Experimental results from dielectric-metal grating coupled surface plasmon resonance device for novel low-cost biosensor

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COLEGIO DE INGENIERÍA

CEID CENTRO DE INNOVACIÓN Y DISEÑO

Introduction

- An optical prototype was fabricated to perform measurements of surface plasmon polaritons in light beams diffracted at angles of less than 90^0.
- Experiments were developed to identify the excitation resonant angle of surface polariton plasmons by a diffraction grating with a pitch greater than the wavelength of the light signal.
- In the laboratory tests, measurements of the intensity curve of the diffracted light signal were carried out in the +1 and -1 orders. The experimental results were consistent with the theoretical approach.
- Based on this method, it is proposed a device for a low cost biosensor, using nanomaterial that can be functionalized with bio-material.

Theory

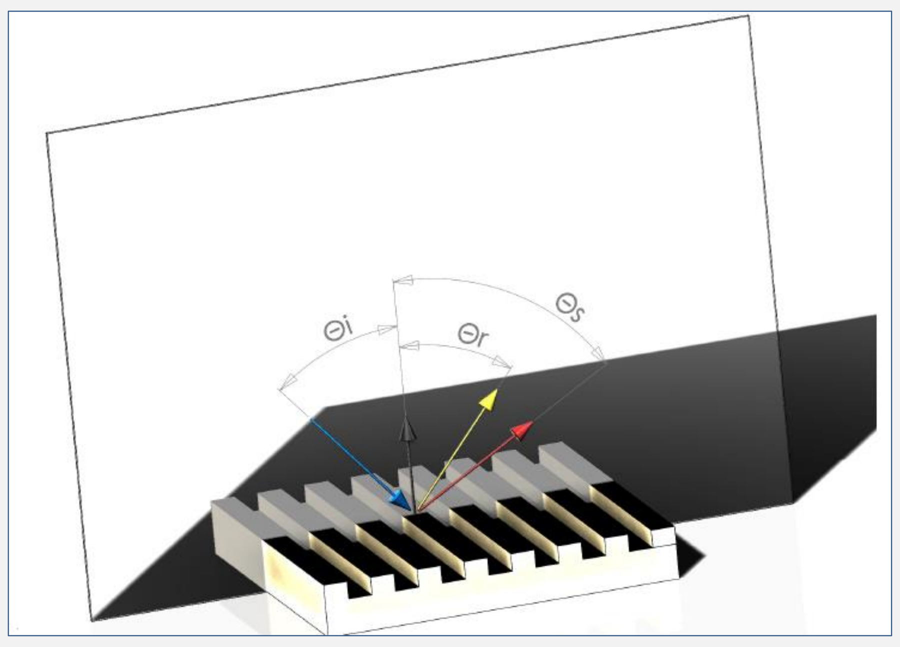


Fig. 1 (a)

