Tablet Analysis and Display of Semiconductor Biosensors

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Abstract and Introduction:

Photonic crystals using silicon-on-insulator (SOI) processes have applications as extremely sensitive biosensors. By taking advantage of the photonic bandgap (PBG), light can be guided through the photonic crystal (PC) using PC micro-cavities to block light and PC waveguides to allow light through. When light shines through the PC biosensor, depending on the design, the output spectrum will display distinct resonances. When a sample is pipetted on the PC biosensor and a wavelength shift is observed. This shift can be used to determine what is in the sample and what its concentration is. Previous work has shown that PC biosensors have the capability to reliably detect biomarkers related to various cancers and dangerous elements in extremely low concentrations.

The goal of this project is to develop software in MATLAB that quickly collects and analyzes spectrum data received from the biosensor. The software is also able to control a near-infrared SLED light source in order to perform repeated scans and analyses on data collected from an optical spectrum analyzer (OSA). This software will run on a tablet in order to explore the feasibility of a portable biosensing platform. Tests were performed on a biosensor using the 2A81G5 antibody as a probe in order to detect cadmium ions in solution. Current work is being done to refine the software suite developed, such as improving the accuracy of resonance detection and tracking. This will make data collection easier so the biosensor will be more practical to use.

Experimental Procedure:

To collect data from the PC biosensor the following tools were used: an OSA with USB connectivity, a near-infrared SLED source, and MATLAB software loaded onto a Surface Pro 2 tablet. MATLAB code was written to interface with the OSA and the SLED source. Further code was written to analyze the collected data and plot the results in a graphical user interface (Figure 1). The *findpeaks()* MATLAB function was used to find and initially plot all the local minima to approximate the location of multiple resonances (Figure 2). Next the *smooth()* function was used to smooth noisy spectrum data from the OSA using a moving average (Figure 3). Finally, *lorentzfit()* was used to fit a Lorentzian curve to the smoothed data using a least squares approximation, and *mins()* was used to find the final location of the resonance wavelength (Figure 2) [1]. All of this functionality was controlled using the MATLAB GUI. For the repeated scans of the biosensor the Surface Pro 2 was connected to the OSA and optical fibers were connected between the OSA, positioning stage, and the SLED. The biosensor was then placed and aligned on the positioning stage and a sample solution was pipetted onto the sensor. Next the user configured the SLED, OSA, and scan time using the GUI. A timer appeared while the scans were in progress, while the spectrum data and the detected minima were plotted and saved in real time. The user could stop the scans or reset the GUI using the onscreen buttons. The CSV files of the spectrum and minima data were saved in a folder for future analysis.
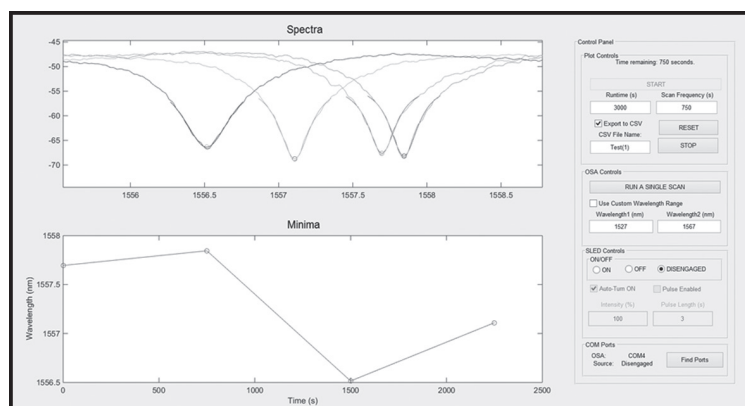

Figure 1: MATLAB GUI performing real time scans and tracking the chosen resonance's wavelength shift.

