The influence of radio-frequency plasma on the optical properties of Nickel oxide thin films obtained by laser ablation

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The major aim in this paper is to obtain homogenous nickel oxide thin films grown by PLD in the presence of RF plasma. The films obtained by RF-PLD have lower roughness and large band-gap energy than those deposited by conventional PLD.

1. Introduction

Nickel oxide thin films have been extensively studied as optically active layers in the field of solar cells. Nowadays, transparent conducting oxide films, like zinc oxide, indium tin oxide, are commonly used as transparent electrodes, window coatings for opto-electronic and electrochromic devices [1]. Nickel oxide (NiO) is a semiconductor material, with a large band gap ranging from 3.6 eV to 4.0 eV [2], transparent to visible and near infrared radiation. NiO films have different attractive properties, such as low resistivity, good chemical stability and controllable transmittance for incident visible light [3,4].

Nickel oxide thin films were obtained by Pulsed Laser Deposition (PLD) and radio-frequency assisted PLD (PLD-RF) techniques on Si and SiO_2 substrates. In order to obtain nickel oxide thin films, a metallic target of nickel was irradiated in oxygen atmosphere.

The influence of substrate temperature and gas pressure on the optical properties, surface topography and structure of nickel oxide thin films in the presence of radio-frequency plasma was studied.

In Fig. 1, the PLD system assisted by a RF discharge (13.5 MHz) is shown. The RF plasma (bright) in oxygen was formed, and increased the reactivity of oxygen species, that combined with Nickel atoms.

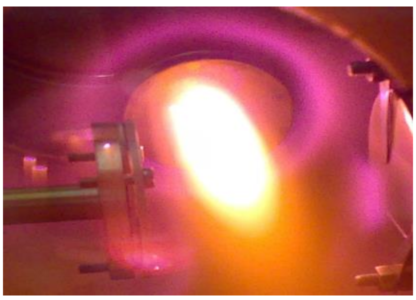

Figure 1.Plume of O_2 RF plasma

The surface topography of thin films was studied using atomic force microscopy (AFM).

Optical properties of nickel oxide thin films were investigated using spectroscopic ellipsometry.

The structural properties of the NiO thin films were investigated by X-ray diffraction (XRD).

2. Topographic and Optical Investigations (AFM, SE).

2.1. AFM

The AFM investigations revealed that the *presence of radio-frequency plasma has a very important role* to obtain uniform thin films without droplets and low roughness (see Fig.2). Comparing the two film surfaces deposited in the same conditions of pressure and laser fluence (0.1 mbar oxygen and 3.7 J/cm^2) excepting the presence of RF plasma, was observed that in the presence of beam radio-frequency the surfaces of the thin films have improved, becoming smoother with less droplets and a lower roughness.

RMS = 14 nm

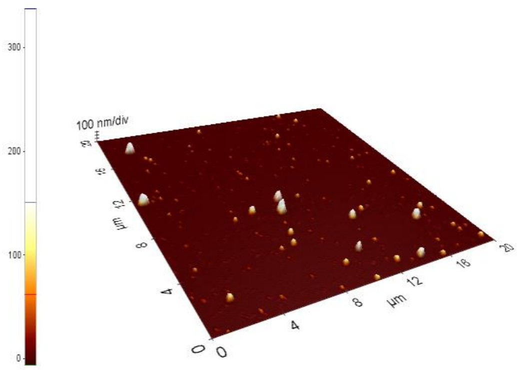

Figure 2. a) NiO thin film deposited on Si without discharge of RF plasma

RMS = 4.4 nm

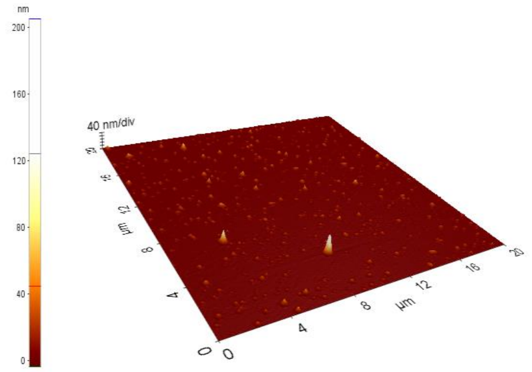

Figure 2). b) NiO thin film deposited on Si in the presence of RF plasma

FIG.2 AFM images of NiO thin films deposited on Si in the same conditions (0.1 mbar, 500 ° C, 3.7 J/cm2) by a) PLD and b) RF-PLD

2.2. SE

The optical properties of NiO thin films were characterized by SE method. The ellipsometric amplitude ratio Ψ and phase difference Δ were recorded at an incidence angle of 70°.

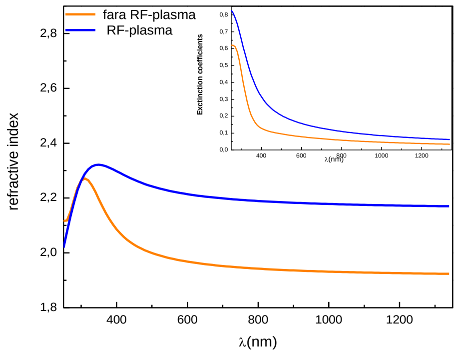

Figure 3. Dependence of optical constants n and k against λ for NiO/Si thin films deposited by PLD and PLD-RF

Thicknesses of the films, the roughness and the preliminary optical constants were obtained using a Cauchy dispersion and Urbach tail, in the 250 −1700 nm wavelength range. The final dielectric function of Nickel oxide thin films was calculated using Gauss oscillator model. The optical band-gap were extracted by Tauc plot.

In Figure 3 it can be seen that the value of refractive index n and extinction coefficient k are higher for the sample deposited by PLD-RF in comparison with sample grown by PLD.

The band gaps obtained for the NiO/Si samples deposited with PLD-RF method are in agreement with literature [5]**.** The growth of the nickel oxide thin films deposited on silicon substrate by PLD causes an increase of band gap energy of the samples at a value of Egap = 3.6 eV, and a decrease of band gap energy for samples deposited through PLD-RF method Eg = 3.3 eV.

2.3. Conclusions:

In principle, the RF discharge provided better condition in the PLD process to maintain high macroscopic homogeneity of the deposited thin films. For all samples of NiO/Si deposited by PLD and by PLD-RF the thickness are similar but the roughness are smaller in case of presence of radio-frequency discharge plasma.

3. References

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