Senior Design
May - 2020

Surface Plasmon Resonance Based Sensor

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Abstract

Surface plasmon resonance (SPR) is an optical phenomenon that occurs at the interface between two materials of different conductivity. This effect is particularly useful in biochemistry and chemical safety applications because of its use in compact and precise sensors. This project aims to make use of the technology from another angle: education. Using low-cost, 3D-printed materials and widely available software like LabView and MATLAB, a prototype SPR-based sensor was created that can be used in high school and university-level biology and chemistry labs to enrich experiments, provide more accurate data collection, and introduce students to modern sensing techniques.

Introduction

Surface plasmons are the collective oscillation of electrons in a metal-dielectric interface. These are considered evanescent waves because they do not propagate in space. Rather, the emitted energy dissipates proportional to distance from the metal-dielectric interface. The behavior of these fields depends on the wavelength and direction of incoming light, which is partially reflected or absorbed in normal scenarios.

Resonance occurs when the magnitude of the evanescent wave vector produced by a source of optical excitation matches the magnitude of the plasmons' wave vector. When this occurs, the surface plasmons absorb nearly all the incident light energy. In this scenario, virtually no light is reflected at the interface.

The SPR conditions of an interface are material dependent; thus the SPR angle or wavelength of the incident beam can be used for material detection.

$$\theta_{SPR} = \sin^{-1}\left(\frac{1}{n_1}\sqrt{\frac{n_2{}^2 n_g{}^2}{n_2{}^2 + n_g{}^2}}\right)$$

Methods | Design | Analysis

The design of our physical device follows the Kretschmann configuration for surface plasmon resonance, consisting of a polarized light source, inverted triangular prism with thin gold deposited on the top surface, which carries the sample of analyte, and light sensor - a digital camera. The figure below illustrates the intended design, where the three main components (light source, gold-coated prism and sensor) can be seen on the left, middle and right side, respectively. The entire device is surrounded by a solid PLA light-blocking enclosure to prevent interference from external light sources.

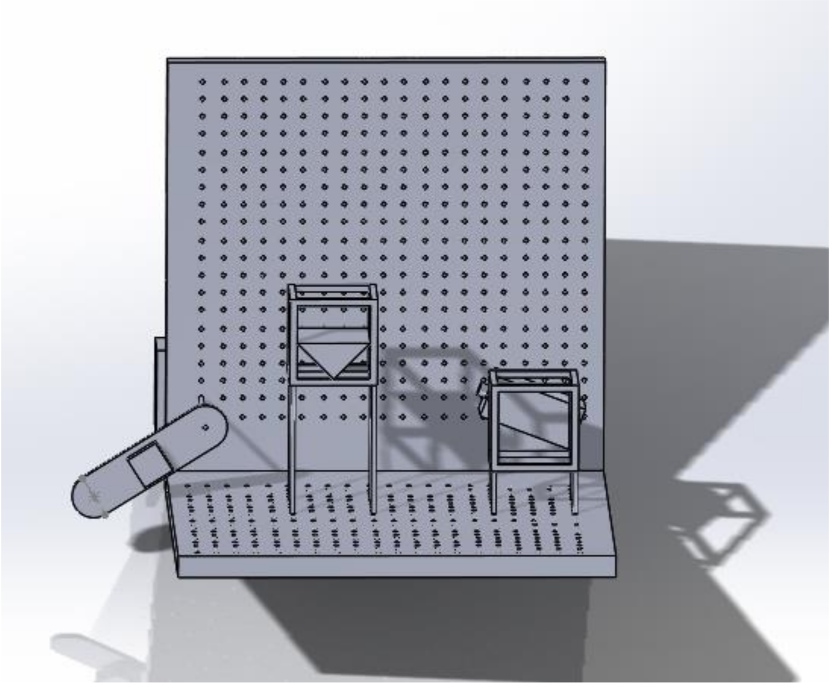

Figure 1. Front view of sensor assembly (cut to see interior)

To achieve surface plasmon resonance, which occurs only at a specific angle of the laser with respect to the prism, the light source is attached to an Arduino-controlled stepper motor. The Arduino is, in turn, controlled by a LabVIEW VI that also serves to keep track of the angle of the motor-arm assembly. The camera sensor receives the reflected light and sends its output to the same VI via the NI-IMAQ driver. The VI averages the numerical values for the color green of each RGB pixel of the received sensor data. A graph of incidence angle versus reflectance coefficient (or versus intensity of reflected light, such as the one shown in Figure 2, is then output to the screen.

