Numerical investigation of a D-Shaped Fiber-Optic Biosensor Utilizing Surface Plasmon Resonance for Early Cancer Cell Detection

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CONTEX

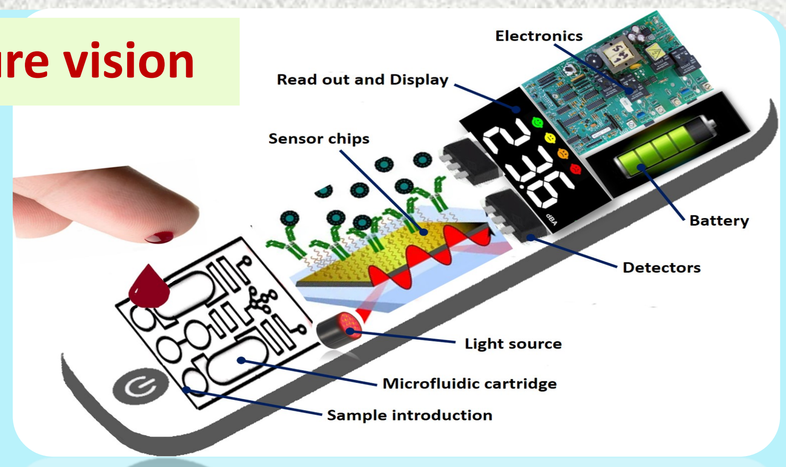
According to the WHO:

- **Cancer is the cause of almost 10 million deaths a year.**
- **More than 20 million new cases of cancer every year.**
- **Early detection of cancer is a key factor in high cure rates.**

Clinical diagnostics: Problem

Solution

Future vision



MATERIALS AND METHODS

The biosensor design comprises : a GeO2 cylindrical core (radius R_{co}=4 µm), a pure fused silica cladding (radius R_{cl}= 62.5 µm), a rectangular polished part of length L (1 mm) on which is deposited an Au thin film with thickness noted (th_Au) coated with TiO2 layer of thickness named (th_TiO2) via pulsed laser deposition or magnetron sputtering.

