

Three-Dimensional Analysis of Polystyrene Nanoparticle Assembly Formed by Laser Trapping at Glass/Solution Interface

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When a tightly focused laser beam is irradiated inside a colloidal solution, nanoparticles (NPs) are generally trapped three-dimensionally and remain confined in the focal volume. However, when the focal spot is shifted to an interface, an assembly of NPs much larger than the irradiated area is prepared due to light propagation. We have reported the optically induced expansion of the assembly from the focal area for polystyrene (PS) NPs of 200 nm in diameter at the solution surface.¹ When the laser was focused at a glass/solution interface, PS NPs of 500 nm were assembled outside the focal spot, forming a tetragonal structure with four horns and hexagonal close-packed structure with six horns by using linearly and circularly polarized light, respectively.² Additionally, we recently reported three horns formation extending from the assembly when 750 nm PS NPs were trapped as shown in Fig. 1a.

In this study, we obtain three-dimensional images of the respective assemblies by utilizing a dual objective lens microscope. By examining the three-dimensional packing structures of PS NPs with different diameters, we conclude that body-centered cubic (BCC) like, hexagonal closed-packed (HCP) and face-centered cubic (FCC) structures (Fig. 1b) are responsible for four, six and three horn assemblies, respectively. In addition, Finite-Difference Time-Domain (FDTD) simulations were performed for the corresponding assemblies to elucidate how the trapping laser propagates through the three-dimensional assembly. With these results, we propose the assembling mechanism based on three-dimensional light propagation.

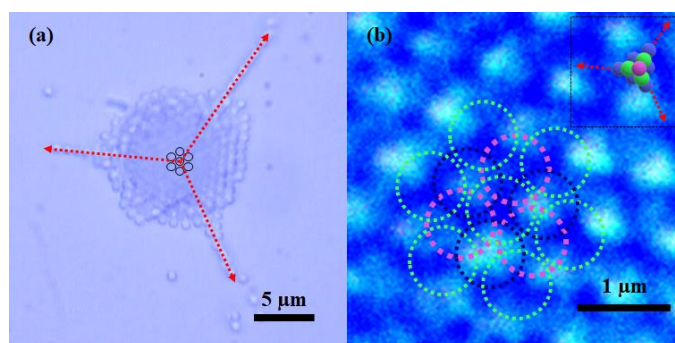


Fig. 1. Transmission image of (a) an assembly of PS NPs, 750 nm in diameter, showing three horns and its alignment (red lines) with respect to the central hexagonal assembly (black circles). (b) Processed and enlarged image of the first layer of corresponding assembly. The particle location of first layer is indicated as dotted blue circles, and that of second and third layers are superimposed in the same image as dotted green and dotted pink circles, respectively.

[1] Wang, S.-F.; Kudo, T.; Yuyama, K.; Sugiyama, T.; Masuhara, H. *Langmuir*, **32**, 12488–12496 (2016).

[2] Kudo, T.; Wang, S.-F.; Yuyama, K.; Masuhara, H. *Nano Lett.*, **16**, 3058–3062 (2016).