Clustering of Microspheres Using Thermoplasmonic Marangoni Effect

サーモプラズモニック・マランゴニ効果を用いたマイクロ球クラスターの生成

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Marangoni flow has recently gained much attention for applications in the particle handling in microfluidic channels. This flow is driven by a surface tension gradient along a vapor-liquid interface, which is induced by temperature gradient along the interface. In our previous study, we generated rapid Marangoni vortex flows around a micro bubble using the thermoplasmonic effect of gold nanoparticles under laser illumination [1]. By holding the laser power constant, stable vortex flows developed around the bubble and tracer microparticles dispersed in the fluid were tidily arranged in a circular pattern. Since the induced flow pattern is sensitive to the laser power, we expect that advanced manipulation of micro particles is realized by temporally modulating the laser power. In this presentation, we focus on the clustering of the tracer particles in the temporally controlled thermoplasmonic Marangoni flows.

A gold island film was prepared on a glass substrate, on which a shallow cell with 50 μm height was prepared. The cell was filled with water in which polystyrene (PS) spheres with a diameter of 2 μm were dispersed in order to visualize the flow. A micro bubble was created in the cell by focusing a laser (wavelength: 785 nm) onto the thin film. Then, the laser spot was displaced slightly from the center of the bubble to induce the Marangoni flow. The laser power was temporally modulated in the range of 0–12 mW by changing the control voltage using a function generator.

Under the laser illumination at a constant power, rapid vortex flows developed around the bubble and the PS spheres were arranged in a single circular pattern. The diameter of the circle was enlarged by increasing the laser power. When the laser power was square-wave modulated at 5 Hz, the single circular pattern of the PS spheres split into double circles. Each circle consists of a row of clustered PS spheres. The clusters on the inner circle formed during lower laser power levels, while those on the outer circle formed during higher laser power levels (Fig. 1). This result indicates that the fast response of thermoplasmonic effect of gold nanoparticles enables to switch the flow direction instantaneously. Consequently, the particle clustering method using the thermoplasmonic Marangoni effect is useful as a particle handling technique.

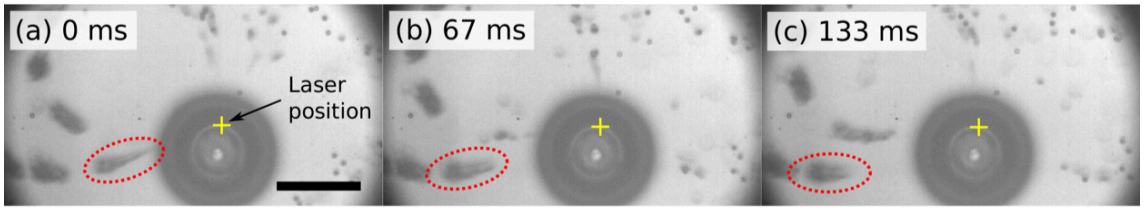

Fig. 1: (a)–(c) Sequences of microscopic images acquired at 15 frames/s showing the clustering of the microspheres at a laser modulation frequency of 5 Hz. The yellow crosses show the laser position, the small black dots are the PS spheres, and the big black circle is the micro bubble, respectively. The red dashed-circles indicate a generated PS sphere cluster. Scale bar: 50 μm.

[1] K. Namura, et al., *Appl. Phys. Lett.* **106,** 043101 (2015).