Design of a Lightweight Multi-Analyte Detection System

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Introduction: The focus of this research is the development of a novel sensor system for the detection of biological compounds. This chemical sensor is based on the changes in the visible absorbance spectrum of an "indicator" molecule when it binds with the analyte(s) of interest. The "indicator" molecule to be used is meso-tetra (4-carboxyphenyl) porphine monethylene diamine coupled to Traut's reagent, also referred to as Traut's reagent porphyrin (TPPT). The detection system proposed minimizes weight, has no moving parts, is low cost, has a small power budget, and is portable. These characteristics allow for various uses such as detection of potentially harmful chemicals, precursors of life in space, or even as a teaching instrument.

Porphyrin: A porphyrin is a light-absorbing compound found in nature, examples of which are chlorophyll and the oxygen-binding moiety of hemoglobin.

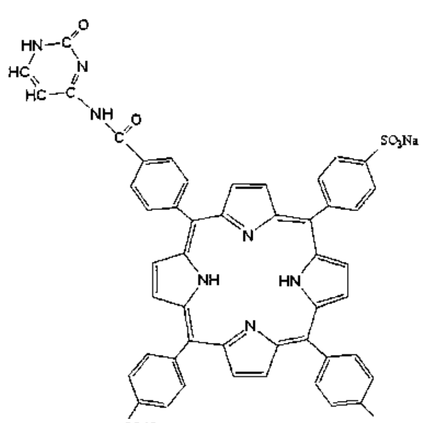

Figure 1 – Diagram of TPPT

As can be observed from the molecular diagram in Figure 1, TPPT consists of a complex ring structure with multiple pi electrons. It is highly sensitive to environmental factors such as pH, ion concentration, and metals. This sensitivity makes porphyrins desirable for use in the chemical sensor.

Experimental: For this detector, a 200 line per mm transmission grating (25mm x 35mm) is coated with a thin film of Traut's reagent porphyrin. This thin film absorbs certain wavelengths of light. In order to detect changes in spectra due to interaction with an analyte, the diffracted light from the grating is captured using a 640x480 pixel Logitech® Webcam Pro 3000 (30 grams).

White light from a 500W projector bulb is first focused using a rod lens, passed through a thin slit (1mm), and illuminates the grating. After the light strikes the grating, it was focused; neutral density filters were inserted to prevent the camera from being "blinded" by the intense light source.

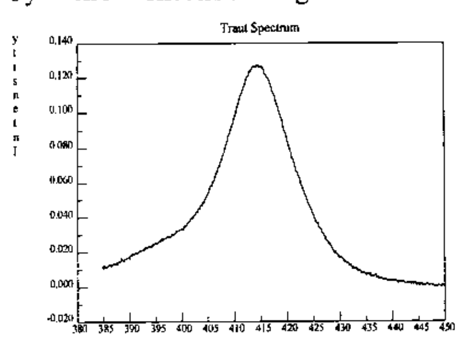

Figure 2 – Absorbance spectrum using spectrometer

Since the absorption peak of the Traut's reagent is 412 nm (cf. Fig. 2), a blue LED light source was used in order to focus on that particular wavelength range (approximately 400-500 nm). An image captured using the blue LED light source is shown in Figure 3.

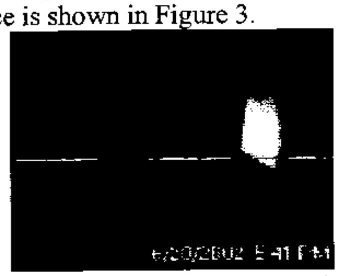

Figure 3 – Spectrum captured by webcam

In order to obtain usable data from the visual spectrum captured, the image was processed using the CorelDRAW 10 Graphics Suite®. By measuring RGB values of the pixels horizontally across the band, a graph of the spectrums of a clear grating and porphyrin-coated grating shown in Figure 4 is obtained.

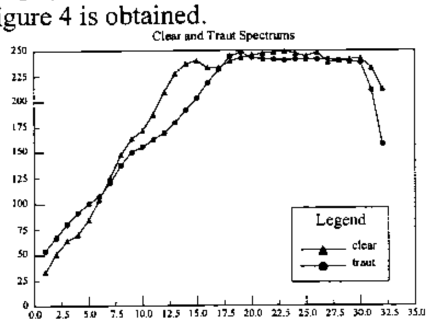

Figure 4 – Clear and Traut spectrums obtained using experimental setup

From the subtraction of the intensities of the pixels of the clear and porphyrin-coated grating, a difference spectrum can be determined as illustrated by the graph shown in Fig. 5.

Calibration of the setup can be performed by comparison of a data set of the clear grating with and without a holmium oxide filter present (data not shown) to a published spectrum. The spectra are aligned allowing for assignment of a λ to a pixel.

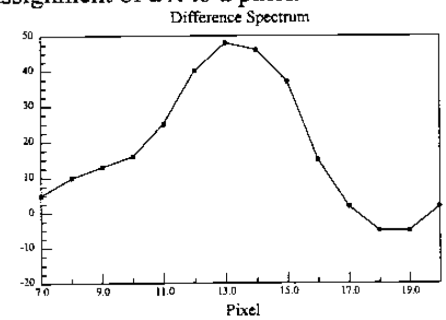

Figure 5 – Difference spectrum using experimental setup

Discussion: The ultimate goal is the design of a portable, lightweight sensor that will be effective in detecting specific biological compounds. The device will be exposed to a sample in any phase. When the analyte binds with the porphyrin, the porphyrin-analyte complex may exhibit a different absorbance spectrum from that of the porphyrin. By measuring the intensity of transmitted light versus wavelength, a spectrum can be measured. Logic operations can then be programmed into the device to determine if the obtained spectrum can be matched with spectra stored in memory. Finally, if the algorithm returns true, the device will indicate that a certain analyte has been detected by outputting to an LED or possibly a LCD.

The detection system presented has shown to be sensitive enough to obtain an absorption spectrum when porphyrin is applied as a thin film on the grating. It also can be calibrated. Current work includes developing C++ code for the robust processing of the image and future work includes increasing the device's portability and sensitivity, as well as further reduction of its size.