Association/Dissociation Dynamics and Rotational Motion of Gold Nanoparticles Optically Trapped at Glass/Solution Interface

Department of Applied Chemistry, College of Science, National Chiao Tung Univ. Taiwan,[1]
Center for Emergent Functional Matter Science, National Chiao Tung Univ. Taiwan,[2]
Division of Materials Science, NAIST, Japan[3]
◦Chih-Hao Huang[1], Tetsuhiro Kudo[1], Teruki Sugiyama[1,2,3], Hiroshi Masuhara[1,2]
E-mail: yj4ymhnr@gmail.com

Laser trapping is a technique which utilizes a tightly focused laser beam to manipulate small objects such as living cells or micro/nanoparticles. Our group is exploring the assembling dynamics of nanoparticles through applying laser trapping at the interface where the particle assembly can dynamically evolve to the outside of the irradiated area. Previously, we reported that gold nanoparticles (Au NPs) formed a dumbbell-shaped swarming by a linearly polarized laser while a spherical swarming is formed by circularly polarized (CP) laser.[1] The initial aligned Au NPs act like an antenna which scatters the trapping laser and traps further NPs outside the irradiated area. Recent experimental results suggest that this assembly can be controlled by several factors such as trapping laser wavelength, particle size, numerical aperture value and longitudinal position of the focus. Furthermore, the self-aligned structure of Au NPs inside the focus affects the swarming drastically. Thus, the dynamics of laser trapping of Au NPs in the initial stage is studied through single particle level trapping experiments.

In this research, the rotational motion of 200 nm Au NP assembly with CP trapping laser is demonstrated at the glass/solution interface. Under laser irradiation, Au NPs are optically bound by the scattered light among each other, making them arrange into the most stable configuration where each interparticle distance is about the wavelength of the trapping laser in a medium. With CP laser, the whole Au NP assembly is rotated in the direction depending on the particle configuration. Interestingly, Au NPs in the assembly occasionally associate with each other during the laser trapping, forming a transient dimer or trimer for only a few tens milliseconds. The dimer spins rapidly with speed faster than 70 rps and the rotational direction always follows the direction of circular polarization. We consider the Au NP dimer is formed transiently by the strong gradient force of the tightly focused trapping laser that overcomes the optical binding force. The associated dimer should receive spin angular momentum from CP light more efficiently than when the NPs are optically bound. Then the dimer quickly dissociates back to two separated Au NPs with the original distance of the wavelength of trapping laser, which may due to the electrostatic repulsive force. The rapidly spinning dimer might be a critical process for initiating the orbital rotation of the whole assembly through coupling with multiple scattering and hydrodynamic effects.

[1] Tetsuhiro Kudo, Shang-Jan Yang, Hiroshi Masuhara, **Nano Lett.**, 2018, 18 (9), pp 5846–5853