DECLARATION

I, the undersigned, hereby declare that the work presented in this dissertation represents the work done by me and that, to the best of my knowledge, this work has not been submitted and not being currently submitted in part or whole for the award of a degree at any other university.

Signature……. Date ……

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Candidate

GROWTH AND CHARACTERISATION OF SPRAY PYROLYTIC DOPED ZINC AND ALUMINIUM OXIDE SPECTRAL SELECTIVE THIN FILMS

By

Prospery C. Simpemba

ABSTRACT

Metal oxide thin films have been used in thin film solar cells and other solar energy applications for many years. The main concern has been to improve their physical, electrical and optical properties in order to increase their efficiency and lower their production costs. Zinc oxide doped with aluminium (ZnO:Al) and aluminium oxide doped with zinc (Al_2O_3:Zn) thin films have been produced by a spray pyrolysis process onto standard microscope glass slides at different substrate temperatures and for different solution concentrations, spray times and pressure. The main objective was to produce single, double and triple layer thin films and characterized them for their optical, electrical and structural properties. The spectral selectiveness of these oxide thin films and their applicability in producing efficient solar cells has been investigated. Optical measurements in the ultraviolet, visible and near infrared ranges have been performed using the Perkin-Elmer Lambda 19 spectrophotometer. Further optical characterization in the far infrared has been performed using the BX Fourier Transform Infrared (FT-IR) spectrophotometer at the University of Dar es Salaam Solar Energy Research Laboratory. Structural characterization for determination of surface morphology and film thickness has been done using the Atomic Force Microscope and the Tencor Alpha Step IQ Profiler. On the other hand electrical properties have been investigated using the four-point resistance square probe. The transmittance, reflectance and thickness of the thin films as well as the sheet resistance have been experimentally obtained. The solar transmittance of 88 percent has been achieved for Al-doped zinc oxide (ZnO) films whereas 71.94 per cent has been obtained for Zn-doped aluminium oxide (Al_2O_3). The film thicknesses fall in the range 0.14 - 87.7 μm. The films have low reflectance in the order of 10 percent. Peak reflectance of 25 per cent has been recorded for the wavelength range 8-12 μm. The wavelength-dependent refractive index of the films has been evaluated from reflectance and transmittance measurements. In the VIS-NIR, the obtained refractive indices were 1.28 for ZnO, 1.97 for ZnO:Al and 2.0 for Al_2O_3:Zn. Features of the film surface microstructure have been analyzed and related to how they affect the general properties of the films. The properties of these thin films have been modeled using the Bruggeman and Maxwell-Garnett effective medium theories obtaining effective values for the permeability constants and using these to calculate the effective values of refractive indices. The film sheet resistance values of 0.75 Ω, 9.5 Ω and corresponding resistivity values of 9.59 x 10^{-4} Ω m and 2.43 x 10^{-4} Ω m have been obtained for ZnO:Al, and resistance values of 5.56 Ω and 12 Ω with corresponding resistivity values of 4.47 x 10^{-4} Ω m and 11.80 x 10^{-4} Ω m have been

achieved for Al_2O_3:Zn. These film properties have been related to applications in thin film solar cells.

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LIST OF SYMBOLS AND ABBREVIATIONS

ε	Dielectric permeability
λ	Wavelength
μ	Micro
AFM	Atomic Force Microscope
Br	Bruggeman
CPU	Central Processing Unit
CVD	Chemical Vapour Deposition
DSSC	Dye-Sensitized Solar Cells
E_g	Energy band gap
EM	Electromagnetic
EMF	Electromotive force
EMT	Effective Medium Theory
eV	Electron volt
FIR	Far infrared
IR	Infrared
ITO	Indium tin oxide
IV	Current-voltage
FTIR	Fourier Transform Infrared
MG	Maxwell-Garnett
MOS	Metal oxide semiconductor
n	Refractive index
NIR	Near Infrared

PVD	Physical Vapour Deposition
SADC	Southern Africa Development Community
TFSC	Thin Film Solar Cells
UV	Ultraviolet
VIS	Visible
ZnO:Al	Zinc oxide doped with aluminium
α	Absorption coefficient