Experimental studies of narrow plasmon resonances in asymmetric environment in diffractive arrays of gold nanoparticles

Andrey G. Nikitin, and Tuyen Nguyen and **Hervé Dallaporta**
Aix-Marseille University, CINaM-CNRS,
Campus de Luminy, Case 913, 13288 Marseille, France
dallaporta@cinam.univ-mrs.fr

Abstract

The plasmon resonances in asymmetric refractive index environment in two-dimensional diffractive arrays of gold nanoparticles can be a good candidate for biosensing purposes. We will present the experimental transmission spectra obtained for different sizes, shapes and periodicities and demonstrated the ability to tune the wavelength of these resonances in the near infrared range.

Diffraction of metallic gratings is well-known since many years to provide a way to excite of surface plasmon polaritons.[1-4] In a same spirit, the properties of the localized plasmons can be manipulated using the diffraction that take place in regular arrays of metal nanoparticles. The narrowing of the plasmon resonance lineshape induced by the diffractive coupling has been widely demonstrated by theoretical modeling[5-9] and optical experiments[10-17]. This collective excitation of localized plasmons of particules is now referred as collective resonances (CRs)[10]. Since for biosensing, the nanostructures must be immersed in medium (superstrate medium) with refractive index very different compare to the one of the substrate, we have studied the transmission spectra of ordered Au nanoparticle arrays in asymmetric environment.

In this contribution, we will presented the transmission spectra of periodic arrays of gold nanoparticles fabricated on a glass substrate (refractive index n_{sub}=1.5) coated with a 20 nm thick indium tin oxide (ITO). The 100 µm×100 µm gold patterns were transferred from a PMA e-beam lithography resist adding a 3nm thick Cr layer to increase the gold adhesion on ITO. The nanoparticles are arrange in a square lattice array with two different shapes: 50nm height cylinders with 120 nm, 150 nm and 170 nm diameter and 50nm thick nanorod with in-plane dimensions of 120 nm × 200 nm. . The transmission spectra were measured at quasi normal incidence on a collimated spot (30µm) using Woollam M2000 spectroscopic ellipsometer.

Figure 1 (a and b) gives examples of transmission spectra for asymmetric configuration for different values of the top medium refractive index (glycerol n_{top}=1.47, water n_{top}=1.33 and air n_{top}=1) and for different values of the array period. The spectra exhibit localized dip adsorption features that correspond to the excitation of CRs. Due to the modification of the coupling between of the single particule localized plasmons by changing the distance between nanoparticles, the resonance of the array experience anomalous spectral shifts. Furthermore, the spectral lineshape is considerably modified as compare to single nanoparticle case. As it has been obtained for symmetric cases, the resonant dip redshifts and its spectral lineshape gets narrower as the lattice period increases[6,7,10]. Since for biosensing, the interest is in the change of resonance shape and shift induced by the change of the refractive index, we give on fig 1 (d) the resonance shifts and the factor of merit (FOM) versus the lattice period. From our results, we will discuss the possibilities that diffractive coupling offer to adjust the width and the wavelength of plasmon resonance by changing the size and geometry of constituent nanoparticles.

From the optical transmission spectra of ordered arrays of gold nanoparticles in asymmetric configuration, we can study the influence of collective effect on plasmon resonances and evaluate the performances that can be obtained on diffractive gold nanoparticle arrays as a sensor.

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Figure

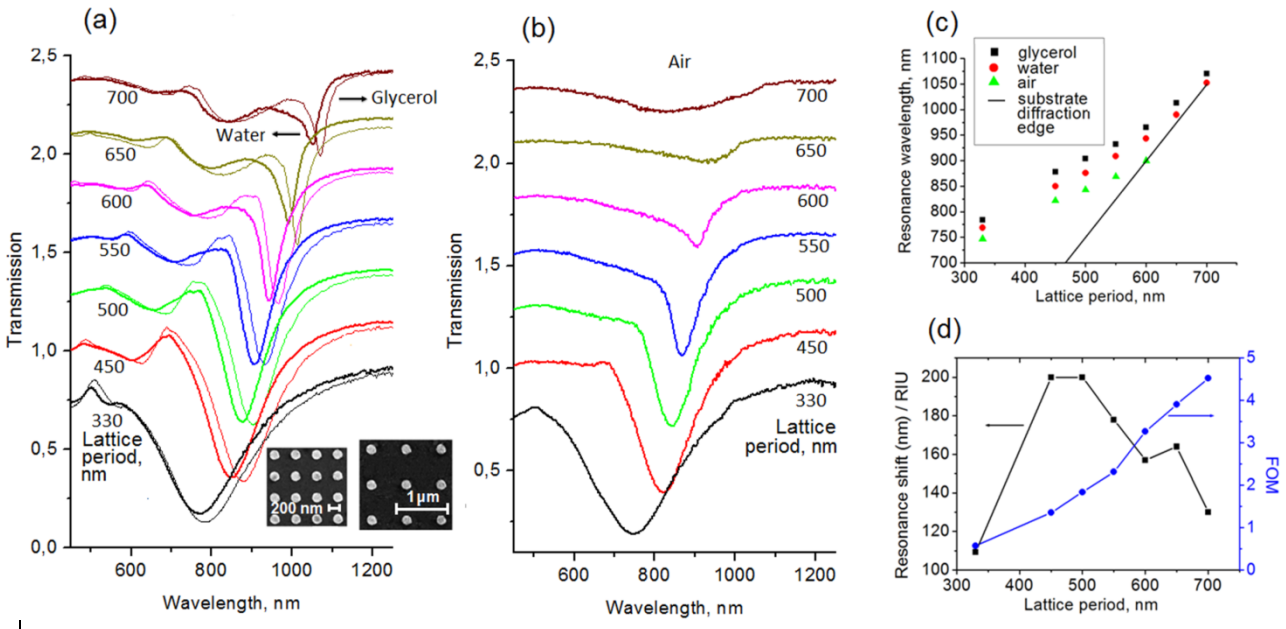

Fig. 1: Transmission spectra of periodic 170nm gold cylinder arrays for different superstrate media: (a) water (thick line), glycerol (thin line) and (b) air. Spectra are shifted by 0.2 units along y axis. (c) Resonance dip wavelength as a function of the lattice period. (d) Shift of the resonance dip in *nm* per RIU obtained from the spectra in panel (a) and FOM for the arrays with different lattice periods. Inset: scanning electron microscope image of 450 and 700 nm arrays.