課題番号	:F-18-HK-0057
利用形態	:機器利用
利用課題名（日本語）	:プラズモニクダイマー構造を用いた蛍光ナノ粒子の光トラッピング
Program Title (English)	:Optical trapping of fluorescent nanoparticles using plasmonic dimer antenna
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キーワード／Keyword	:光圧，ナノ粒子，プラズモン，金ナノ構造，リソグラフィ・露光・描画装置

1. 概要（Summary）

By focusing the light, it is possible to generate an optical trap that can attract and retain particles in suspension. This technique is commonly known as optical tweezers. However, because of the small polarizability of dielectric nanoparticles, optical trapping of nanoparticles requires focusing the light at a scale beyond the diffraction limit. In this work, we use plasmonic nano-gap antennas in order to focus the incident light into a nanoscale volume. The strong intensity gradient of the evanescent field in the vicinity of the nano-gap leads to enhanced gradient optical forces capable of attracting and trapping nanoparticles.

2. 実験（Experimental）

【利用した主な装置】

電界放射型走査型電子顕微鏡、超高精度電子ビーム描画装置 100 kV、超高精度電子ビーム描画装置 125 kV、ヘリコンスパッタリング装置。

【実験方法】

We fabricated gold dimer and trimer nanostructures using ebeam lithography and helicon sputtering systems. The ebeam lithography process was optimized by comparing different fabrication techniques. After fabrication, the gold nanostructures were observed using a scanning electron microscope, and the far-field optical response of the plasmonic antennas was characterized by dark-field optical spectroscopy. The plasmonic antennas were used in order to trap different kinds of fluorescent nanoparticles: dye-doped polystyrene nanobeads (Ø ~ 40 nm), reprecipitated dye-molecule nanoparticles (Ø~30-40 nm), and diamond nanparticles (Ø~50-100nm). A CW laser source emitting at 1064 nm was used to excite the plasmonic resonance of the nano-antennas. A green laser source emitting at 532 nm was used in order to excite the fluorescence of the nanoparticles.

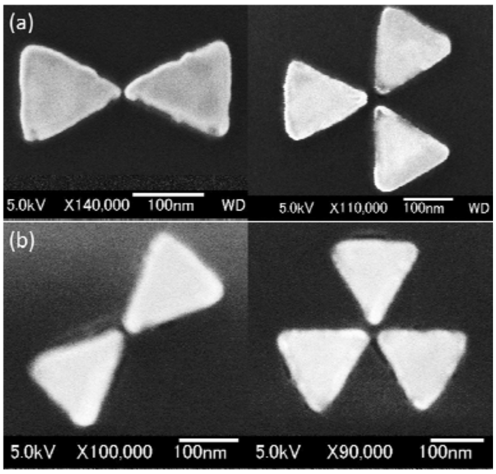

Fig. 1 SEM images of gold dimer and trimer nano-antennas fabricated by a) low-temperature development process and simple triangle design, and b) room-temperature development process and optimized double-triangle design.

3. 結果と考察（Results and Discussion）

In this work, nano-antenna were exposed to intense laser irradiation (1.0~1.8 $MW.cm^{-2}$). A thin microfluidic chamber was used to prevent any perturbation due to thermal convection flow. Nanoparticles were attracted toward the targeted gold nano-antenna. After being trapped, the nanoparticles were adsorbed at the sample's surface. Figure 2 shows SEM images of gold nano-antennas

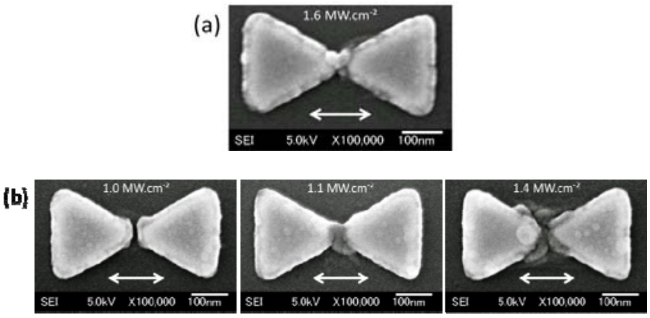

Fig. 2 SEM images of a) dye-molecule nanoparticles and b) polystyrene nanoparticles deposited in the nano-gap of gold nano-antennas.

with deposited nanoparticles. As it can be seen, both dye molecule nanoparticles and polystyrene nanoparticles were successfully deposited in the nano-gap of the antenna under the action of the near-field optical gradient force. Above a given intensity threshold, few nanoparticles, close to the single particle level, could be deposited. As the laser intensity was slightly increased, more particles were deposited. The long range attraction of the particles (over several micrometers) was attributed to some thermo-osmotic flow resulting from the localized heating of the gold antenna.

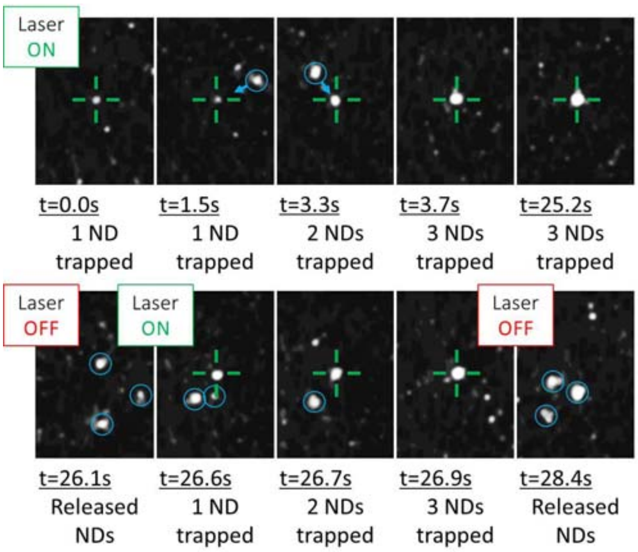

Fig. 3 Plasmonic trapping of fluorescent diamond nanoparticles using a gold nano-bowtie.

As shown in Figure 3, plasmonic trapping of diamond nanoparticles with average size of 50nm was also achieved using a laser intensity of 110kW/cm². Several particles (up to three) could be stably assembled in the trap for more than 20s. When the laser was turned off, the diamonds were released. After turning on the laser again, the three diamonds were trapped again for few seconds and then finally released.

4. その他・特記事項(Others)

・We acknlowledge Mr. Sakai and Mr. Odashima for their help with the optimization of the ebeam nanofabrication process. また、当研究室の藤川聖也氏、高橋玄太氏、須藤広太氏の協力により実験を遂行した。

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5. 論文・学会発表(Publication/Presentation)

なし。

6. 関連特許(Patent)

なし。