Results:

Tests were performed using samples such as DI-water, glycerol, glutaraldehyde, BSA with and without probe proteins, and cadmium-ion solution. The sensor preparation is described in Reference 2, Part C. Preliminary tests were done using an L13 comparing the wavelength shift between water and glycerol to calibrate the OSA and test the minimum detection software. Subsequent tests were also done using an L13 biosensor conditioned using established methods from the lab group's previous work [2]. The wavelength shift observed in the most successful (Figure
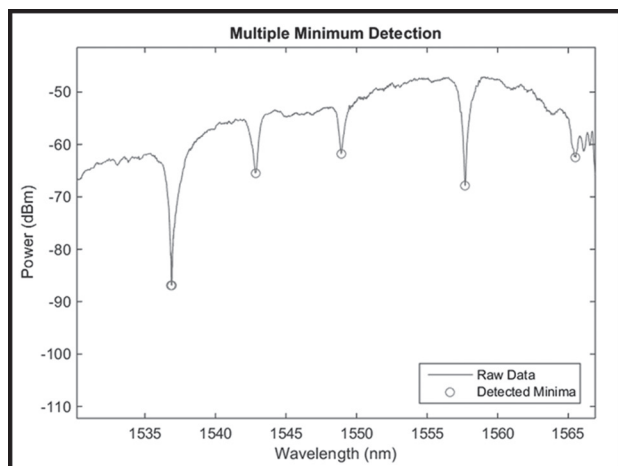
Figure 2: Example of multiple minima being detected by MATLAB.
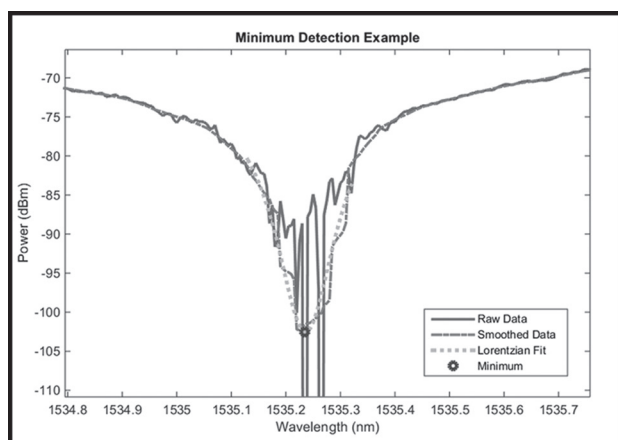

Figure 3: MATLAB smoothing raw data and fitting a Lorentzian curve to find a more accurate minimum.
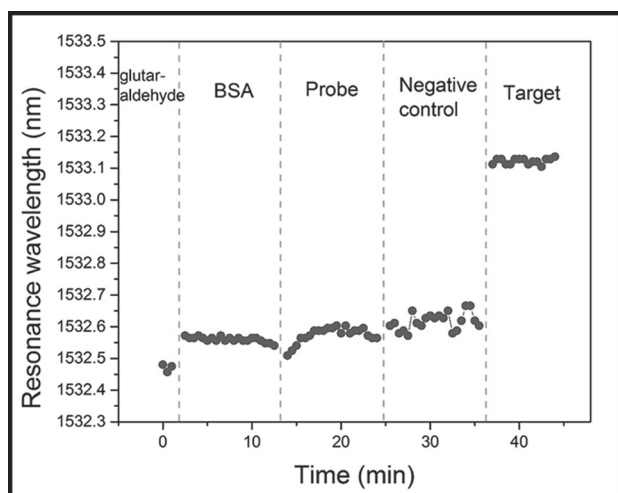

Figure 4: Data from an L13 biosensor during a repeated scan test where a resonance wavelength shift can be observed.

4) matches expected values of about a 0.5 nm wavelength shift for about 50 ppm cadmium-ions in solution.

Conclusions:

The software developed performs at a level equal to or better than manual analysis. Biosensor behavior is more easily characterized in response to different samples in solution. More work on this software will make PC biosensors more practical sensor for use in real-world applications. Future work includes automating sample placement over the sensor using microfluidics and specialized pumps [3]. The biosensors could potentially be used to detect many different materials with more complete characterization data. These advances will allow more widespread use of PC biosensors and more accurate detection of materials in solution.

Acknowledgements:

References:

[1] lorentzfit(x,y,varagin) by Jered Wells, MATLAB File Exchange, August 3, 2015.

[2] Zou, Y.; Chakravarty, S.; Chen, R.; et al.; "Waveguide Coupling Engineered High Sensitivity Silicon Photonic Crystal Microcavity Biosensors With High Yield"; IEEE Journal of Selected Topics in Quantum Electronics, 20, 4 (2014).

[3] Wang, Z.; Yan, H.; Chakravarty, S.; Chen, R.; et al.; "Microfluidic channels with ultralow-loss waveguide crossings for various chip-integrated photonic sensors"; OPTICS LETTERS, 40, Page 1563-1566 (2015).