

## Advanced Biophotonics Sensors for Environmental and Medical Applications

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The field of biomedical photonics has recently experienced an explosive growth due to the non-invasive or minimally invasive nature and the cost-effectiveness of biophotonic modalities in environmental sensing, medical diagnostics and therapy. This lecture discusses the development and application of advanced biomedical photonics, molecular spectroscopy, biosensors and biochips for environmental and biomedical diagnostics.

The first research area involves the development of metallic nanoprobe that can produce the surface-enhanced Raman scattering (SERS) effect for ultrasensitive biochemical analysis. The intensity of the normally weak Raman scattering process is increased by factors as large as  $10^6$ - $10^{13}$  for compounds adsorbed onto a SERS substrate, allowing for trace-level detection. Our nanoparticle-based SERS technology has enabled sensitive detection of a variety of compounds of environmental and medical interest. The SERS nanoprobe technology has also been incorporated in several fiberoptic probe designs for remote analysis. The development of a SERS gene probe technology based on the solid surface-based technology has also been reported. In one study, the selective detection of HIV and cancer gene was demonstrated.

An important area in chemical and biological sensing is the sensitive detection and selective identification of toxic chemical compounds (carcinogens, pollutants, etc.) or living systems (bioaerosols, bacteria, viruses or related components) at ultra-trace levels in complex samples. Combining the exquisite specificity of biological recognition probes and the excellent sensitivity of laser-based optical detection, biosensors are capable of detecting and differentiating bio/chemical constituents of complex systems in order to provide unambiguous identification and accurate quantitation, and open new horizons for chemical and biological sensing.

Recently, we have developed a novel integrated *Multi-functional Biochip* (MFB) which allows simultaneous detection of several disease end-points using different bioreceptors such as DNA, antibodies, enzymes, cellular probes) on a single biochip system. An important element in the development of the MFB involves the design and development of an integrated circuit (IC) electro-optic system for the microchip detection elements using the complementary metal oxide silicon (CMOS) technology. The biochip has recently been developed to detect the gene fragments of Tuberculosis and the HIV gene system as well as the *p53* and *FHIT* proteins. The biochip could be used to diagnose genetic susceptibility and diseases, or to monitor exposure to biological pathogens and to bioactive environmental samples.

For *in vivo* medical diagnostics, the optical diagnostic procedure based on laser-induced fluorescence (LIF) was developed for direct *in-vivo* cancer diagnosis without requiring biopsy. LIF measurements were conducted during routine gastrointestinal endoscopy examinations of patients. The fiberoptic probe was inserted into the biopsy channel of an endoscope and lightly touched the surface of the tissue being monitored. The system was programmed to measure the fluorescence of the target tissue for each laser pulse. The LIF measurement was completed in approximately 0.6 second for each tissue site. The results of this LIF approach were compared with histopathology results of the biopsy samples and indicated excellent agreement (98%) in the classification of normal tissue and malignant tumors of gastro-intestinal cancer in clinical studies involving over 100 patients.

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