ABSTRACT

Dye-sensitized solar cells (DSSCs) with natural dye sensitizer are pollution free, natural, and low consumption with the simple manufacturing procedures. The working principle of dye sensitized solar cell (DSSC) is based on the photo generation of an electron by a dye as in photosynthesis and the dyes play a vital role in increasing the efficiency of the solar cells. The increase in the power efficiency makes the devices more cost competitive compared to traditional sources of energy. Among DSSCs, counter electrode (CE) plays an important role in collection of electrons.

Graphene possess high surface area, good electron transport capabilities, strong mechanical strength and excellent thermal and electrical conductivities. Graphene, a monolayer arrangement of carbon atom closely packed into honeycomb network to which oxygen functional groups are attached and this special structure of graphene oxide (GO) makes a hydrophilic material with improved bonding ability, thereby facilitating its composite preparation. Graphene oxide / metal oxide nanocomposites have aroused wide interest, as hybridization improves the catalyst performance of graphene materials. Graphene oxide nanosheet acts as supporting materials as it anchors semiconducting particles and improves the performance of optoelectronic and energy conversion devices.

Metal oxide nanoparticles are desirable for many electron transport applications. Metal oxides such as NiO, Y_2O_3 and SnO_2 can be combined with graphene oxide surface to strengthen the mechanical stability of the graphene sheet, which makes it likely to increase the photovoltaic performance of carbon based DSSCs.

The sensitizer plays an important role in the performance of DSSCs. The dyes with a broader absorption and higher molar absorption coefficients are required for efficient light harvesting with TiO_2 (photo anode) films. Hence, natural dyes such as Solanum Procumbens (SP), Solanum Torvum (ST), Artabotrys Hexapetalus (AH), Galinsoga Parviflora (GP) and Jasminum Grandiflorum L (JG) extracts are used as a sensitizer for DSSCs, a natural dye never reported before, and it is the novelty of the present work. This natural dye extract contains, namely, chlorophyll, betanins,

anthocyanins, and carotenoids. These dyes exhibited wide ecological range and found extensively all over India. The present work demonstrates the performance of GO/NiO/Y_2O_3/SnO_2 (Pt-free)-based CE with SP/ST/AH/JG/GP extracts as a dye sensitizer for DSSC.

Graphene nanosheet are prepared by the modified Hummers' method. XRD, FE-SEM and HR-TEM analysis revealed that the GO nanosheet are successfully prepared. The elemental analysis confirmed the Graphene oxide is prepared without any impurities. The UV-Vis studies showed that the prepared dyes SP, ST, AH, GP and JG belong to chlorophyll group with absorption peak around 260 nm, 270 nm, 220 nm, 288 nm and 339 nm respectively. GO nanosheet can act as a counter electrode. The low cost and environmental friendliness of these dyes make them attractive for their use as a sensitizer in Dye sensitized solar cells.

Influence of different concentrations (5:1, 5:2, 5:3 5:4 and 5:5) of nickel oxide (NiO) nanoparticles blended on the surface of GO nanosheet are synthesized by chemical precipitation method. FE-SEM and HR-TEM analysis revealed that the NiO nanoparticles are successfully embellished on the Graphene oxide nanosheet. The EDX analysis confirmed the different concentrations of NiO nanoparticles and Graphene oxide elements in the prepared nanocomposites without any impurities. The prepared GO / NiO (5:1, 5:2, 5:3, 5:4 and 5:5) nanocomposite can be used as a counter electrode for Dye Sensitized Solar Cell Applications.

The various concentrations of (5:1, 5:2, 5:3 5:4 and 5:5) Y_2O_3 nanoparticles embellished on the GO nanosheet are synthesized by chemical precipitation method. The FTIR analysis showed that the depth of the YO band at 501 cm^{-1} is gradually increased by increasing the concentration of Y_2O_3 from 5:1 to 5:5, which confirms the Yttrium oxide nanoparticles are gradually spread on the surface of graphene oxide nanosheet. FESEM and HRTEM analysis confirmed that the Yttrium oxide nanoparticles are evenly dispersed onto the surface of Graphene oxide nanosheet. The prepared nanocomposites can be used as a counter electrode for dye sensitized solar cell applications.

GO / SnO_2 (5:1, 5:2, 5:3, 5:4 and 5:5) nanocomposites are synthesized by chemical precipitated method. The structural, morphological and element composition

of synthesized GO/SnO_2 (5:1 to 5:5) nanocomposites are studied by FTIR, XRD, FESEM and EDX analysis and confirmed that the prepared Tin oxide nanoparticles are equally blended on the GO nanosheet. This prepared nanocomposite entitled to use as a counter electrode for Pt Free Dye sensitized solar cell application.

The EIS analysis discovered that the GO / NiO (5:4) nanocomposites with JG sensitized DSSC achieves the low electron transfer resistance. The I-V characteristics confirmed that the power conversion efficiency of GO as counter electrode in DSSCs with SP, ST, AH, GP and JG sensitizer are 0.3 %, 0.7 %, 0.65 %, 0.8 % and 0.96 % respectively. GO/ NiO (5:4) counter electrode and JG as sensitizer in DSSC efficiency is higher than SP, ST, AH and JG sensitizer in GO / NiO (5:1 to 5:5) based counter electrode DSSCs. This work confirmed that the prepared GO / NiO (5:1, 5:2, 5:3, 5:4, and 5:5) nanocomposites as counter electrode has a low cost and environmentally friendly dyes (SP, ST, AH, GP, and JG) that make them attractive for their use as a sensitizer in dye sensitized solar cells.

Photovoltaic characterization of prepared GO / Y_2O_3 (5:1, 5:2, 5:3, 5:4 and 5:5) nanocomposites counter electrode with SP, ST, AH, GP and JG dyes as a sensitizer in DSSC investigated by I-V characterization. The UV-Vis studies showed that the prepared GO / Y_2O_3 (5:1, 5:2, 5:3, 5:4 and 5:5) nanocomposites absorption peak around 250 nm and 408 nm, 257 nm and 411 nm, 260 nm and 416 nm, 262 nm and 419 nm, 268 nm and 421 nm respectively. I-V characteristics showed that the photovoltaic efficiency of GO / Y_2O_3 (5:1, 5:2, 5:3, 5:4 and 5:5) nanocomposites Pt free counter electrode with SP, ST, AH, GP and JG as a sensitizer for DSSCs and the best efficiency is found to be 1.3%, 0.9%, 1.75%, 2.76% and 2.8% respectively.

The efficiency studies for GO / SnO_2 (5:1, 5:2, 5:3, 5:4 and 5:5) nanocomposites as a counter electrode with SP, ST, AH, GP and JG as sensitizer in DSSC are investigated. The EIS results revealed that the GO / SnO_2 (5:5) nanocomposites with JG sensitizer achieve the largest semicircle in the highest frequency region which indicates low resistance in counter electrode. The I-V characteristic showed that the best efficiency for Pt free counter electrode GO/SnO_2 (5:1, 5:2, 5:3, 5:4 and 5:5) nanocomposites with SP, ST, AH, GP and JG as sensitizer

in DSSC as 0.9 %, 1.4%, 2.1 %, 12.3 % and 2.9 % respectively. It is confirmed that Pt free counter electrode with GO / SnO_2 (5:5) nanocomposites has highest efficiency.

In summary, the prepared GO / metal oxides (NiO, Y_2O_3 and SnO_2) nanocomposites act as excellent counter electrode with SP, ST, AH, GP and JG as sensitizers. Hence, an alternative, eco-friendly and low cost DSSC has been successfully fabricated.