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Molecular nanoprobes and nanosensors: A new generation of biosensing nanoplatforms for toxicological and biomedical monitoring

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This lecture provides an overview of recent developments in our laboratory for several plasmonic nanoplatforms and biosensing technologies that allow sensing of nucleic acid biomarkers (e.g., mRNAs and miRNAs) for toxicology research and biomedical diagnostics. MicroRNAs (miRNAs) have been implicated in post-transcriptional regulation of many gene expressions and control of different processes such as apoptosis, DNA repair, oxidative stress response, cancer and cellular development. In recent years, miRNAs have attracted great interest in the field of toxicology. When organisms are exposed to toxic species, miRNA expressions are altered, thus affecting mRNA transcription and protein translation and leading to adverse biological effects. Discoveries in miRNAs research have opened new insights in toxicology. We will discuss the development of a new generation of nanotechnology-based biosensing systems designed to detect miRNA biomarkers. The technologies involve interactions of laser radiation with metallic nanoparticles, inducing very strong enhancement of the electromagnetic field on the surface of the nanoparticles. These processes, often called 'plasmonic enhancements', produce the surface-enhanced Raman scattering (SERS) effect that could enhance the Raman signal of molecules on these nanoparticles more than a million fold. The SERS-based nanoprobe technologies, referred to as 'Molecular Sentinel' nanoprobes, use a label-free sensing modality for detecting miRNAs. In the field of biosensing of individual cells, a unique advance has been the development of optical nanosensors, which have dimensions in the nanometer (nm) size scale. Using lasers as excitation sources for these nanosensors, it has become possible to probe physiological parameters (e.g., pH), toxicants (e.g., carcinogens), exposure biomarkers (e.g., DNA adducts) and monitor molecular pathways (e.g., apoptosis) in a single living cell for toxicological research and assessment. These nanosensors lead to a new generation of nanophotonic tools that can detect the earliest signs of chemical exposure and health effect at the single-cell level and have the potential to drastically change our fundamental understanding of the life process itself. Examples of using these sensing tools for disease detection and toxicology research will be discussed. Spectrochemical detection using plasmonic nanomaterials and nanobiosensing technologies are definitely bringing a bright future to toxicological and medical research and could ultimately lead to the development of new modalities of environmental exposure sensing, early diagnostics, drug discovery and toxicological monitoring.

Biography

Tuan Vo Dinh is R Eugene and Susie E Goodson Distinguished Professor of Biomedical Engineering, Professor of Chemistry, and Director of the Fitzpatrick Institute for Photonics at Duke University. After completing High School in Vietnam, he pursued his education in Europe where he received a BS in Physics in 1970 from EPFL (Swiss Federal Institute of Technology) in Lausanne, Switzerland, and a PhD in Physical Chemistry in 1975 from ETH (Swiss Federal Institute of Technology) in Zurich, Switzerland. Before joining Duke University in 2006, he was Director of the Center for Advanced Biomedical Photonics, Group Leader of Advanced Biomedical Science and Technology Group, and a Corporate Fellow at Oak Ridge National Laboratory (ORNL). His research has focused on the development of advanced technologies for the protection of the environment and the improvement of human health. His research activities involve nanophotonics, biophotonics, nano-biosensors, biochips, molecular spectroscopy, bioimaging for medical diagnostics and therapy (nano-theranostics), toxicology research, personalized medicine and global health. He has received seven R&D 100 Awards for Most Technologically Significant Advance in Research and Development for his pioneering research and inventions of innovative technologies. He has received the Gold Medal Award, Society for Applied Spectroscopy (1988), and so on. He has authored over 400 publications in peer-reviewed scientific journals. He holds over 37 US and international patents, five of which have been licensed to private companies for commercial development.

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