Local structure and optical and electrical properties of Zinc-Iridium oxide thin films

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Introduction

Thin films of Zinc oxide with different additives are widely investigated as a potential substitute to ITO. Depending on the additive, the films may exhibit either n- or p- type conductivity [1]. This report focuses on Zinc-Iridium oxide as a candidate for p-type electrical conductor [2].

Experimental details

The films have been deposited by reactive sputtering from metallic mosaic targets made of Zn and Ir pieces, with Zn 92-96%, Ir=4-8% surface area. For comparison pure IrO_{2-x} and ZnO:Al thin films has been also deposited. The substrate was glass kept at ≈310°C temperature, the sputtering was conducted at 3 mTorr working pressure and 100W sputtering power. The process was controlled by plasma optical emission spectroscopy, based on Zinc emission line at 480.05 nm and Iridium emission line at 390.2 nm; an example of OES spectrum recorded upon ZnO:Ir deposition is shown in Fig.1.

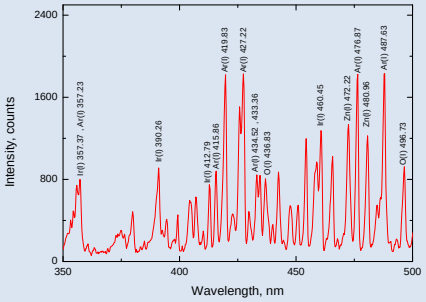

Figure 1. Plasma optical emission spectrum upon sputtering of a metallic mosaic target made of Zn and Ir segments.

Results

The structure of the films has been characterized by XRD. The ZnO:Al films are polycrystalline, the ZnO:Ir films are X-ray amorphous (Fig.2).

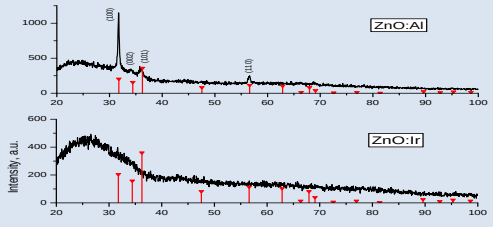

Figure 2. XRD spectra for the films of ZnO:Al (top), ZnO:Ir (bottom).

The Ir L3-edge EXAFS (Extended X-ray absorption fine structure) signals $\chi(k)k^2$ of c-IrO2 and the thin films were extracted and analyzed. Comparative analysis of the Fourier transforms (FTs) of the EXAFS signals (Fig. 3-4) for the thin film and crystalline c-IrO2 indicates that the FT peaks amplitude for the thin film decreases relative to that for c-IrO2 when the distance increases [3].

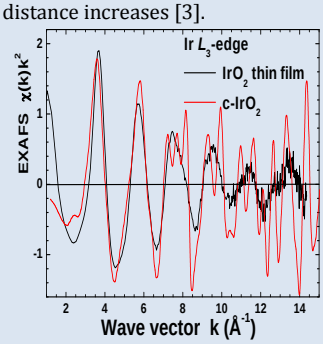

Figure 3. EXAFS signal

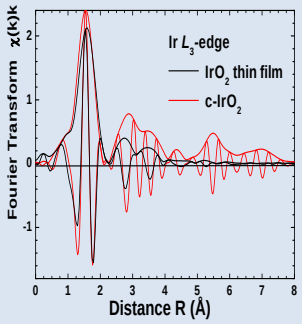

Figure 4. Fourier transforms

The thickness of the films, as measured by profilometer, was approximately 300 nm for ZnO:Al and 75 nm for ZnO:Ir. With the deposition time kept constant at 10 minutes, the difference in thickness reflects the difference in the sputtering rate.

Electrical resistivity of the films, as determined using a 2 point method with aluminium contacts is shown in Fig. 5.

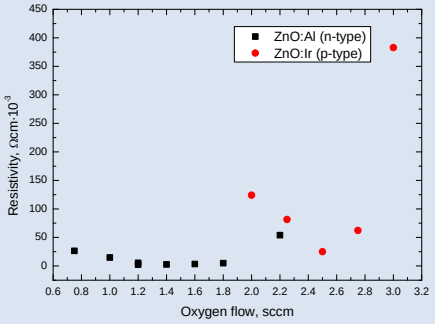

Figure 5. Resistivity of ZnO:Al and ZnO:Ir films as a function of oxygen flow in the sputtering atmosphere.

In both cases, the resistivity passes through a minimum as a function of the oxygen flow during the deposition. One of the reasons for the higher resistivity of ZnO:Ir most likely is the amorphous structure of the films.

Optical transmittance is considerably higher for the ZnO:Al films than for the ZnO:Ir and IrO_{2-x} films (Fig. 6).

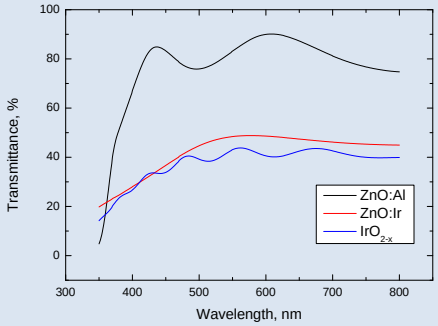

Figure 6. Optical transmittance spectra for ZnO:Al, ZnO:Ir and IrO_{2-x} films.

Conclusion

Films of n-type Aluminium-Zinc oxide and p-type Iridium-Zinc oxide have been deposited by DC reactive magnetron sputtering from metallic targets with the process control based on plasma optical emission spectroscopy.

Elementary analysis has been performed by XRF. XRF showed intense Zn(Kα, Kβ) and Ir(Lα, Lβ) lines. XRF confirmed that iridium concentration in films is ≈25%, ≈5 times more than on target surface.

With the resistivity for both types of films passing through a minimum as a function of oxygen flow in the sputtering atmosphere, the resistivity for ZnO:Ir films is approximately 10 times higher than for ZnO:Al films. One of the likely reasons for the higher resistivity of ZnO:Ir is the amorphous structure of these films, compared to the polycrystalline films of ZnO:Al.

Fig. 6 showed that transmittance for ZnO:Ir and IrO_{2-x} similar, but ZnO:Al transmittance is considerably higher.

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