Abstract

Recently, the fields of energy conversion and storage have drawn great interests in the research community due to the wide range of practical applications in the society. Among them, photodetector (PD) and supercapacitor (SC) have attracted potential imprints for energy conversion and storage applications. This thesis is thus focused on the fabrication of efficient self-powered ultraviolet (UV) PD and SC based on optically and electrochemically active heterostructure materials.

Firstly, self-powered UV PD is explored based on one dimensional zinc oxide (ZnO) nanorods (NRs). The charge carrier density of ZnO NRs was modified by doping of halogen elements to enhance the self-powered photo response. Interestingly, 5.5 times enhancement in the photo response of halogen doped ZnO NRs was noticed as compared to pristine ZnO NRs. Further charge carrier modification of ZnO NRs was performed *via* hydrogenation process of ZnO NRs. Efficient increase in the carrier density of hydrogenated ZnO (H: ZnO) NRs allows enhancing the photo response to nearly 900% and 82% as compared to pristine ZnO NRs and halogen doped ZnO NRs, respectively. The optically as well as electrochemically active heterostructure was then introduced by integrating zinc cobalt oxide ($ZnCo_2O_4$) with H: ZnO NRs to form $ZnCo_2O_4$/H: ZnO NRs for the applications of UV PD and SC. Further enhancement of 75% in the photo response of $ZnCo_2O_4$/H: ZnO NRs was obtained as compared to H: ZnO NRs in self-powered configuration. The photo response behaviour of the $ZnCo_2O_4$/H: ZnO NRs PD was investigated under different UV illumination intensities in absence of external bias voltage. A power law dependence of the response of the PD on UV illumination intensity was displayed. Moreover, faster photon detection speed in the order of few milliseconds was also achieved for the self-powered PD. Furthermore, efficient UV detection efficiency for the PD was obtained.

The electrochemical performance of the $ZnCo_2O_4$/H: ZnO NRs was then investigated in detail. Efficient energy storage performance of $ZnCo_2O_4$/H: ZnO NRs was obtained where 63% enhancement in energy storage performance of $ZnCo_2O_4$/H: ZnO NRs electrode was observed as compared to $ZnCo_2O_4$ alone. For the investigation of energy storage performance of $ZnCo_2O_4$/H: ZnO NRs in presence of UV illumination, a solid-state symmetric SC (SSC) was fabricated composed of $ZnCo_2O_4$/H: ZnO NRs electrodes. The energy storage performance of the SSC was analysed both in the absence and the presence of UV illumination. An appreciable, 2.7 times enhancement in specific capacitance of the SSC was noticed under UV illumination as compared to the absence of UV. It was found that with the increase in UV illumination intensity, the electrochemical performance of the SSC increases linearly. The capacitance stability of the SSC was further studied for 4000 cycles both in the presence and the absence of UV. Notably, only 2% degradation of the capacitive response of the SSC was noticed under UV illumination as compared to absence of UV. Moreover, 175% enhancement in energy density of the SSC was obtained in presence of UV.

To expand the working voltage of the SSC, an asymmetric solid-state SC (ASC) was fabricated composed of $ZnCo_2O_4$/H: ZnO NRs as positive electrode and activated carbon (AC) as negative electrode. The working voltage of the ASC is increased from 0.6 to 1.5 V, thus providing an increase in overall energy storage performance of the ASC as compared to SSC. The charge storage mechanism of the ASC was discussed in detail. For the direct practical implementation of the ASC, a PD was fabricated based on $ZnCo_2O_4$/H: ZnO NRs as photosensitive material and connected in series configuration with the ASC. As-fabricated ASC can easily offer desired power to the $ZnCo_2O_4$/H: ZnO NRs PD during the conversion of optical

to electrical signal. Increase in the photo response of the PD was observed in presence of UV illumination.

For further expansion of the working voltage of ASC, three ASCs were connected internally in series to form solid-state asymmetric tandem SC (ATSC). The electrochemical response of the ATSC electrodes composed of hybrid reduced graphene oxide (rGO)-carbon nanotubes (CNTs)-ZnCo2O4 (rGO-CNTs-ZnCo2O4) as positive and rGO-CNTs-iron (III) oxide (rGO-CNTs-Fe2O3) negative electrodes were performed systematically. The efficient energy storage performance of the ATSC is due to the synergistic contribution of each of individual nanomaterials in the hybrid electrodes. The working voltage of the ATSC was measured to be 4.5 V which is three times larger than ASC. As a result, a significant increase in energy density (61%) and power density (33%) was noticed as compared to ASC. Moreover, the electrochemical measurement of the ATSC was also studied at different mechanical bending deformation angles ranging from 0 to 60o at a working voltage of 4.5 V. Interestingly, no significant deviation in electrochemical response was observed under the mechanical deformations of the ATSC. In addition, the energy storage performance of the ATSC was measured at different working voltage ranging from 1.5 to 4.5 V. With increase in the working voltage, the energy storage performances (energy density and power density) of the ATSC increase following a linear function. In addition, for the direct practical application, ZnCo2O4/H: ZnO NRs PD was driven by the ATSC used as a power source for the detection of UV light.