Morphology Control of Gold Nanoparticles Swarming by Optical Trapping at Glass/Solution Interface

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Optical trapping has been widely used among various research fields to manipulate micro- and nanoscale objects using a focused laser beam. Our group has been studying the unique optical trapping and assembling phenomena at the interfaces, where the optical potential is expanded through the propagation and scattering of trapping laser. The trapped targets (including molecules, dielectric particles, and metallic particles) assemble and evolve to the outside of the laser beam, forming assemblies much larger than the irradiated area. We called this “optically evolved assembling”.[1] Among them, gold nanoparticles (Au NPs) present swarming assemblies in which NPs dynamically fluctuate as a group similar to a swarm of bees.[2]

In this research, we study the Au NPs swarming behavior by a dual objective lens microscope: one lens for observing image and the other for focusing laser. Such a system allows us to adjust the axial position of observing and trapping separately. As a result, the Au NPs assembly shows ellipse, dumbbell-shaped, and ring-shaped swarming when the 1064 nm laser is shifted axially for only few μm (Fig. 1). The dynamic equilibrium state between the ellipse and dumbbell-shaped swarming is observed during the evolution of swarming. Moreover, the morphology of dumbbell-shaped swarming can be further controlled by the laser incident angle before and after the objective lens. The results are elucidated in terms of the overwhelming scattering force that comes from the momentum transfer between photons and Au NPs. This work shows the importance of the momentum direction of incident photons when optical trapping is conducted near an interface, establishing the critical steps for us to control the “optical evolved assembling” comprehensively.

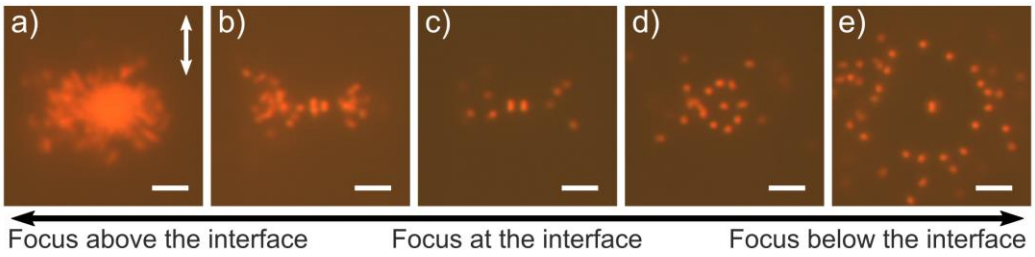

Figure 1. Back scattering images of Au NP swarming when the trapping laser focus is shifted for a) +4 μm, b) +2 μm, c) 0 μm, d) -2 μm and e) -4 μm. The laser is linearly polarized along the direction of white arrow. The scale bar indicates 2 μm length.

1. Hiroshi Masuhara, Ken-ichi Yuyama, **Annu. Rev. Phys. Chem.**, 2021. 72:565–89
2. Tetsuhiro Kudo, Shang-Jan Yang, Hiroshi Masuhara, **Nano Lett.**, 2018, 18 (9), 5846–5853