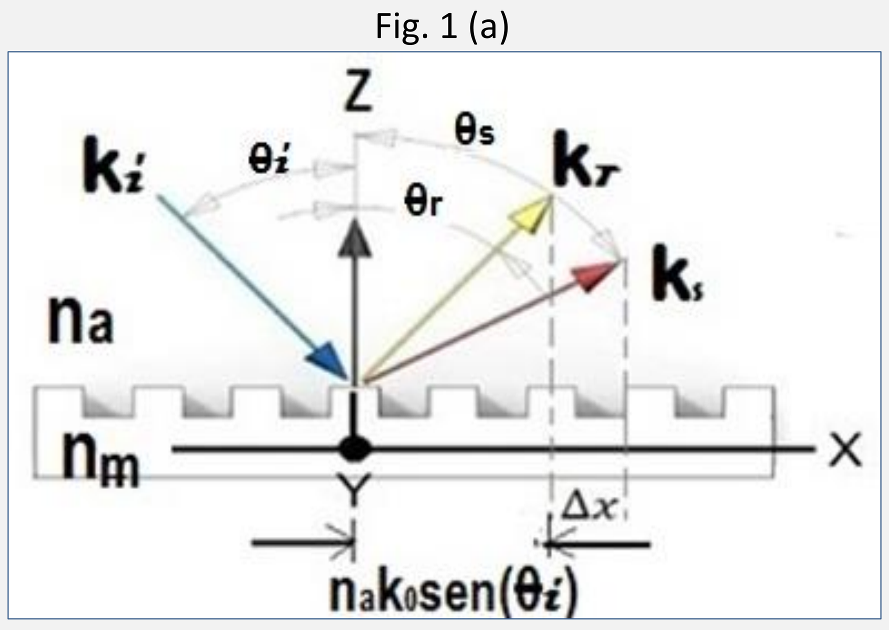


Fig. 1 (b)

Fig. 1. (a) Gold metallic diffraction grating. (b) Side view of the diffraction grating. Note the projection of the diffracted wave vector (K_s).

Wave vector of an Evanescent Electric Field (k_{spp}) for a Diffraction Grating.

$$k_{spp} = n_a k_o \sin \theta_i + n\, k_g \qquad (1)$$

k_{spp}	Wave vector of the Surface Plasmon Polariton
n_a	Refraction index of air
k_o	Wave vector of the light signal
θ_i	Angle of incidence
k_g	Wave vector of the grating

Wave vector of a Plasmon Polariton (k_x) for a Plane Wave in a Gold Flat Surface.

From the boundary conditions and using Maxwell equations:

$$k_x = \frac{w}{c}\sqrt{\frac{\varepsilon_1\,\varepsilon_2}{\varepsilon_1 + \varepsilon_2}} \qquad (2)$$

k_x	Wave vector of the Plasmon in a Metallic flat surface
w	Frequency of the light signal
c	Speed of light

ε_1	Dielectric constant for gold
ε_2	Dielectric constant for air

Experiments

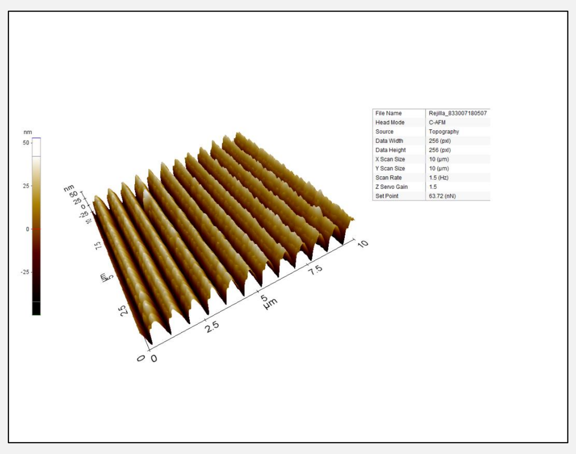


Fig. 2 (a)

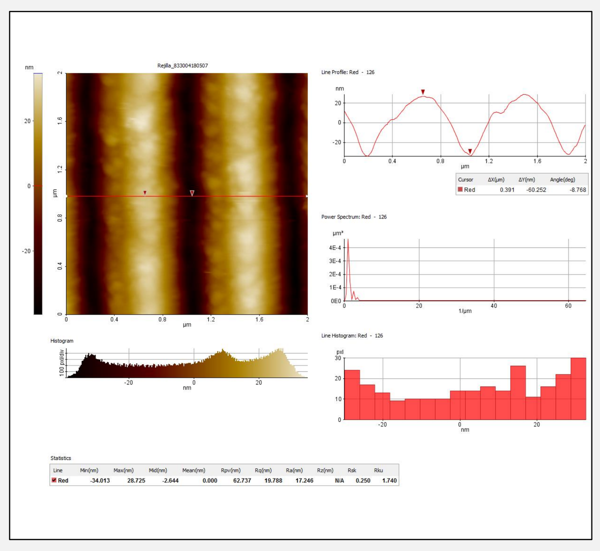


Fig. 2 (b)