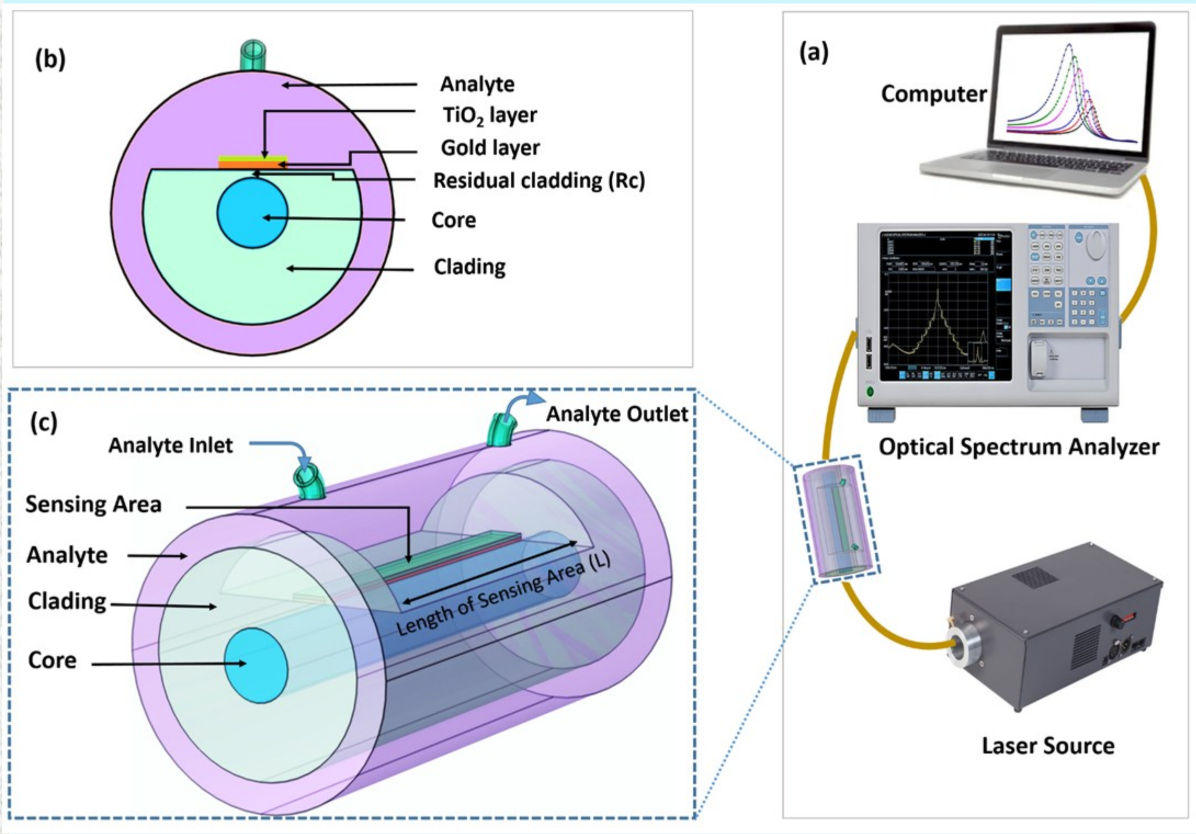


Fig. (1a) illustrate the basic scheme for analyzing cell samples using the biosensor

Fig. (1b) shows the cross-section of the optical fiber biosensor.

Fig. (1c) 3D optical fiber sensing probe

THEORETICAL ANALYSIS

The optical property of **gold** is obtained from the Drude-2-critical points model by the following relation (1) [1]:

$$\varepsilon_{DCP}(\omega) = \varepsilon_\infty - \frac{\omega_D^2}{\omega^2 + i\gamma\omega} + \sum_{p=1}^{2} A_p\Omega_p\left(\frac{e^{i\varphi_p}}{\Omega_p - \omega - i\Gamma_p} + \frac{e^{-i\varphi_p}}{\Omega_p + \omega + i\Gamma_p}\right)$$

The empirical formula (2) was employed to examine the refractive index of TiO2 in relation to the wavelength (λ)[2]:

$$n_{TiO2}(\lambda) = a + \frac{b}{1-\left(\frac{c}{\lambda}\right)^2} - d\lambda^2$$

Sellmeier's equation (3) provides a RI model for GeO2 and SiO2 [3]:

$$n(\lambda) = \sqrt{1 + \frac{b_1\lambda^2}{\lambda^2 - c_1} + \frac{b_2\lambda^2}{\lambda^2 - c_2} + \frac{b_3\lambda^2}{\lambda^2 - c_3}}$$

The propagation of light in an optical fiber is described by the following Maxwell's equations (4) [4]:

