Thermoelectric Properties of Al Doped ZnO Thin Films Fabricated Through Inkjet Printing

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Abstract. The effects of Al doping to the thermoelectric properties of ZnO thin films fabricated through ink-jet printing were studied in this paper. Ink-jet printing was used to deposit the Al doped ZnO thin films. A minimum of 50 print cycles was required to obtain continuous film with approximately 9 μm thick thin films. It was possible to obtain high thermoelectric properties of ZnO by controlling the ratios of dopant added and the temperature of the heat treatments. The XRD traces of Al doped ZnO exhibit a polycrystalline hexagonal structure for the wurtzite phase of ZnO. There were no additional phase detected for Al doped ZnO thin films with increasing amount of Al dopants and heat treatment temperature. The results show Al doping had improved the thermoelectric properties of ZnO with an increased in electrical conductivity. The electrical conductivity of pure ZnO thin film (5 S/cm) was enhanced with increasing the dopant to 4wt% Al doped ZnO (114 S/cm). Negative Seebeck values were observed for all the samples that indicated n-type semiconductor. Pure ZnO samples have a measured Seebeck coefficient -17.63 μV/K decreased to -14.35 μV/K with 4 wt% Al doped.

Introduction

Thermoelectric materials are capable of converting a heat into electrical energy, making them interesting for applications within power generation [1]. The thermoelectric efficiency is measured by the thermoelectric figure of merit (ZT) [2]. According to the definition of the figure of merit, a material with good thermoelectric properties shows a high power factor while keeping a low thermal conductivity [3]. The materials need to be low thermal conductivity (κ), which is necessary to introduce a large temperature difference into both ends of the material. Besides, it needs to be high electrical conductivity (σ), which is required to reduce the internal resistance of the material. The material should also have large Seebeck coefficient, which is needed to obtain a high voltage.

Zinc oxide (ZnO) has been widely researched in recent years due to its physical and chemical properties. The combinations of non-toxicity, low cost and unique properties have fuelled much of the research in zinc oxide for various applications [4]. Doped zinc oxide thin films have been studied for their application as conducting electrode materials in flat-panel displays, sensor and solar devices [5]. The main drawback of ZnO as thermoelectric materials is due to the low electrical conductivity [6]. The addition of dopants is an alternative route to enhance the thermoelectric performance of existing materials [7].

Among the ZnO films doped with elements such as barium, aluminium (Al), gallium and indium, Al doped ZnO thin films show the lowest electrical resistivity [8]. The electrical conductivity can be increased by special heat treatment and doping of specific impurities into the crystal lattice. In the hexagonal close packed lattice of the ZnO wurtzite structure, half of the tetrahedral holes and all of the octahedral holes are empty, providing further possible dopant sites [9]. A dopant ion introduced to modify the electronic properties of a material needs to be incorporated into the crystal structure of the host material (either in lattice sites or interstitially). ZnO can even be made to exhibit metallic conductivity as for transparent electrode similar to Indium tin oxide glass. Al has one valence

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