Conducting Oxide Nanorod Arrays and Their Extraordinary Optical Properties for Sensing Applications

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BIOGRAPHY

R.P.H. (Bob) Chang is a recognized innovator in materials research, interdisciplinary science education, and international networking. Chang earned his B.S. in Physics and a Ph.D. in Astrophysics at MIT and Princeton respectively. He spent 15 years performing basic research at Bell Labs (Murray Hill). He was one of the pioneers who helped in the development of low temperature plasma processing for the microelectronics industry.

During his tenure at Northwestern University, he headed the NSF-funded Materials Research Center for fourteen years during which time he provided a new vision for the center and launched new interdisciplinary research initiatives. His current research interests include nanostructured materials, nanophotonics, and advanced solar cell development. He has graduated over 35 Ph.D. students, and trained over 25 postdocs. He teaches his students to take system's approach to designing new materials and new processes in order to advance new device development. An example is the next generation of all solid state flexible solar cell with high efficiency and low production cost. Chang is a Fellow of the American Vacuum Society and the Materials Research Society.

TECHNICAL ABSTRACT

Transparent conducting oxides (TCOs), in general, are degenerated semiconductors with wide electronic band-gap. The combination of these two features makes them transparent at visible spectrum while still conductive as metals. Thus, they are found in the applications like optoelectronics, photonics, and photovoltaics. However, applying them to infrared sensors is a sparsely exploited research area. With the breakthrough of nanofabrications, nanostructures of TCOs are synthesized. It is then possible for people to create high crystal quality TCO nano-size building blocks and assemble them to designed infrastructures to control light at subwavelength regime and focus it to desired positions.

Comparing to silver and gold, which are the materials under intensive studies for their application at nano-photonics, the electron density of TCOs is typically one order of magnitude lower. Therefore, while silver and gold are the materials for nano-photonics in visible light spectrum, TCOs are for infrared regime. In addition, most TCOs have the advantage that the inter-band transition occurs at high frequencies (ultraviolet regime) due to their large band-gap while their phonon modes are at very low frequencies (far-infrared regime).

In this report, the recent development on the synthesis, patterning, and characterization of physical properties of the ITO-nanorod(NR) arrays will be presented. A classical scattering model, along with a 3-D finite-element-method and a 3-D finite-difference-time-domain numerical simulation method has been used to interpret the unique light scattering phenomena. It is also shown that the intrinsic plasma frequency can be varied through careful post-synthesis processing of the ITO NRs. Examples are given on how coupled plasmon resonances can be tuned through patterning of the ITO NR arrays. In addition, environment dielectric sensing has been demonstrated through the shift of the resonances as a result of index change surrounding the NRs. These initial results suggest potential for further improvement and opportunities to develop a good understanding of infrared plasmonics using ITO and other transparent conducting oxide semiconducting materials.

Keywords: Plasmonics, ITO Nanorods, Degenerated Semiconductors, Infrared Spectroscopy, Infrared Sensors

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