Miniature Optical Sensors for Detection of Water and Air Contaminations

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ABSTRACT—During the past years, several complex, bulky, and expensive spectroscopic instruments have been replaced by portable systems based on solid-state components. This project developed multi-band LED chips and solid-state photodetectors integrated into a miniature portable system capable of detection and quantification of a large variety of effluents in a gas, liquid, or solid form.

Fluorescence intensity measurements are now utilized in hand-held compact sensors for detection of important compounds in various applications. However, the detection and quantification capabilities of these devices are still much lower than those of laboratory-based measurement systems. Any effluent that interacts with light in the range from near ultraviolet to near infrared in the form of at least one of the following phenomena — optical absorption, reflection, scattering, luminescence, or fluorescence — can be potentially identified and characterized by the system. System operation and signal acquisition rely upon the latest state-of-the-art developments in signal coding and electronic circuit design and allow measurements with an accuracy of few ppm.

Identification and characterization of various compounds is based on the employment of artificial neural network architecture, built upon the principles of a human brain. The inherent spectral selectivity results in unique spectroscopic signal patterns from each tested effluent. These patterns are used to train the neural network first, in order to provide for their future identification by the system.

Goal

The goal of this current project is to further improve the performance of the portable system, based on light intensity, by the introduction of fluorescence lifetime (temporal) measurements, which are extremely sensitive to the specific compound signatures.

Results

Preliminary results have shown higher than 70% accuracy achieved in detecting *E. coli* bacteria without any knowledge of the tested environment. Under similar conditions, accuracies from important organic effluents exceeded 90%, and soared to 98-100% when data on the environment were fed into the neural network. The rapid development of semiconductor technology has enabled the solid-state components to satisfy critical requirements for lifetime measurements. Our first-of-a-kind portable lifetime measurement system utilizes LEDs as excitation sources and fast photodiode or reverse-biased LEDs as photodetectors.

This system can be tailored for specific applications as well as for universal use. The III nitride based components used in the sensor design allow for its operation in normal and super-ambient environments related to the following applications: detection and characterization of crude oil, oil in seawater, environmental pollution, bio-chemical hazards in military and industrial process control and monitoring, health monitoring in the biomedical field, identification and characterization of the variables in space applications, and the quality assurance of drugs in the pharmaceutical industry.

A new high-sensitivity intelligent lifetime based prototype is currently under development in collaboration with the Bio-Processing Laboratory at the University of Quebec at Montreal (UQAM). This project is supported by current US Air Force Phase II SBIR contract on the development of advanced fire/flame detectors.

Publications

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