Optical sensor based on the Surface Plasmon Resonance of noble metal nanoparticles on the surface of a transparent conductive oxide for cholesterol detection

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1. Objective

To create by laser techniques a sensing device based on an oxide thin film covered with noble metal nanoparticles, able to detect a chemical substance (analyte - cholesterol). The scope of this research is to simplify an optical sensor's manufacturing without sacrificing the sensing resolution.

2. Materials

Thin oxide

ITO - member of the CMOs materials, which encompasses both degenerate wide band gap semiconductors (*sp*-type) and semimetals (d-type)[1]

Metal

Au NPs on a dielectric generate coherent electron oscillations called surface plasmons[2]

cholesterol + O_2 $\xrightarrow{\text{Enzyme}}$ cholest-4-en-3-one + H_2O_2

3. Experimental Details

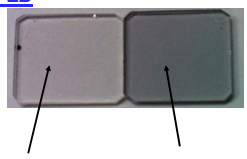
Nd:YAG (λ = 355 nm, τ = 10 nsec, ν= 10 Hz)

Growth of ITO by PLD

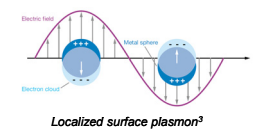
No. of sample	Target	Substrate	$D_{target-substrate}$ (cm)	F (J/cm²)	P (Pa)	T (°C)	N (pulses)
I	ITO 99.99%	glass	5	15	13	RT	36 000
II	ITO 99.99%	glass	5	15	13	120	36 000
III	ITO 99.99%	glass	5	15	50	RT	36 000
IV	ITO 99.99%	glass	5	15	50	120	36 000

Growth of gold NPs by PLD

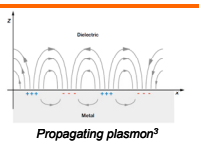
Targets: Au 99.99%
Substrate: ITO/glass
P = 10^{-4} mbar
F = 7 J/cm²
$d_{target-substrate}$ = 5 cm
T = 140°C
N = 1 800 pulses



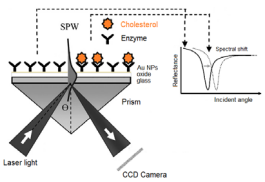
4. SPR configurations



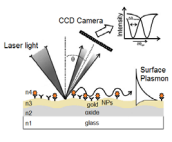
Localized surface plasmon[3]



Propagating plasmon[3]



SPR biosensor

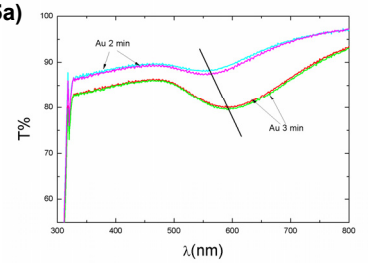


Grating coupling SPR biosensor

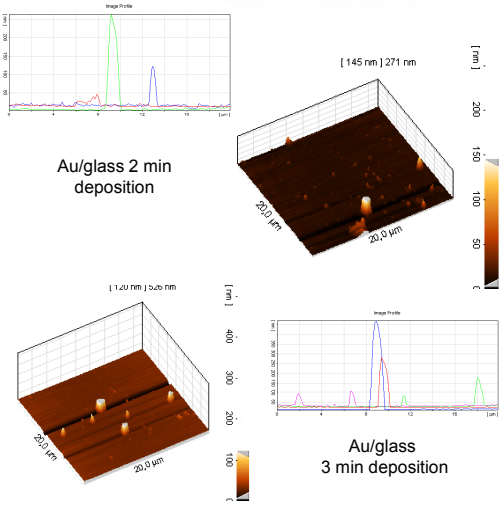
Reference:
1. C. Rhodes et al., J. Appl. Phys 100 (2006), 054905
2. O.S Wolfbeis (series editor), J. Homola (volume editor), Springer Ser Chem Sens Biosens (2006) 4: 3–443
3. K.A. Willets et al., Annu. Rev. Phys. Chem. (2007) 58:267–97

5. Results

(5a)



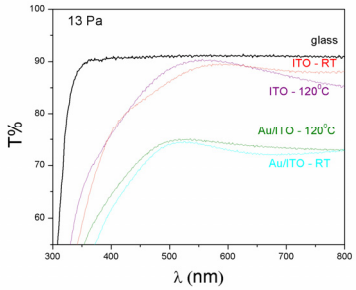
Transmission Au/glass

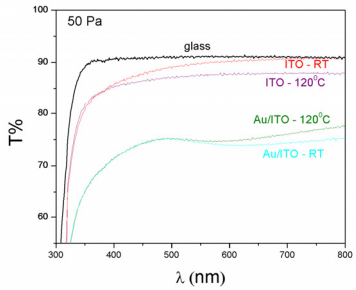


Au/glass 2 min deposition

Au/glass 3 min deposition

(5b)





Au SPR for Au/ITO/glass for different deposition temperatures

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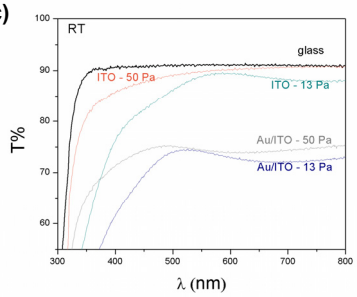
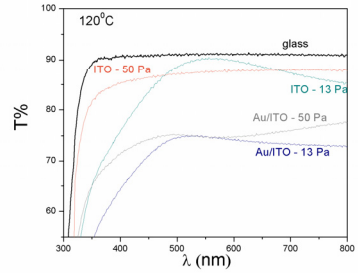
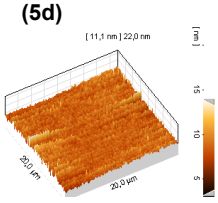
(5c)



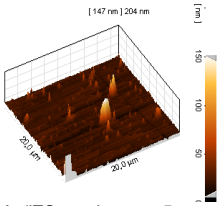


Au SPR for Au/ITO/glass for different oxygen pressures

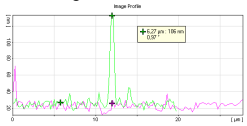
(5d)



ITO roughness ~ 1 nm



Au/ITO roughness ~ 5 nm



Au nanoparticle ~ 100 nm

6. Conclusions

We obtained by Nd:YAG laser Au NPs on glass and Au/ITO transparent conductive (TC) thin film structures. The images of the Au NPs morphology on glass and the SPR signal, identified by transmittance in the region 530 – 635 nm, allowed us to choose the loading amount of Au NPs on ITO (5a).

We observed that the deposition of TC ITO is affected by the substrate temperature and the pressure inside the PLD reaction chamber (5b, 5c). The thickness of ITO film, increases with increasing substrate temperature and decreasing oxygen pressure. The Au SPR signal of the metal/oxide layer clearly affects the transmission of the sensing structure (5b). When increasing the temperature and pressure we obtained better result for the SPR of Au NPs (5c).

The ITO thin film deposited at 50 Pa and 120°C was thin and followed the roughness of the glass substrate. Subsequent deposition of the Au NPs increased the roughness of the sensing structure. The largest size of the Au NPs was estimated ~ 100 nm.