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Novel sol-gel deposited p-type SnO:Mn:K for solar cell applications

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ABSTRACT

Novel p-type SnO:Mn:K thin films were synthesized by a sol-gel deposition technique on soda-lime glass substrates. The structure of the SnO:Mn:K thin films were investigated by scanning electron microscopy and X-ray diffraction pattern measurements and were found to be strongly influenced by the dopant concentration, with a significant changes in film morphology as the KMn dopant increases. Hall effect measurement revealed that p-type SnO:Mn:K thin films can be obtained within the optimized doping concentration. The p-type doping was also confirmed by integrating the SnO:Mn:K thin film onto n-type crystalline silicon to form a heterojunction device.

1. Introduction

Recently, oxide-based semiconductors have gained increasing research attention due to its potential enhancement in applications such as solar cells [1], protective coatings [2], sensors [3] and thin film transistors [4]. There are also considerable attention in the formation of diluted magnetic SnO_2 doped with transition metals (Cr [5], Co [6] or Mn [7]) for spintronic applications. Stannic oxide (SnO_2) is a naturally n-type semiconductor with a wide band gap ~3.6 eV and high electron mobility [8–10]. This n-type conduction behaviour can be further enhanced by doping SnO_2 by F (FTO) that is commonly used as transparent conductive electrode in dye sensitized solar cells [11]. Fundamentally, most of the semiconductor devices relies on the pn junction configuration. Therefore, obtaining a stable p-type SnO_2 with sufficient hole mobility is important [12,13]. Theoretically, p-type SnO_2 can be achieved by doping using elements with lower valence cation (Al [14], Sb [15] and Mn [16]) as acceptors that increases hole carrier concentration. A number of experiments have shown that high quality p-type SnO can be achieved by Mn doping due to the similar ionic radii to Sn4+ that facilitate substitution and high solubility [16,17]. To the best of our knowledge, most of the SnO:Mn have been prepared with single source doping using Mn [16–18] and there have not been study on p-type SnO using the co-doping strategy. In terms of deposition techniques, SnO:Mn thin films have been deposited using sol-gel [17], mechanochemical method [19], sputtering [20] and spray pyrolysis deposition [21]. Amongst the different deposition technologies, sol-gel spin coating is particularly attractive as it offers efficient precise control of composition, utilizes a simple set-up and can be up scaled to industrial production [18]. In this study, p-type SnO:Mn:K thin films were prepared by sol-gel spin coating method using KMn as dopant compound. The structure and optoelectronic properties of the samples were investigated as a function of increasing doping concentration using scanning electron microscopy, X-ray diffraction, Hall effect measurement and current voltage measurements.

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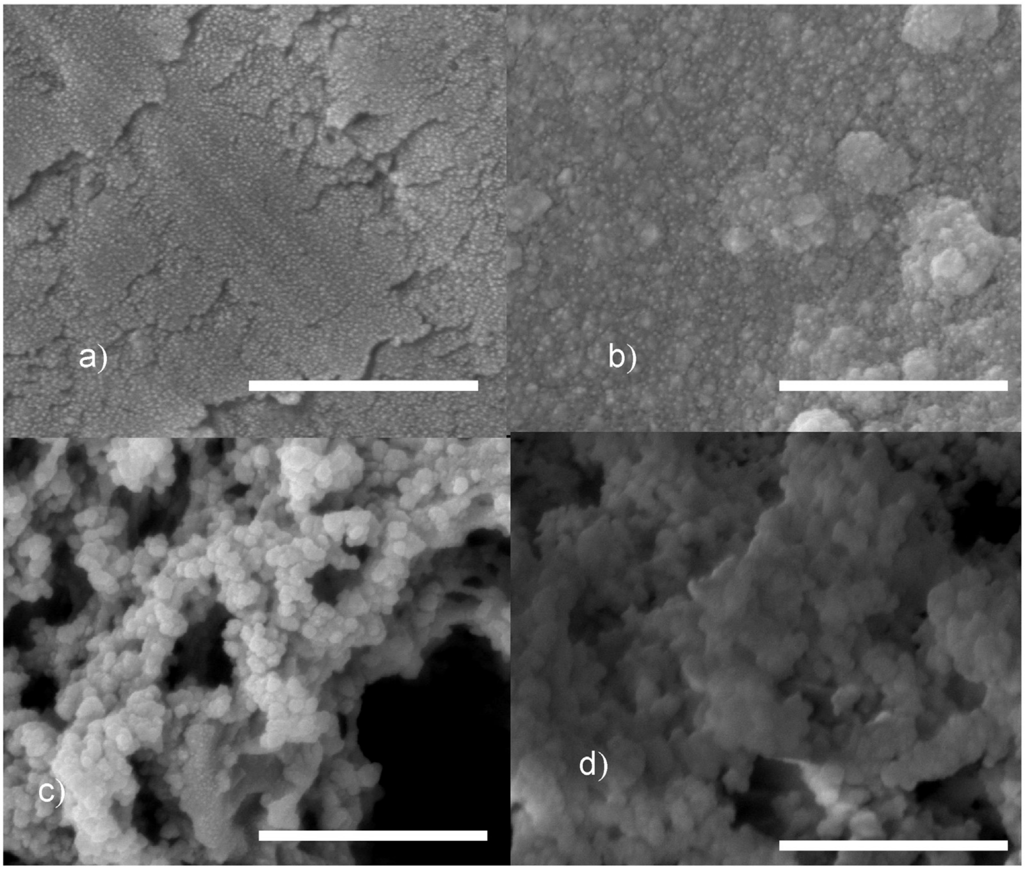

Fig. 1. SEM image of the SnO:Mn:K doped with a) 1 wt%, b) 2 wt%, c) 5 wt% and d) 8 wt% of KMn (scale bar 2 μm).

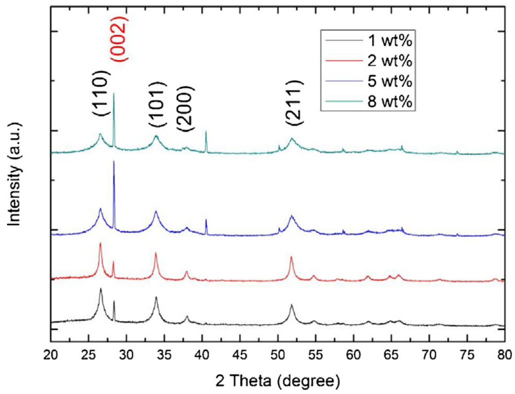

Fig. 2. XRD pattern of the SnO:Mn:K doped with 1–8 wt% of KMn.

2. Experimental procedures

All of the chemicals used during this study were obtained from Sigma Adrich and used as received. Before the deposition, Corning glass (Eagle 2000) substrates were degreased by using sequential ultrasonication in acetone, isopropanol (IPA) and water. For the precursor solution, 0.4 M solutions were prepared by dissolving hydrated tin chloride in IPA. The solution was magnetically stirred for 2 h on a hotplate set at 60 °C. Potassium manganate (1–8 wt%) was then added into the solution as a source of Mn dopant and oxidizing agent. The mixed solution was further stirred at 60 °C for 3 h and left to age for 48 h to age. For the film coating, the prepared precursor solutions were spin coated at 3000 rpm that was repeated five times to yield a film thickness of around 250 nm. After each spin coating procedure, the films were crystallized by annealing at 550 °C.