$$\nabla^2\vec{E} = n^2\frac{\omega^2}{c^2}\vec{E}$$

RESULTS & DISCUSSION

$$T = exp\left(\frac{-4\pi\kappa_{eff}L}{\lambda}\right)$$

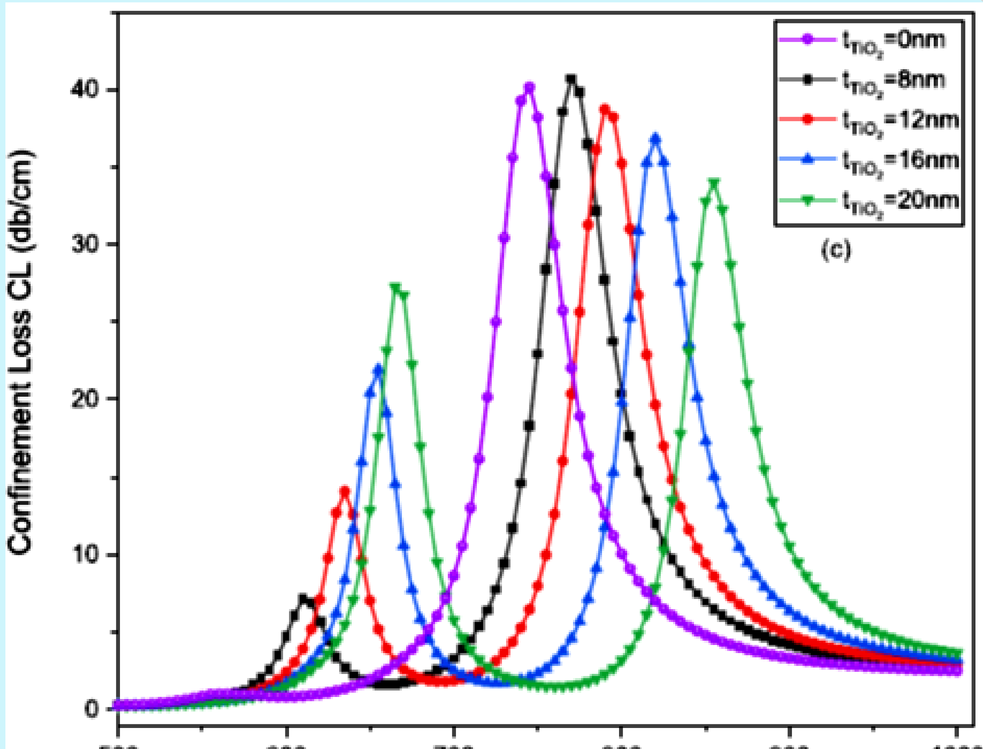
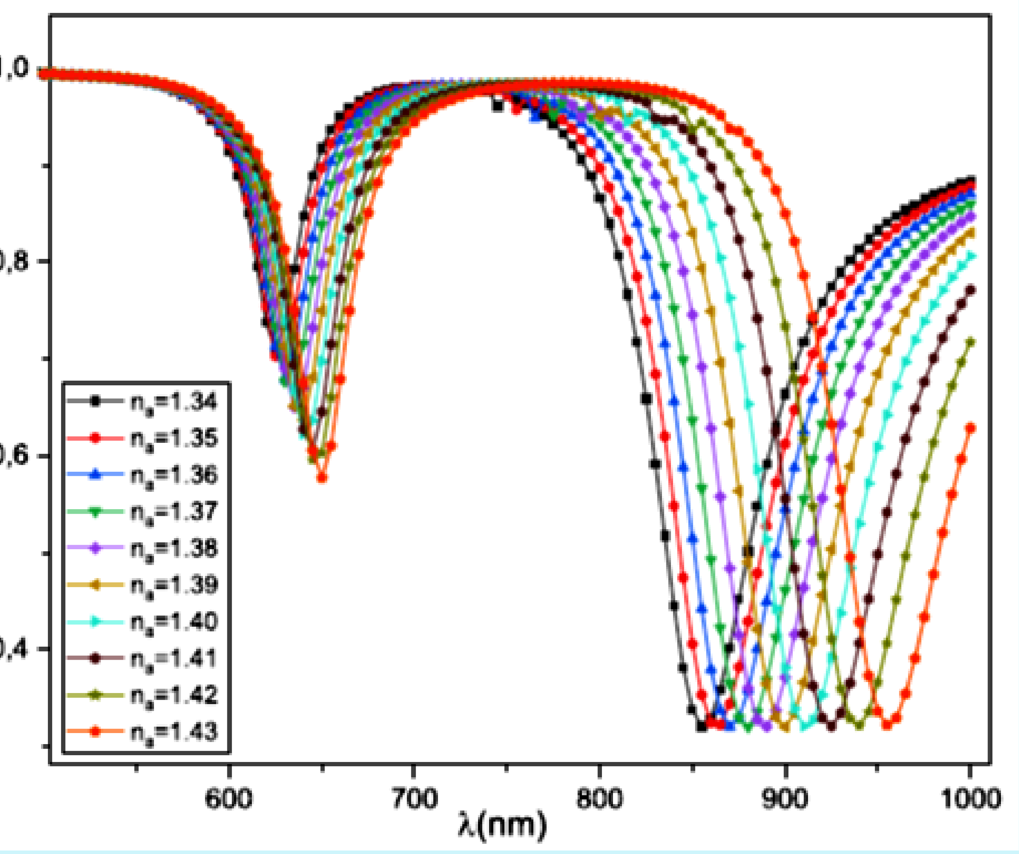
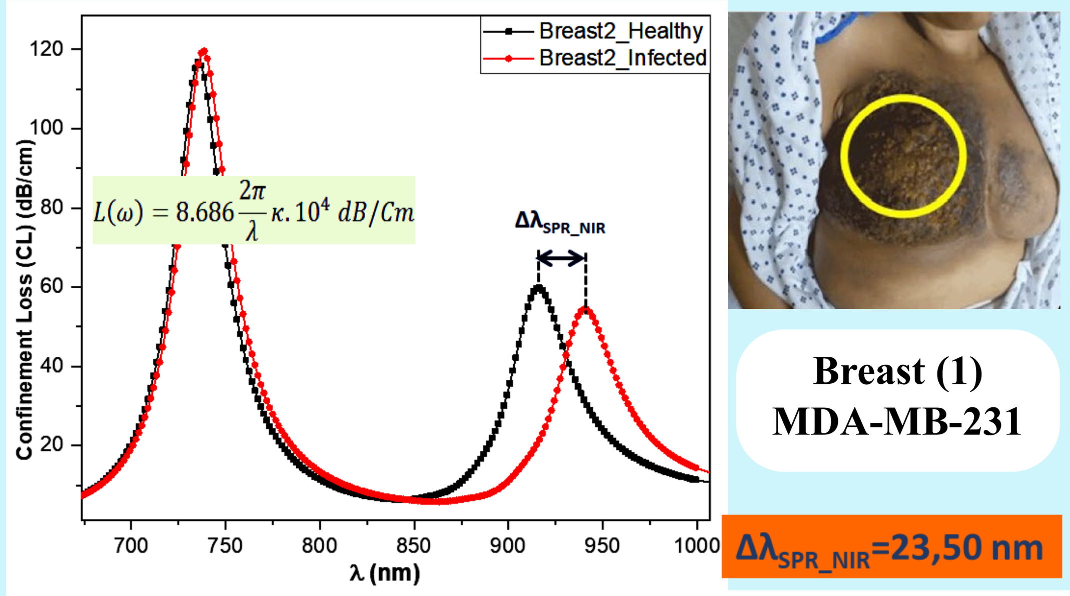


