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Keio University

Thesis Abstract

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Thesis Title

Optical Characterization and Rotational Dynamics Observation of Colloidal Gold Nanoparticles via Polarized Light Scattering Microscopy

Gold nanoparticles exhibit unique optical properties compared to the bulk form. These properties are size- and shape dependent, and originates from the localized surface plasmon resonance LSPR of the nanoparticle. The enhanced absorption and scattering, photochemical stability, good biocompatibility and polarization-sensitive optical response, make gold nanoparticles suitable probes for biosensing and detection applications. In such applications, gold nanoparticles can be conjugated to a variety of biomolecules in order to monitor dynamics/conformations of biomolecules during their functional task. To enhance the sensitivity in these applications, robust techniques for optical characterization of nanoparticles as well as for monitoring their dynamics are highly needed.

In this dissertation, we propose the using of polarized light scattering microscopy to characterize colloidal gold nanoparticles (nanospheres and nanorods) in solution, as well as to observe their rotational dynamics. Anisotropic nanoparticles (i.e. non-spherical such as rods) cause the scattered light polarization to be different from the excitation polarization; however, isotropic nanoparticles (i.e. spherical) don't change the incident light polarization. Based on this concept (called: polarization anisotropy), optical characterization is achieved by measuring the polarization anisotropy of the nanoparticle and then deducing its aspect ratio. On the other hand, rotational diffusion of colloidal nanoparticles is observed as fluctuations in the scattering polarization, from which we were able to extract the rotational diffusion time on the microsecond time scale which is an important parameter in many biological phenomena. Comparison of the experimental measurements with theoretical expectations is found in a good agreement confirming the validity of the proposed method.

Chapter 1 summarizes the background, survey of metal nanoparticles research topics and the objectives of this study. Chapter 2 describes the fundamentals of electromagnetics in metals based on the macroscopic Maxwell equations and the metal dielectric function. Chapter 3 discusses the first branch of the plasmonics research area: surface plasmon polaritons at metal/dielectric interface. Further, it reviews their excitations and imaging techniques. Chapter 4 describes the second branch of the plasmonics research area: localized surface plasmons LSPs of metal nanoparticles which is the basic background of this study. Some related theories such as the quasi-static approximation of nanoparticles and Mie theory are outlined. It also discusses the observation methods of LSPs and their properties. Chapter 5 describes experimental results of a study of the polarization anisotropy for nearly spherical gold nanoparticles dispersed on a glass substrate. Chapter 6 discusses experimental results of optical characterization of nearly spherical gold colloidals in (solution) via polarization microscopy. Similarly, Chapter 7 describes experimental results of optical characterization of colloidal gold nanorods. Also, it discusses the rotational dynamics of the nanorods and how we could access the rotational diffusion time. We figured out the relation between the rotational time with both the rod's aspect ratio and the solution viscosity. Chapter 8 outlines the promising applications of gold nanoparticles and polarized light scattering in biosensing applications. Chapter 9 summarizes the conclusions and future perspectives.