Abstract

Sensors are extensively used in a wide range of technologies due to their front-end applicability in portable electronic devices, biomedical imaging, night-vision, optical communication, environmental monitoring, gas sensing, defence and the space industry. The expanding range of application has made it essential to develop high-performance materials and sensing platforms. The focus of this work is to develop highly efficient electronic devices for sensitive, selective and fast detection of Ultra-violet and Gram-positive bacteria, which comprises of superior device design, materials engineering, and standard micro-fabrication. A range of active sensing nanostructured semiconductors such as Metal-oxides (WO_3, TiO_2, In_2O_3), Metalloprotein (Azurin), TMCs (MoS_2) are employed on silicon based platform for the scalable and robust device development process. The novel approaches and techniques are developed to diminish various device performance-related issues.

In this Dissertation, a new class of metal-oxide based photodetector is developed using conventional CMOS fabrication process by employing fabrication of the multiple WO_3 nanowires for ultra-violet detection. High conductivity of the nanowires is observed upon irradiation which is highly sensitive to ultra-violet light. This photodetector exhibits a photo to the dark current ratio of the order of 4 with a significant relative change in conductance around 8100 upon 340 nm illumination at 0.87 $mW.cm^{-2}$. The photodetector exhibits high responsivity of 47.3 $A.W^{-1}$ and magnificent rejection ratio (340 nm to 450 nm) of ~8800 with excellent stability. The WO_3 nanowires-based photodetector exhibits fast transient response with rise time (t_r) of 112 µs and fall time (t_f) of 84 µs. These promising results demonstrate the applicability of the WO_3 nanowires based photodetector in high-speed ultra-violet detection. In order to enhance the performance, heterostructure of the different stacked nanostructured semiconductor can be advantageous by transporting the charge carrier with high-efficiency at the heterojunction interfaces. Further, the development of high performance metal-semiconductor-metal ultraviolet photodetector based on In_2O_3/TiO_2 heterostructure is presented. The energy levels of TiO_2 exactly match with In_2O_3 and electron transfer is facilitated from In_2O_3 to TiO_2, which improves the electron-hole dissociation efficiency. The In_2O_3/TiO_2 heterostructure photodetector achieves a significant responsivity of 799.5 $A.W^{-1}$ and gain of 3541.8 under 280 nm wavelength of illumination with rejection-ratio of 103.1 at 2 V bias, which is eight times higher than the In_2O_3 Photodetector. For the In_2O_3/TiO_2

photodetector, NEP and Detectivity at 0.1 V are 5.5 x 10^{-12} W.$Hz^{-1/2}$ and 1.1 x 10^{12} Jones, respectively. Hybrid semiconductor nanostructures have attracted tremendous response due to their unique properties and applications in nano-optoelectronics and sensors. In this series, the development of a back-gated transistor based on 300 nm channel of the Azurin/TiO_2 hybrid nanostructure is presented. The high responsivity of 8.7x10^5 A.W^{-1} is achieved, which is much improved than the earlier reported hybrid photodetectors. The short carrier transit time and considerable recombination time with multiple recirculation of photogenerated carriers facilitate the high gain of 2.6x10^6. The enhanced performance is attributed to the synergetic effect of the metal oxide heterojunction with Azurin. This work provides an insight into an Azurin/TiO_2 bio-hybrid nanostructure, which can be multitudinously harnessed in bioelectronics systems.

Field-effect transistor (FET) biosensors based on hybrid nanostructures present unique advantages of high sensitivity, small size, excellent dynamic range and compatibility with integrated circuits. In the next part of the metal-oxide sensor application, the fabrication of highly sensitive and selective hybrid TiO_2/MoS_2 nanostructure-based FET for the detection of Gram-positive bacteria is demonstrated. The fabricated FET biosensors are efficiently capable of discriminating between Gram-positive and Gram-negative bacteria with a limit of detection of 50 cfu.mL^{-1}. The biosensor exhibits a high sensitivity of 49.5 ± 1.7 % for *S. aureus* among eight different bacteria at a concentration of 10^2 cfu.mL^{-1}. The FET biosensor possesses a wide dynamic range (50-10^6 cfu.mL^{-1}) and the lowest limit of detection (50 cfu.mL^{-1}) for *S. aureus*. The real-time detection of bacteria with a response time of 22.19 s is achieved at concentrations as low as 50-100 cfu.mL^{-1}, suggesting rapid and low concentration detection of selective bacteria. The FET biosensor is also able to quantify bacteria in the physiological conditions as well as discriminate between live and dead bacteria. The unique hybrid nanostructure-based FET with desirable bio-sensing properties presents the potential to screen the pathogenic bacteria. Live/dead monitoring of bacteria may help in deciding the course and dosage of the antibiotic treatment.