Title of Project : Nano-Material Manipulation and Structural Order Control with Optical Forces

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【Purpose of the Research Project】

This project aims at the realization of optical force technologies for mechanical manipulation (trapping, transportation, positioning, and aligning) of individual nano-objects, such as molecules and quantum dots, in a direct and selective way according to their individual properties, leading to scientific principles of a novel scheme for creating structural order through the manipulation of microscopic substances. To achieve the technologies of manipulating the mechanical motion of individual nano-objects, we develop the design method for optical forces using linear and nonlinear optical responses of various targets exhibiting quantum mechanical properties. Our project will realize novel schemes to create structural order reached only by optical force technologies, e.g., optical sorting and isolation of targets in different quantum resonance conditions, manipulation of crystal morphology and alignment, and manipulation of chemical processes by selective control of molecular diffusion and condensation.

【Content of the Research Project】

To visualize the achievement of our goal, we will conduct the following three collaborative subprojects: [A] Isolation of particular kinds of nano-objects and their precision arrangement over a macroscopic region, [B] control of interparticle interactions for the creation of hierarchical structures including crystallizations, and [C] control of chemical processes through selective manipulation of molecules. Furthermore, we set four planned researches that are the bases of the above subprojects, i.e., A01: Theories, metrologies, and observations of optical forces for establishing basics of optical manipulation ("basics of optical forces"), A02: advancement of manipulation methods utilizing the microscopic degrees of freedom of matter systems ("creation of optical forces"), A03: single molecular manipulation on the nanometer scale by utilizing localized electric field, and the operation over macroscopic regions ("ultimate scheme of optical forces"), and A04: creation of superstructures and new phenomena by selective control of interparticle interactions ("exploitation of optical forces"). We will achieve these three subprojects by synergizing the four planned researches.

Because researchers from a variety of fields such as physics, chemistry, and engineering join this project, we manage several "training dojos" where young researchers can learn methods of different fields, which will strongly promote collaboration for the subprojects [A], [B], and [C], and build the ability of young researchers.

【Expected Research Achievements and Scientific Significance】

Scientific principles and technologies realized by this project will lead to the following achievements. (1) Selective motion-control and observation of spatial arrangement of nano-objects on the molecular scale enable technologies for unconventional metrology, screening, and visualization that cannot be performed using existing methods. (2) Control of interparticle interactions by manipulating the local density and orientation of particles in high-concentration solution enables novel design of crystallization and self-assembly of nanoparticles. (3) Manipulation of local diffusion and density of particular kinds of particles using optical forces enables unconventional schemes for studying and controlling chemical processes, novel types of position-selective molecular sensing, and technologies to dramatically improve efficiencies of chemical reactions.

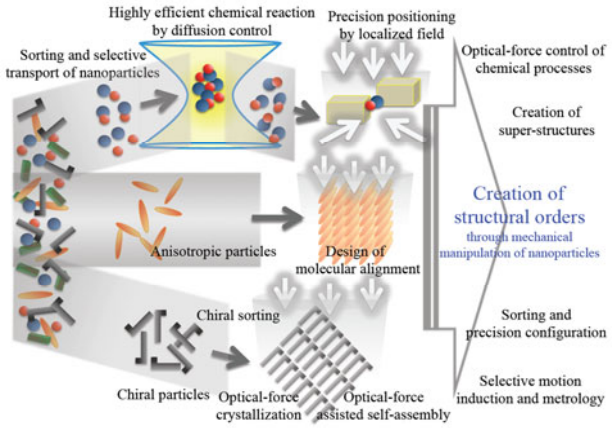

Figure: Schematic image of structural order control using optical manipulation of nanoparticles

【Keywords】

Optical force: A force arising from either momentum transfer when light is scattered and/or absorbed by a matter system or the electromagnetic interaction between the applied field and the induced polarization.

Localized electric field: Oscillating electric field associated with localized plasmons sustained in metallic nano/microstructures, usually enhanced by several orders of magnitude compared with the incident field intensity.

【Term of Project】 FY2016-2020

【Budget Allocation】 1,049,900 Thousand Yen

【Homepage Address and Other Contact Information】

http://optical-manipulation.jp