Analysis of Adhesive Layer Material Influence on Transmission Characteristics of Plasmonic Based Biosensor with Nano-Hole Array

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***Abstract*— Noble metal thin films have good optical properties as is required for Surface Plasmon Resonance (SPR) biosensors. The use of such films is often limited by their poor adhesion to glass substrates. It makes them susceptible to critical mechanical damage, creating a barrier for use outside laboratory. An intermediate adhesive layer can solve this problem but will affect the biosensor's optical properties.**

Keywords-Surface Plasmon Resonance; NHA; EOT.

I. Introduction

Thin films of noble metals are well known for their good optical properties for biosensors. Among these noble thin films, gold films are suffered from poor adhesion to the oxide glass substrates. An intermediate adhesive layer can solve this problem such as Titanium and Tantalum, but it will affect the gold thin film biosensor optical performance. Among different type of sacrificial layer Aluminum (Al), Titanium (Ti), Tantalum (Ta), Chromium (Cr), and Tungsten (W) are the most promising candidates for gold based Extraordinary Optical Transmission (EOT) applications [1] [2].

II. Numerical Simulations

The Surface Plasmon Resonance (SPR) sensor is based on the interaction between light and metal nanoparticles. A number of numerical methods are used to solve Maxwell's equations; however, a Finite Difference Time Domain (FDTD) method has been widely applied to study the interaction of an electromagnetic wave and surrounding medium and objects. In this study, a plane wave of linearly polarized light along the Y-axis (λcenter = 575 nm with λspan = 350 nm) which propagates along the Z-axis, was used. The background environment was taken as water with a refractive index n=1.333. A periodic Nanohole Structure (NHA) with hole radius of 100nm, gold film thickness of 100 nm was considered in this study. The effect of five different metals were considered as an adhesive film with different thicknesses in the range of 2 nm to 25nm on optical performance of a NHA array as a biosensor. The calculation cell was considered as 400×400×1500 nm3, and the Periodic Boundary Condition (PBC) was used in the X- and Y-directions. Whilst the Anisotropic Perfect Matching Layer (APML) was used in the Z-direction as an absorbing boundary condition. The calculation grid resolution was as high as 1 to 3 nm in the calculation time was set as 200 fs. The transmission spectra were calculated using an X-Y monitor at 150 nm away from the gold NHA surface.

III. Results and Conclusion

After a series of numerical analysis by targeting different sacrificial layers and thicknesses, it was found that using chromium film has no effect on the transmission properties of the NHA structure, while using tungsten as a sacrificial layer resulted in 12% and 19% increases in the transmission intensity of the resonance peaks at the wavelengths of 624 nm and 762 nm, respectively. It was also found that by using tantalum and titanium sacrificial films an extra resonance pea was recorded at the wavelength of 720 nm with transmission of 18% which could be attributed to the surface plasmon resonance of the sacrificial layer. The sacrificial layer resonance wavelength of the NHA structure with titanium intermediate layer was recorded at the wavelength of 740 nm with transmission intensity of 27.5%.

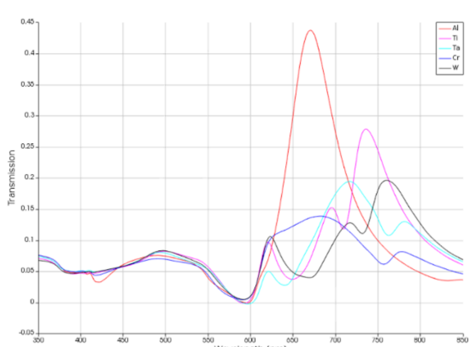
In conclusion, aluminum is a promising candidate as a sacrificial layer for NHA biosensors to achieve higher sensitivity and Figure of Merit (FOM). More analysis on the effects of using aluminum as an intermediate layer is underway and its results will be presented in due course.

References

[1] X. Fan et al., "Assembly of gold nanoparticles into aluminum nanobowl array", Scientific Reports, vol. 7, no. 1, 2017. Available: 10.1038/s41598-017-02552-z.

[2] J. Bhattarai, M. Maruf and K. Stine, "Plasmonic-Active Nanostructured Thin Films", Processes, vol. 8, no. 1, p. 115, 2020. Available: 10.3390/pr8010115.

(a)



(b)

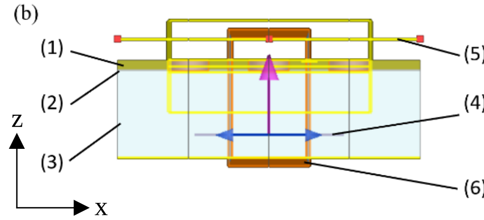


Figure 1. (a) Recorded transmission spectrum for various adhesive layer materials with the same geometrical properties. (b) Lumerical FDTD simulation, (1) NHA structure, (2) sacrificial layer (3) substrate, (4) light source, (5) T_monitor, (6) FDTD region