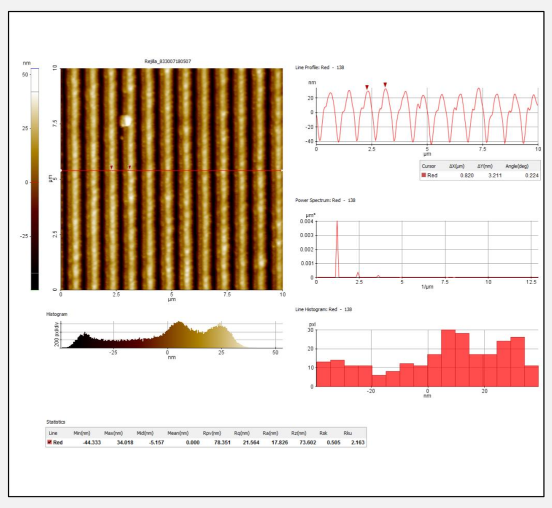


Fig. 2 (c)

Fig. 2. Images from an Atomic Force Microscope. (a) Profile of a gold diffraction grating. (b) Measurement of the depth in the metallic grating (60.252 nm). (c) Measurement approach of the pitch for the metallic grating (820 nm). More accurate measurements can be taken with optical method (833.33 nm).

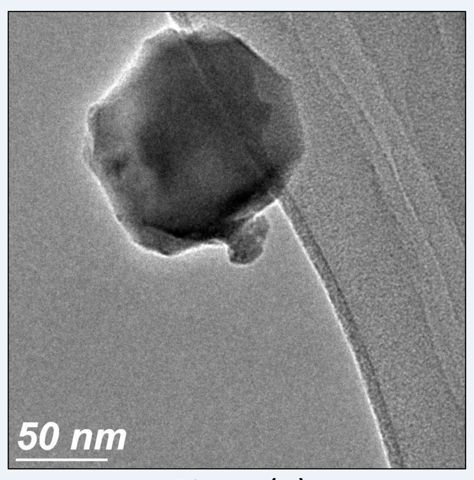


Fig. 3 (a)

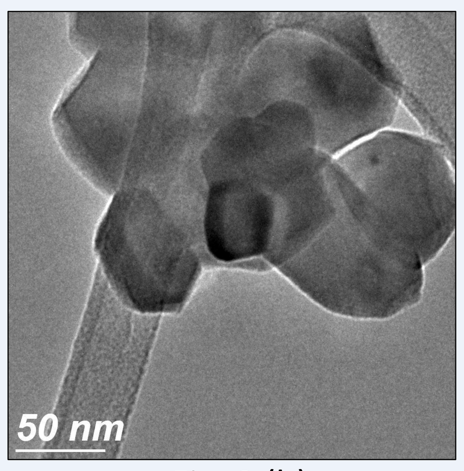
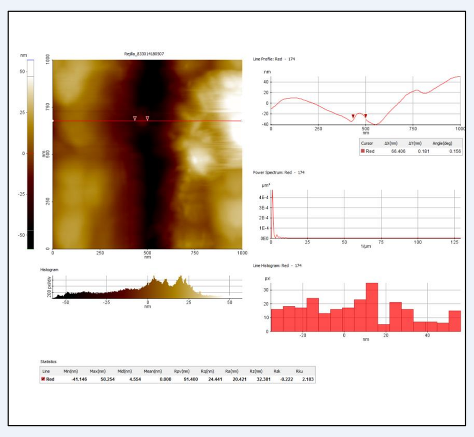
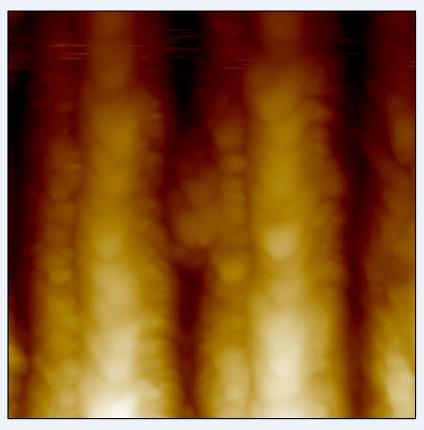


Fig. 3 (b)

