# Enhancing the Performance of Dye-Sensitized Solar Cells through Doping / Co-doping $TiO_2$ Electrodes

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## ABSTRACT

Dye-Sensitized Solar Cells (DSSCs) are the most promising solar cells and alternative to the conventional silicon solar cells due to low cost, facile fabrication, ability to work under low-light conditions and eco-friendly nature. Generally, the visible light is converted into electricity in DSSCs through wide bandgap semiconductors such as $SnO_2$, $SrTiO_3$, $Nb_2O_5$, ZnO and $TiO_2$. Among the metal oxides explored for DSSCs so far, $TiO_2$ remains the most promising material due to transparency under visible light, high refractive index, thermal stability and high surface states. However, the performance of the device is limited due to limited spectral response, poor electron transport of carriers in porous $TiO_2$, recombination of the injected electrons with the oxidized redox species and relaxation of oxidized dyes. Doping is considered as one of the strategies to overcome these problems. In this study, initially Ru and Ni doped electrodes were separately made and it was found that both electrodes exhibit similar photovoltaic performance; however, Ni-doped electrode is cost-effective and Ni is more abundant and less toxic. Hence, Ni /N co-doped with P25-$TiO_2$ nanomaterials were then synthesised and, structurally and optically characterized by X-ray diffraction (XRD), Atomic Force Microscopy (AFM), Energy-dispersive X-ray (EDX), and UV-Visible (UV-Vis) spectroscopies. UV-Visible absorption spectra of doped and co-doped $TiO_2$ show a red shift on Ru, Ni, N doping and Ni/N co-doping. The XRD patterns of un-doped, doped and Ni/N co-doped $TiO_2$ electrodes confirmed the presence of mixed anatase and rutile phases of $TiO_2$; and the presence of constituent elements in doped and co-doped nanomaterials was evident by EDX spectroscopy. Further, AFM studies illustrate that doping and co-doping on $TiO_2$ increase the surface area for dye adsorption. The optimized individual DSSCs with separate Ru-doped, Ni-doped, N-doped and Ni/N co-doped $TiO_2$ photoanodes exhibited power conversion efficiencies (PCEs) with 20, 20, 20, and 35 % enhancement, respectively compared to the control device under simulated irradiation of 1 sun illumination intensity (100 $mW/cm^2$) with AM 1.5 filter. It should be noted that, the improvement in PCE is mainly due to the increase in short-circuit current density ($J_{SC}$) as a result of the enhanced visible light harvesting ability, and reduced recombination rate / improved charge transport which were confirmed by Electrochemical Impedance Spectroscopy (EIS).

**Keywords:** P25-$TiO_2$; Transition metals; Ruthenium; Nickel; Non-metal; Nitrogen; Doped $TiO_2$; Co-doped $TiO_2$; DSSC