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NANOPLASMONICS : FROM BIOCHEMICAL SENSORS TO SURFACE ENHANCED SPECTROSCOPIES

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ABSTRACT. Plasmonics is a field connected to optics dealing with the properties and applications of surface plasmons which are modes of metal dielectric interfaces. Nanoplasmonics concerns the excitation, manipulation and detection of the surface plasmons at the nanometric scale. It has highly potential applications for ultrasensitive biochemical sensing. Surface enhanced spectroscopies are the ultimate sensor tools as they can reach single molecule sensitivity. We will present in this paper our results towards the realization of highly controllable and reproducible nanoplasmonics substrates.

1. Introduction

Plasmonics is now a well established field finding numerous applications in pharmacology, biology, optoelectronics and metamaterials among others. For the detection of hazardous molecules or markers Surface Enhanced Spectroscopies are well widespread [1]. Among them, Surface Enhanced Raman Spectroscopy (SERS) and Metal Enhanced Fluorescence (MEF) are the most used for applications. Both these enhanced spectroscopies are based on local field enhancement entailed in the near vicinity of metallic nanoparticles when Surface Plasmon oscillations are driven for a specific optical wavelength. SERS can achieve single molecule detection when two or more metallic nanoparticles are near-field coupled, resulting in enhancements ranging between 12 and 14 orders of magnitude. However, these particular SERS substrates are difficult to reproduce. Less enhancement is obtained with MEF but usually the intrinsic fluorescence cross section of a molecule is 14 orders of magnitude less than that of its Raman cross section. Another approach for detecting various molecules is biochemical sensors relying on the detection of the spectral shift of the Surface Plasmon resonance of metallic nanoparticles after the adsorption of these same molecules. This technique, even if not reaching single molecule detection so far, has the advantage of being not limited to specific types of molecules. This contribution will show the ties between SERS, MEF and sensors. Some of the works of the LNIO laboratory in that direction will also be presented [2, 3, 4].

2. Results and discussions

There is definitely a parallel between SERS and MEF as both types of spectroscopies deal with enhancement of incoherent spontaneous phenomena: spontaneous emission for

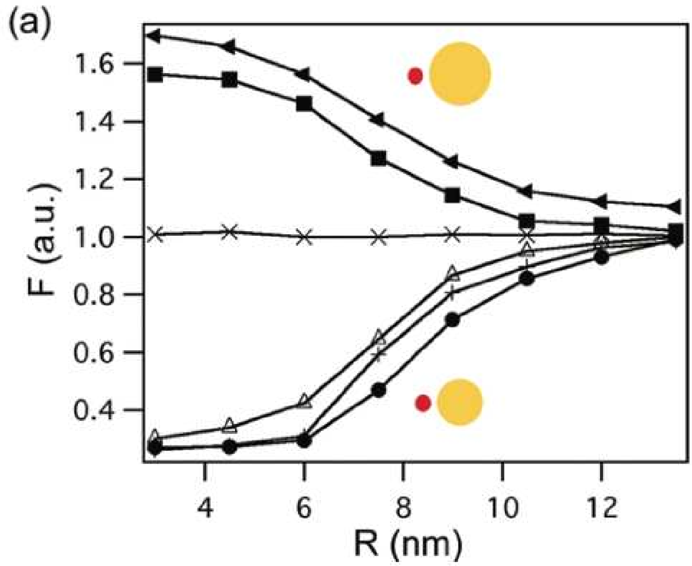

Figure 1. Luminescence modification factor F of quantum dots near gold nanocylinders in function of the distance R between dots and nanoparticles. Quenching occurs for cylinders diameters lower than 130 nm. Enhancement occurs for diameters greater than 130 nm.

fluorescence, spontaneous scattering for Raman. Both phenomena can thus be treated the same way from the theoretical point of view [5]. One major difference however is the finite lifetime of the excited levels in fluorescence. This leads to specific phenomena such as non radiative quenching. An example of different enhancement and quenching behaviours is shown in Fig. 1. This figure shows the modification of luminescence of core/shell quantum dots (CdTe core) in presence of resonant gold nanoparticles of different sizes [4].

When performing SERS or MEF experiments the emitting or scattering molecules do necessarily, by their presence in the near vicinity of the metallic nanoparticles, entail a shift in the surface plasmon resonance of the latter. This is indeed the principle of nanoplasmonic biochemical sensors [4]. This shift is due to the modification of the refractive index of the surroundings of the metallic nanoparticles. If we go back to surface plasmons on planar interfaces, the dispersion law of such true surface waves does depend on the dielectric properties of both adjacent media.

3. Conclusions

Nanoplasmonics is an emerging branch of nanoptics with a high potential for applications in biochemistry. It is also worth mentioning that from the fundamental point of view new effects have already been recently observed and this will pave the way to other possible directions for applications in sensors and enhanced spectroscopies.

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