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An environmentally friendly green synthesis of Co^{2+} and Mn^{2+} ion doped ZnO nanoparticles to improve solar cell efficiency

Shelan M. Mustafa [a,b,*], Azeez A. Barzinjy [a,c], Abubaker H. Hamad [d]

[a] Scientific Research Centre, Soran University, Soran-Erbil, Kurdistan Region, Iraq
[b] Department of Automation Industrial Technology Engineering, Erbil Technology College, Erbil Polytechnic University, Erbil, Iraq
[c] Physics Education Department, Faculty of Education, Tishk International University, Erbil, Iraq
[d] Department of General Science, Faculty of Education, Soran University, Kurdistan Region, Iraq

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ABSTRACT

Global warming is a threat to human health in the context of increasing organic or inorganic pollutants, which are produced by various products. The "Green synthesis" method effectively eliminates toxic and/or harmful effects that arise due to the wet-chemical synthesis process. Different concentrations of Co^{2+} and Mn^{2+} ion doped ZnO-nanoparticles (NPs) were designed at a low temperature, about 70 °C by utilizing an eco-friendly sustainable method with dandelion leaf (DL) extract as a solvent and these biosynthesized NPs were annealed to grow the crystallinity enhancement. The confirmation of NPs crystal phase, phase purity, and grain size was performed by XRD, showing the hexagonal-Wurtzite phase structure. SEM and TEM images of the NPs demonstrated sub-100 nm spherical-shaped particles. Fourier transform infrared displays characteristics band about ~523 cm^{-1} which corresponds to Zn–O tetrahedron asymmetric stretching vibrations. Both UV-Visible and luminescence studies confirmed the adjacent band edge emission of ZnO and successive incorporation of Co^{2+} and Mn^{2+} ion-doped ZnO host. For improving power conversion efficiency, the polycrystalline silicon solar cells (PSSCs), different layers of Co^{2+} and Mn^{2+} ion-doped ZnO-NPs coated on bare PSSCs are promising strategies. Additionally, solar cell efficiency decreases with further coating of NPs layers and/or thickness. Optimum solar cell efficiency was observed for 5 at% Mn^{2+} ion-doped ZnO-NPs with three layers. Finally, Radish and Cress plants are grown, using the biosynthesized ZnO-NPs supernatant from DL extract, which showed high environmental biocompatibility.

1. Introduction

Global warming, diminishing fossil fuels and environmental pollution are making it more challenging to develop renewable energy resources [1]. As one of the many renewable green energy sources on Earth, solar energy is environmentally friendly and also highly available. It is extremely important to trap light using solar harvesting devices, such as photovoltaic devices to harvest solar energy. Furthermore, the dye-sensitized solar device power conversion efficiency relays on the reflectivity of top surfaces of the distinct types of solar energy harvesting materials used.

Current technology grapples with suppressing light reflection from flat solar cell surfaces. Globally, solar photovoltaic installations have increased by 21-fold between 2010 and 2021, to over 843 gigawatts [1]. It has been found that silicon solar cells often reflect around 30% of solar energy, depending upon their refractive index. This issue has been addressed in many ways. One of the best methods of anti-reflective coating is nanoparticles (NPs) and transition metal oxide thin films that cover solar cells. As a result of their superior optical and electrical properties, this method enhances the efficiency of a photon-to-electron conversion [2,3].

Nanotechnology is currently one of the most exciting branches of science that use the physical, chemical and optical properties of bulk materials at the nanoscale to improve life. NPs, size < 100 nm, are used in various fields such as engineering, science, and technology. Meanwhile, NPs (size <100 nm) can be used in numerous fields, such as food, agriculture, healthcare, pharmaceuticals, and industry, and they are being sold as commodities extensively [4]. A total of 320 tons of "Ag–silver NPs" are manufactured every year for use in food processing, nanomedical imaging, solar energy, and biosensing applications [5,6]. In many of these NPs synthesis protocols, toxic solvents are used, and toxic by-products are generated. Unlike chemical synthesis, "green

* Corresponding author at: Department of Automation Industrial Technology Engineering, Erbil Technology College, Erbil Polytechnic University, Erbil, Iraq.
E-mail address: shelan.mustafa@epu.edu.iq (S.M. Mustafa).

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