Development of Polymer Nanocomposite based Photovoltaic Devices with Improved Efficiency

ABSTRACT

The present thesis deals with the synthesis and characterization of various aspect ratio zinc oxide (ZnO) and gold (Au) nanorods and finally their application in the field of solid state bulk heterojunction (BHJ) and quasi solid state dye-sensitized solar cells (DSSCs). ZnO nanorods of aspect ratio 8-20 were synthesized by a standard hydrothermal method and Au nanorods of aspect ratio 2-3.5 were synthesized by a seeded growth method. The nanorods were successfully incorporated into a conducting polymer matrix such as poly(9-vinylcarbazole) (PVK) and poly(3-alkylthiophene) (P3AT) and studied the device performance of these nanocomposites in BHJ photovoltaic device. The effect of the aspect ratio of the nanofiller on the device performance was investigated. Again the prepared Au nanorods were immobilized into gelatin hydrogel and studied the effect of this nanocomposite as a gel electrolyte in DSSCs. Conventional titanium dioxide (TiO_2) photoanodes in DSSCs were replaced by the synthesized ZnO nanorods. In both the cases the effect of the aspect ratio of the nanorods on the device performance was thoroughly studied.

Chapter 1 deals with the motivation and research background of the present investigation. The chapter provides an insight into the definition and working principle of the BHJ and DSSCs. The use of conducting polymers like PVK, P3AT etc. to BHJ solar cell is also discussed. Now-a-days, various anisotropic nanoparticles such as ZnO nanorods and Au nanorods are used in the field of solar photovoltaics. Gelatin hydrogel as a biodegradable polymer can act as a very promising alternative to liquid electrolytes in DSSCs. The chapter also outlines the scopes and objectives of the present investigation along with the plan of work.

Chapter 2 is divided into two parts. First part of the chapter describes the synthesis of ZnO nanorods of aspect ratio 8-20 by a standard hydrothermal method and incorporation

of the nanorods into PVK matrix. Structure, morphology and properties of the synthesized nanorods and nanocomposites are studied by Fourier transform infrared spectrometer (FT-IR), X-ray diffractometer (XRD), Scanning electron microscope-energy dispersive x-ray spectroscopy (SEM-EDX), Ultraviolet-visible (UV-visible) spectroscopy, Photoluminescence (PL) spectroscopy, Thermogravimetric analysis (TGA) and Cyclic voltametry (CV) analysis. A set of BHJ solar cells is fabricated by using the synthesized nanocomposites as the active layer and the device performance of the solar cells is carried out under simulated (AM1.5) solar illumination at 1 sun (100 mW/cm^2) in laboratory air. The effect of aspect ratio of ZnO nanorods on the device performance was investigated. Maximum photo conversion efficiency (PCE) of 0.44% is achieved with the nanorods of aspect ratio 20. Second portion of chapter 2 describes the synthesis of Au nanorods of aspect ratio 2-3.5 by a seeded growth method and incorporation of the nanorods into PVK matrix. Morphology, structure and properties of the synthesized nanorods and nanocomposites are studied by Transmission electron microscope (TEM), SEM-EDX, FT-IR, UV-visible spectroscopy, PL spectroscopy, TGA and CV analysis. A set of BHJ solar cells is fabricated by using the synthesized PVK/Au nanocomposites as the active layer. The device performance of the solar cells is carried out under simulated (AM1.5) solar illumination at 1 sun (100 mW/cm^2) in laboratory air. The effect of aspect ratio of Au nanorods on the device performance was investigated. Maximum PCE of 1.45% is achieved with the nanorods of aspect ratio 3.5.

Chapter 3 deals with the synthesis of ZnO nanorods (aspect ratio 8-20) by a standard hydrothermal method and the incorporation of the nanorods into poly(3-octylthiophene) (POT) matrix. Morphology, structure and property evaluation have been carried out by SEM-EDX, FT-IR, UV-visible spectroscopy, TGA and CV analysis. The synthesized POT/ZnO nanocomposites are used as the active layer in a set of BHJ solar cells. The device performance of the solar cells is carried out under simulated (AM1.5) solar illumination at 1 sun (100 mW/cm^2) in laboratory air. The effect of aspect ratio of ZnO nanorods was investigated. Maximum PCE of 1.33% is achieved with the nanorods of aspect ratio 20.

Chapter 4 reports the synthesis of Au nanorods of aspect ratio 2-3.5 by a seeded growth method and immobilization of the nanorods into gelatin hydrogel. Morphology, structure and property evaluation of the synthesized nanocomposites are carried out by TEM, SEM-EDX, FT-IR, UV-visible spectroscopy and electrochemical impedance spectroscopy (EIS). The synthesized Au/gelatin nanocomposites are used as the gel electrolyte in a set of quasi solid state DSSCs. The fabricated devices are studied under simulated (AM1.5) solar illumination at 1 sun (100 mW/cm^2) in laboratory air. The effect of aspect ratio and the concentration of Au nanorods on the device performance are investigated. Maximum PCE of 1.98% is achieved with the nanorods of aspect ratio 3.5 at a concentration of 0.04%.

Chapter 5 describes the synthesis of ZnO nanorods (aspect ratio 8-20) by a standard hydrothermal method. The chapter also reports the immobilization of multiwalled carbon nanotubes (MWCNTs) into gelatin hydrogel. Morphology, structure and property evaluation of the synthesized nanorods and the nanocomposites are carried out by TEM, SEM-EDX, XRD, FT-IR, and UV-visible spectroscopy. A set of quasi solid state DSSCs has been fabricated by using the synthesized MWCNT/gelatin as the gel electrolyte and the ZnO nanorods as the photoanodes. Electrochemical property of the gel electrolyte and the photoanode are studied by EIS. The device performance of the DSSCs is carried out under simulated (AM1.5) solar illumination at 1 sun (100 mW/cm^2) in laboratory air. The effect of aspect ratio of the ZnO photoanode is investigated. Maximum PCE of 1.35% is achieved for nanorods of aspect ratio 20 at a MWCNT concentration of 0.2% in the gel electrolyte.

Chapter 6 summarizes the concluding remarks and highlights the findings and future scopes of the present investigation. Nanocomposites based on ZnO and Au nanorods provide better PCE than their pristine polymer. Again, both the nanorods also show better device characteristics in the quasi solid state DSSCs. The aspect ratio of the nanorods has a great impact on the performance characteristics of the solar cells. Thus, the observed results of the present investigation suggest high potential of the ZnO and Au nanorod based nanocomposites in the field of solar photovoltaics.