Fig. 2. Plot graph of Transmission spectra of the sensor versus λ for different TiO_2 layer thicknesses.

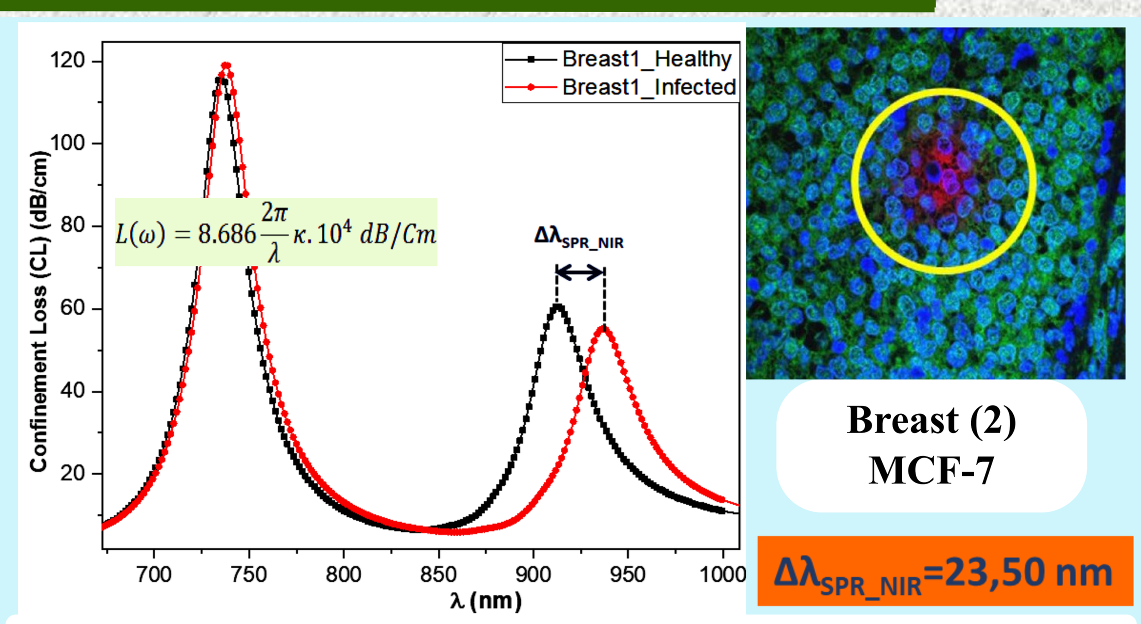


$$L(\omega) = 8.686\frac{2\pi}{\lambda}\kappa.10^4\ dB/Cm$$

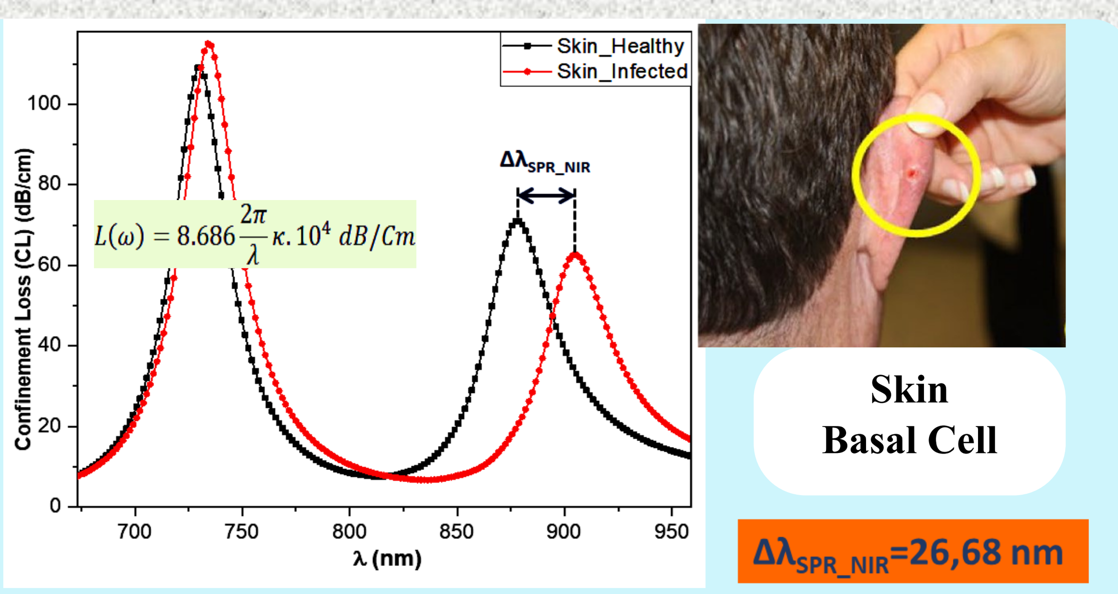
Fig. 2. Confinement Loss spectra of the sensor versus λ for different RI values of the analyte.



RI (Healthy Cell)=1.385 ; RI (Infected Cell)=1.399 ; Δn=0.014



RI (Healthy Cell)=1.387 ; RI (Infected Cell)=1.401 ; Δn=0.014



RI (Healthy Cell)=1.360 ; RI (Infected Cell)=1.380 ; Δn=0.020

Fig. 3. Confinement Loss spectra obtained by the sensor as a function of wavelength (λ) for various normal and cancerous cells with th_TiO2=30 nm and th_Au=80 nm.

CONCLUSION

$$R = \Delta n_a \times \frac{\Delta\lambda_{min}}{\Delta\lambda_{SPR}}[RIU]$$

In this proposed study, we numerically examined a D-shaped optical fiber sensor based on (SPR), using the (FEM). The sensor performance such as sensitivity (S), figure of merit (FOM), when compared to other sensors, our simplified structure using a D-shaped optical fiber coated with nanometric TiO2 layer proves to be more sensitive in measuring the RI of biological media. In particular, our proposed sensor shows better RI resolution of 4.96 x 10^{-6} [RIU] for Breast cells and 6.37 x 10^{-6} [RIU] for Skin basal cells.

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