

Magnetic Lorentz force modulates circular oscillations of free electrons in thiolate-protected silver nanoparticles

Silver and gold nanoparticles are especially attractive because their free electrons can be excited to oscillate collectively with visible light irradiation, which is known as “surface plasmon resonance (SPR)” oscillation, and it strongly contributes to their apparent color. A challenging issue regarding the SPR behavior is its modulation via external parameters such as a magnetic field. The modulation of SPR via the magnetic field, creating “surface magnetoplasmon”, is particularly interesting because enhanced magneto-optical (MO) effects are expected to appear in correspondence with plasmonic excitations.

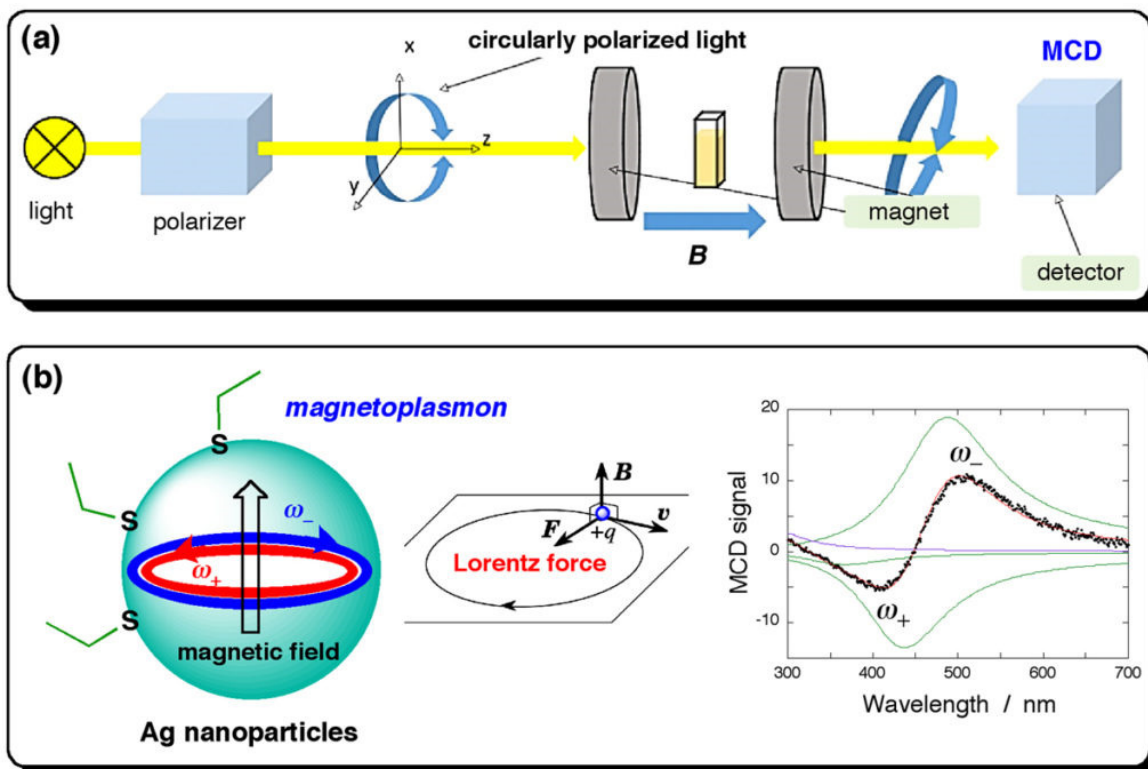


Fig. 1. (a) Set-up for the measurements of magnetic circular dichroism (MCD). (b) Schematic model of surface magnetoplasmons in thiolate-protected Ag nanoparticles created via magnetic Lorentz force imparted on the circularly oscillating free electrons. Typical MCD spectrum of the Ag nanoparticles is also shown.

We have demonstrated for the first time large MO responses at the energy of SPR, that is, surface magnetoplasmons, in thiolate-protected Ag nanoparticles with magnetic circular dichroism (MCD) spectroscopy. MCD is the differential absorption of left and right circularly polarized light induced by a longitudinal magnetic field (Fig. 1a). In the Ag nanoparticles (3~5 nm in diameter) examined, a derivative-like MCD signal is observed under an applied magnetic field of 1.6 T, which can be explained in terms of

two circular modes of magnetoplasmon caused by the increase (or decrease) in the Lorentz force imparted on the free electrons that oscillate in left (or right) circular orbits in the nanosphere (Fig. 1b). It is known that, when a charged particle q is moving in presence of a magnetic field B , it will experience a force perpendicular to its direction, called “Lorentz force” (Fig. 1b).

For the well-dispersed Ag nanoparticles, it is found that (i) an amplitude of the magnetoplasmonic component with lower frequency (ω_-), resulting from the reduction in the confinement strength of free electrons by the Lorentz force, is stronger than that with higher frequency (ω_+); (ii) a cyclotron frequency, defined as $\omega_c = \omega_+ - \omega_-$, is size-dependent and has a very large value with implications for an apparent enhancement of the local magnetic-field in the Ag nanoparticles. The results strongly suggest that the Ag-S bonding on the nanoparticle surface plays a significant role in the MO enhancement. We believe that magneto-optical modulation in thiolate-protected metal nanoparticles by controlling the surface ligand structure will bring a wide range of impact to the field of active plasmonics and magnetoplasmonics.

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[Individual and collective modes of surface magnetoplasmon in thiolate-protected silver nanoparticles studied by MCD spectroscopy.](#)

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