EFFECT OF Li, Cu AND N DOPING ON THE MORPHOLOGY, OPTICAL AND ELECTRICAL PROPERTIES OF ZnO THIN FILMS PREPARED BY SPIN-COATING TECHNIQUE

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Motivation

- Extensive research is performed to obtain ZnO thin films with enhanced conductivity and high optical transparency in the visible region of the spectrum for applications as transparent conductive oxide (TCO) materials [1, 2].
- Doping processes, able to control the band gap of ZnO and therefore to improve optical properties such as transmission/absorption as well as the electrical conductivity are at present widely investigated [3-6].
- In this study we analyzed the effect of Li, Cu and N doping, at concentrations in the range 1-5 at.%, on the morphology, optical and electrical properties of ZnO thin films.

Experimental details

- Sol preparation: zinc acetate dehydrate (99.0%), 2-methoxyethanol (99.8%), monoethanolamine (≥99%). Concentration of solution was 0.35 mol/l.
- Dopant: lithium acetate (99.95%), Li, copper acetate monohydrate (≥99.0%), Cu and N dopant in the form of ammonium nitrate (≥99.0%).

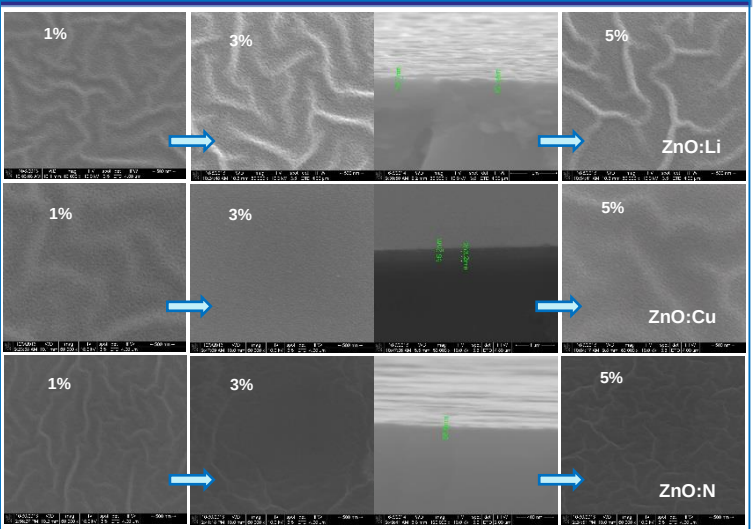
Sol Preparation

Thin film deposition

Spinning rate: 3000rpm/30s
Pre-heating 130°C/5 min
Thermal treatment 500°C/1h

ZnO and Li/Cu/N doped ZnO thin films

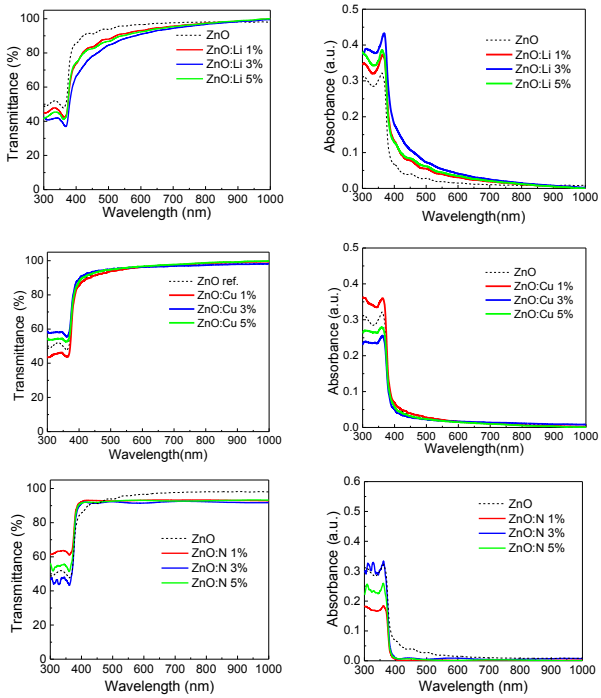
Films surface characterization



FE-SEM images of Li/Cu/N doped ZnO films

Li:ZnO and N:ZnO films surface show pronounced wrinkles like structures, while these features are reduced on Cu:ZnO films surface.

Optical properties



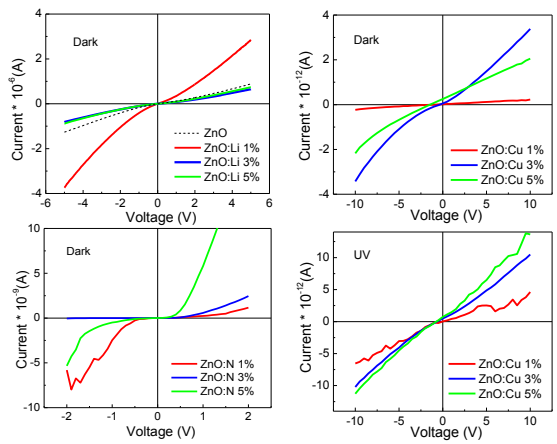
Transmittance and absorbance spectra of ZnO, Li/Cu/N thin films

All the films obtained demonstrate high transparency in the visible spectral region. Sharp absorption edge confirms high crystallinity of the films.

Table: Optical transmittance, band gap energy and electrical resistivity parameters of Li/Cu/N:ZnO thin films

Thin films		T (%)	Eg (eV)	ρ (Ω·cm)
ZnO		91	3.21	0.41 x10^2
ZnO:Li at.%	1	83	3.21	1.28 x10^2
	3	78	3.16	1.89 x10^2
	5	82	3.22	1.63 x10^2
ZnO:Cu at.%	1	91	3.14	6.92 x10^8
	3	94	3.18	6.25 x10^7
	5	93	3.16	7.5 x10^7
ZnO:N at.%	1	93	3.25	6.42 x10^5
	3	91	3.22	2.90 x10^4
	5	92	3.25	3.09 x10^3

Electrical characteristics



I-V characteristics of ZnO, Li:ZnO, Cu:ZnO and N:ZnO thin films

The current–voltage characteristics of Li/N doped ZnO films exhibit non-linear, diode like behavior. The lowest resistivity achieved for 1 at. % Li:ZnO films and 5 at.% N:ZnO films.

Conclusions

- Li, Cu, N doped ZnO thin films with thickness of about 60 nm were deposited on Si (100)/ SiO_2 substrates by sol-gel.
- FE-SEM micrographs revealed that the films morphology and their porosity are affected by type and dopants concentration.
- Lowest resistivity was achieved for 1 at.% Li, 3 at.% Cu and 5 at.% N. Particularly, Cu:ZnO films present photo-generated currents under UV light illumination.
- The films transmittance in the visible region (400-800 nm) is 91 % for undoped ZnO films, 78-83 % for Li:ZnO films, 91-94 % for Cu:ZnO films and 91-93 % in the case of N doping.
- The energy of optical band gap for Li doping remains close to those of undoped films, 3.21 eV, decreases to 3.14 eV for Cu doping, and increases to 3.25 eV for N doping.
- The results demonstrate that Li/Cu/N doped ZnO thin films obtained by sol-gel spin-coating present a high transparency in the visible region, making them suitable for applications in TCO based devices.
- Further improvement of the films conductivity are expected by optimize the sol-gel preparation (to decrease the films porosity and wrinkles formation) and post-annealing parameters (appropriate atmosphere, temperature).

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