GROWTH AND CHARACTERIZATION OF ZnO:Sn SEMICONDUCTING THIN FILMS

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Semiconductor materials that exhibit ferromagnetism above room temperature (RT) [1] could be the basis of new spin based electronics, leading to new nano devices where the traditional use of semiconductors (logic) and magnetism (storage) merge. Recent works report ferromagnetic behaviour in doped wide band semiconductors above 300 K. Among them, those based on ZnO are particularly interesting due to the fact that ZnO is a wide band semiconductor and is transparent in the visible part of the spectrum. The appearance of a ferromagnetic phase has been reported recently when mixing ZnO and MnO_2 powders [2], and although the mechanism of ferromagnetism is still under discussion, seems to be originated by the diffusion of Zn into the MnO_2 grains and the presence of Mn^{+3} and Mn^{+4} mixed states[3,4].

In order to convincingly distinguish the ferromagnetic behaviour originated from charge carriers mediated exchange, well characterized and good quality ZnO based semiconductor films are a desirable first step. Our approach uses ZnO doped with different tin concentrations as a previous step to the implantation of localized spins. The different phases present in the system for different Sn concentrations for bulk (pellets prepared by conventional ceramic routes) and thin films samples grown by pulsed laser deposition (PLD) have been characterized. Electrical (resistivity, carrier concentration and mobility from 30 up to 300K) and structural characterizations have been measured for both bulk and thin films.

Thin films were grown by PLD using premixed ZnO and SnO_2 ceramic targets with different SnO_2 contents (0, 0.1, 1 and 10%) onto both Si and Pyrex substrates. The substrate temperature and oxygen pressure were 600ºC and 2.10^{-2} mbar, found to be the best conditions for ZnO crystallinity on previous works [5].

Figure1 shows XRD that demonstrate that both 0 and 0.1% samples share the same XRD pattern with (001) orientation. The sample with 1% Sn content exhibits the same orientation but with a slight shift towards higher 2θ values and better crystallinity, while the sample with 10% Sn content presents a completely different XRD pattern revealing several segregated phases (Low crystalline ZnO, SnO, SnO_2 and Zn_2SnO_4). Electrical characterization (using Al/Au ohmic contacts) shows that the 0.1% Sn content film is the one with lowest resistivity ($2x10^{-3}$ Ω.cm) and higher carrier concentration ($n = 1x10^{20}$ cm^{-3}) (see figure 2 and table 1), while the other Sn contents do not lead to an increase on the carrier concentration ($n = 2x10^{-19}$) and the higher the Sn content is the higher is the resistivity, because of phase segregation.

References

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Figures

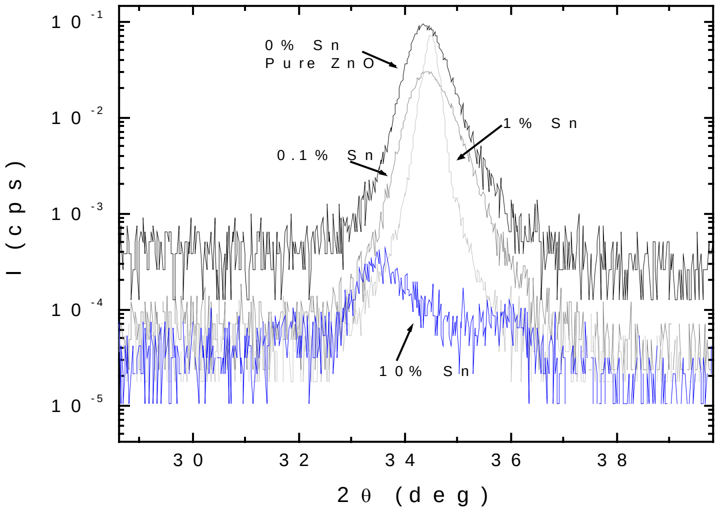

Fig.1. XRD patterns of ZnO thin films doped with different Sn contents.
Pure ZnO and the sample doped with 0.1%Sn show the same XRD pattern, 1%Sn doped sample shows a shift towards higher 2θ values, while as can be observed 10%Sn sample has a different XRD pattern, mixture of different phases (ZnO, SnO, SnO_2 and Zn_2SnO_4).

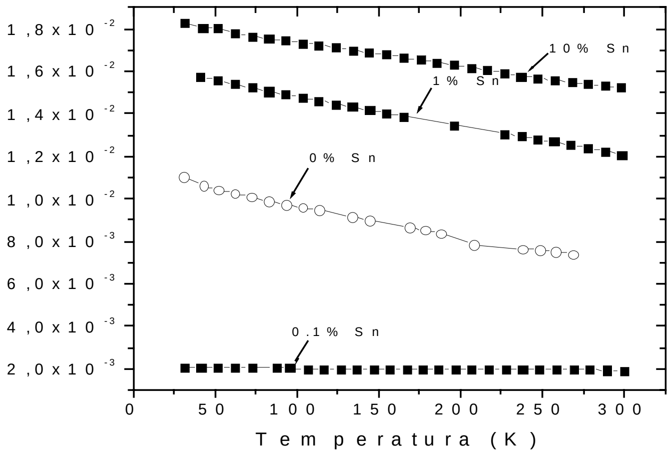

Fig.2. Temperature dependence of the resistivity for different Sn contents. As we can observe Sn contents higher than 0.1% lead to higher resistivity than pure ZnO due the phase segregation.

Table 1. Electrical characterization data at 300K for different Sn concentrations.

Sample	Resistivity (Ω.cm)	Carrier concentration (cm^{-3})	Hall mobility ($cm^2.V^{-1}.s^{-1}$)
Undoped film	7×10^{-3}	1.1×10^{19}	20
0.1% Sn	2×10^{-3}	2.0×10^{20}	10
1% Sn	1.2×10^{-2}	2.4×10^{19}	10
10% Sn	1.5×10^{-2}	1.1×10^{19}	7