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TOPIC:

Nanoengineered Sensors and Actuators

ABSTRACT:

Since the late 1990s till date, research on nanoscale systems has progressed leaps and bounds with the synthesis of new materials and the unraveling of hitherto unexplained phenomena at such small length scales. Engineering such systems has always been of extreme interest to the scientific community with most implementations of nanotechnology targeted towards development of novel sensing and actuation schemes. With that in mind, we shall explore the usage of some important nanostructures, namely nanotubes and nanowires for sensor and actuator applications.

We begin with a field-effect transistor (FET) based humidity sensor with a twist: the FET channel has been realized by deoxyribonucleic acid functionalized carbon nanotube (DFC) network. Variation in channel conductance forms the backbone of the sensing mechanism with exponential dependence on ambient relative humidity ensuring extreme sensitivity. It can be shown that the device is highly selective to atmospheric relative humidity, exhibiting inert behaviour to common ambient components and fast response and recovery times. The lack of any significant baseline shifts implies that sensor response is solely due to a charge transfer mechanism from water molecules to the nanotubes. Temperature behaviour of the sensor indicates enhancement in device sensitivity performance at higher temperatures. Such sensors can prove to be highly efficient and low cost in comparison to traditional sensing schemes.

We synthesized the ZnO nanostructure for biological applications. ZnO nanostructure was synthesized by solution processed for easy fabrication. The morphological and structural characterizations of ZnO nanostructure, especially nanosphere were carried out by Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM) and X-Ray diffraction (XRD). Circular Dichroism (CD) spectroscopy was performed to investigate the chemical interaction between the biomolecules and Zinc Oxide nanosphere. Optical detection was performed using Absorbance and Fourier transform infrared spectroscopy (FTIR) studies. We employed a comparative study between optical and electrical detection scheme. As optical detection scheme has some limitation, we demonstrate an electrical detection technique using solution processed Zinc Oxide nanostructure for ultra-low level detection of bio-molecule like BSA protein. The device works on the basis of the variation of conductance of the ZnO nanostructure

with different concentration of biomolecules. Detection of BSA was carried by electrical detection technique. The device exhibits sensitivity 0.126 nA/pM, lower limit of detection (LOD) 10 pM and the fast response time around 5 sec, confirming the highest sensitivity for BSA detection achieved so far. Sensing mechanism is governed on the basis of the charge transfer phenomenon between BSA and ZnO. All measurements were carried out at 1V bias for low power operation.

We go on to explore the utility of MnO₂ nanowires in the reaction chamber implementation of liquid monopropellant H₂O₂ microthrusters. It is observed that such nanowires serve to catalyze H₂O₂ oxidation reactions exothermically, traditionally occurring in heated reaction chamber beds, of the thruster resulting in the decrease in dependence on electrical energy to drive such systems and a drastic reduction in power consumption. Thrust measurements show significant specific impulse values characteristic of extremely efficient devices. The possibility of low cost realization of propulsion MEMS opens up avenues for energy efficient actuators as well as chemical energy harvesting devices whose energy conversion capabilities can be harnessed for driving strategic microscale propulsion systems for nanosatellite.

¹DNA functionalized carbon nanotube network as humidity sensors, IEEE Sensors Journal, vol. 13 (2), 2013

²Synthesis of ZnO Nanosphere for Picomolar Level Detection of Bovine Serum Albumin , IEEE NanoBio early version available, 2014

³MnO₂ nanowire embedded hydrogen peroxide monopropellant MEMS thrust, IEEE/ASME Journal of Microelectromechanical Systems, vol. 22 (5), 2013

PROFILE:

Tarun K. Bhattacharyya obtained his B.Sc. (Hons.) in Physics and B.Tech in Radio-Physics and Electronics in 1984 and 1987 respectively, from University of Calcutta. He obtained his M.E. and Ph.D. degrees in Electronics and Telecommunication Engineering from Jadavpur University, Kolkata in 1991 and 1996 respectively. He has served as a scientist in areas of thin film technology and micro-electronics in reputed laboratories like Indian Association for Cultivation of Science, Central Glass and Ceramic research Institute, Kolkata and University of Kaiserslautern, Germany.

He has been a visiting faculty in University of Washington and University of Michigan. He joined Electronics and Electrical Communication Engineering department, Indian Institute of Technology and is currently Professor and also the professor-in-charge of the Advanced VLSI Laboratory and the National MEMS Design Centre of IIT Kharagpur. His current research interests include low power RF IC design, MEMS and nano-electronics. He was a recipient of the UNIDO (Vienna) fellowship in 1992. He served as a technical committee member of VLSI Design Conference in 2007 and is the RFIC track chair for VLSI Design Conference 2013. He is also a technical program committee member of the IEEE SENSORS 2013. He is a member of Indo-Japan collaborative committee on Advanced Micro-Nano Manufacturing Science.

He is also a member of Indo-US Frontiers of Engineers. He has been awarded IBM faculty award for the year 2012. He has published more than 150 publications in reputed international journals and IEEE conferences.