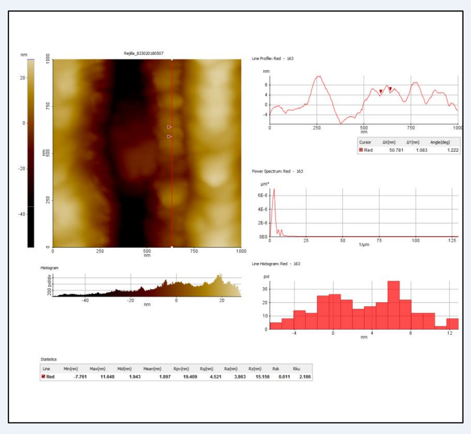
Fig. 3. Synthesized nanoparticles (NPs) through the Sol-Gel method. Nanomaterial is formed with Yttrium Oxide doped with Erbium and Ytterbium, Y_2O_3:Er,Yb (1,1%). This nanomaterial shows upconversion luminescence property. (a) Single nanoparticle (50 nm). (b) Cluster of nanomaterial.



(a)



(b)



(c)

Fig. 4. Gold diffraction grating doped with the nanomaterial described in Fig. 3. (a) Nanoparticle (66.406 nm) in a slit of the grating. (b) Cluster of nanomaterial in a groove of the metallic grating. (c) Measurement of NPs on the profile of the grating (50.781 nm).

Prototype results

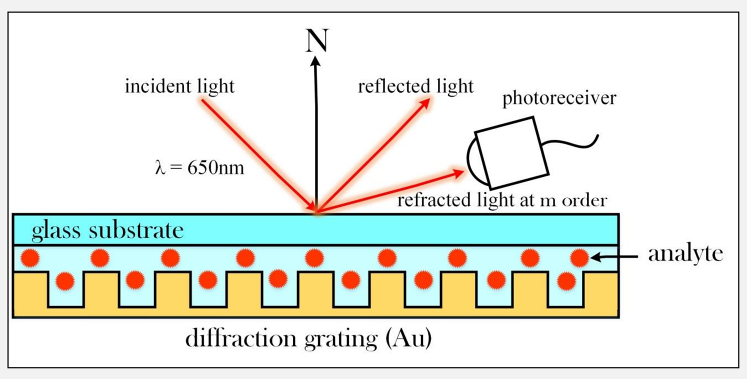


Fig. 5 (a)

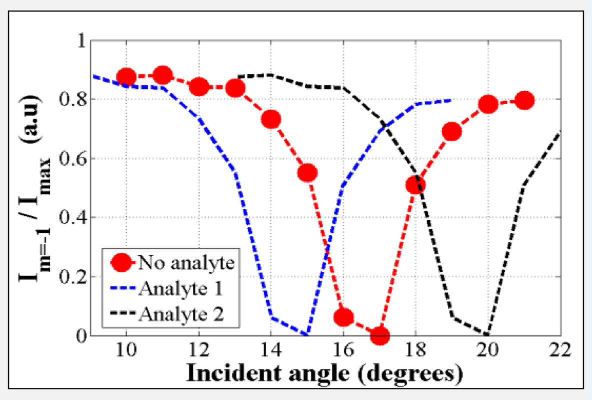


Fig. 5 (b)

Fig. 5 Experimental set up.

- A gold diffraction grating with a period of $\Lambda > \lambda$ is illuminated by a laser beam (λ =650nm) at an angle of incidence θ_i, the incident medium is air (no analyte).
- Λ is the fundamental design parameter needed to measure the diffraction orders (m) outside the boundary of the grating.
- Fig. 5(b) shows experimental results of the normalized intensity measured in the order m=-1 ($I_{m=-1}$) when the incident angle θ_i is swept from 10 to 22 degrees (red line).
- Using rigorous Coupled Wave Analysis Method, we calculate the normalized intensity when the grating has an analyte on its surface. It is possible to observe a shift of the minimum (at the resonant angle) intensity value due to the analyte nature used.

References
[1] Shalaev, V. M y S. Kawata. Nanophotonics with Surface Plasmons. Elsevier (2007).
[2] Raether, H. (1988). Surface Plasmons on Smooth and Rough Surfaces and Gratings. Springer, Berlin.