Control of Colloids by Thermophoresis Driven Depletion Force: Experiments and Thermodynamic Formalism

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Optical trapping is widely used for manipulating colloidal objects in scientific studies and biological applications. However its use is in general restricted to transparent, polarizable objects having an index of refraction higher than that of surrounding solutions. Here we present discovery of the all optical control of entropic force which overcomes the limitation of conventional laser tweezers. Colloidal particles such as submicron sized beads, non-tethered DNA molecules, and biological cells are easily trapped when only a little amount of polymer is added in solutions. We show that the local polymer depletion induced by the temperature gradient, so-called thermophoresis, can create a controllable external force on colloids by an all-optical method, resulting in a novel trapping tool for more generic colloidal particles than with other methods.

A slight increase in local temperature in polymer solution by laser depletes the polymer concentration at the focal point, and the resulting polymer gradient exerts force on colloidal objects thus increasing the overall disorder. Interestingly, even particles and macromolecules with positive thermodiffusion coefficients (implying that particles prefer colder regions) can be trapped by the depletion of polymer molecules, which have the same tendency to escape toward colder regions. Quantitative measurement of trapping ability depending on polymer concentration and temperature revealed that the force has an entropic origin. This new all-optical trapping will be useful for collecting, accumulating, and manipulating colloids, and will become a scientific tool to control cell osmotic pressure.

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