Results

While the proposed design was not achieved, a demonstration of the underlying phenomenon of surface plasmon resonance was successfully performed and serves as a testament to the viability of a low-cost setup for the academic environment.

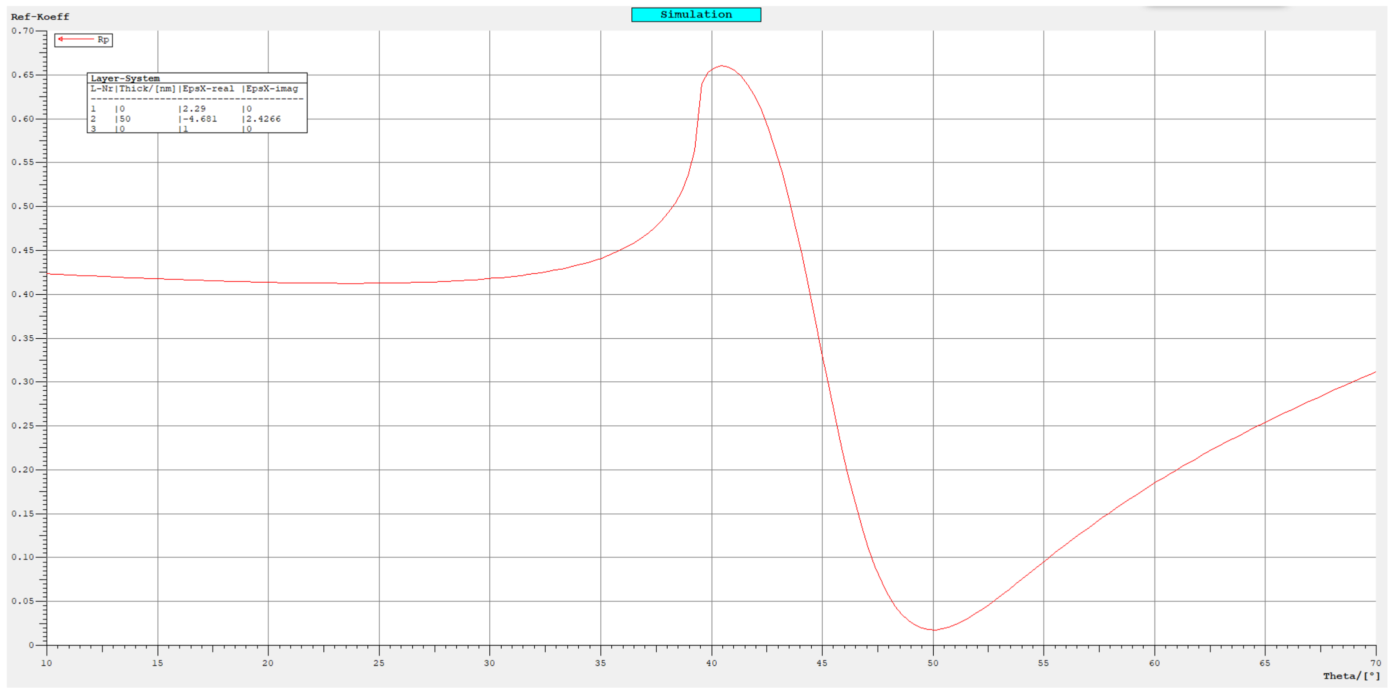

Figure 2. SPR Simulation Results

Conclusion

The simplicity of our final demonstration setup successfully illustrates that a sensor of this kind can be implemented easily and with a small budget. The crude prototype was capable of matching simulated responses closely. While a major tradeoff has been made between cost and breadth of possible analytes, the proposed design is sufficient for our intended purposes, namely classroom demonstrations.

Acknowledgments

We would like to thank Dr. Kim from the Electrical and Computer Engineering Department for his continued support throughout the design process, especially in the face of unforeseen circumstances and major procedural changes in the academic process.

References

Tang, Y., Zeng, X., & Liang, J. (2010). Surface Plasmon Resonance: An Introduction to a Surface Spectroscopy Technique. Journal of Chemical Education, 87(7), 742–746. doi: 10.1021/ed100186y