fig. 1: (a) SEM image of self-assembled Au nanorods in a thin trench (b) Aligned Au nanorods of 50 nm heights, 15 nm diameters and 10 nm gaps.

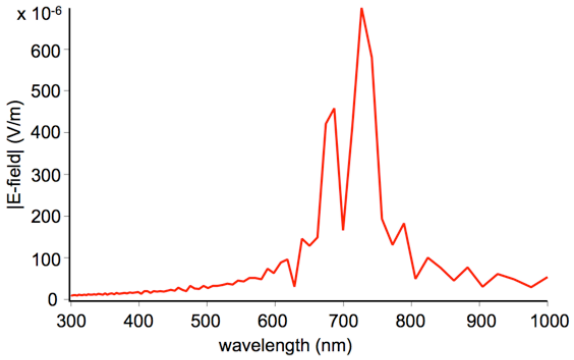

Fig. 2: FDTD calculation of E-field at the output side of 11 aligned Au nanorods chain in air. The strongest peak appeared at 727 nm.

References:

[1] S. Kawata et al., *Nature Photonics* **2,** 7 (2008).
[2] S. M. Yang and G. A. Ozin, *Chem. Commun.*, **2000,** 2507.