Investigation of Optical Properties of Magnesium Oxide Films Obtained by Spray Pyrolysis Technique

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***Abstract*— Today more and more areas of optoelectronics used oxide materials, as a result, their study, is very important. Therefore, in this paper, we study optical properties of magnesium oxide films.**

Keywords—films; magnesium oxide, band gap, spray-pyrolysis, optoelectronics, optical properties.

I. Introduction

Magnesium oxide is promising material in semiconductor technology. It is used as a chemically stable buffer layer for growing high-temperature superconductors and ferroelectric materials, as a dielectric layer in plasma screens and microwave devices, as an alternative to SiO_2 insulator in high capacity electrical circuits and etc. Due to the high optical transparency in a wide wavelength range, MgO is a promising candidate for a variety of new applications, such as in lighting industry, optical systems and laser technology, control technology, as well as creation thermal sensors. Furthermore, the compound has been applied as a protective and antireflection layer in photovoltaic solar energy [1, 2].

There are various methods for obtaining MgO films, such as metalorganic molecular beam epitaxy [5], vapor phase epitaxy [3], sol–gel synthesis [4], reactive sputtering [6], pulsed laser deposition [7], chemical vapor deposition [8, 9]. Compare to methods that listed above the spray pyrolysis has a number of advantages. It does not require expensive vacuum equipment and high-quality substrates, it provides high-speed deposition of layers on large area substrates with various precursors.

During deposition process of semiconductor and dielectric films, a nanoparticle of precursor solution is spraying onto a heated substrate surface where the components of the solution under the influence of temperature interact to form chemical compounds. Chemicals are selected so that, in addition to the required compound, the remaining reaction products are volatile at the temperature of film deposition.

II. General Information

Magnesium oxide thin films were obtained by spray pyrolysis method. For sample preparation, the glass substrates were ultrasonically cleaned with distilled water for 6 minutes. 0.2 molar of magnesium chloride hexahydrate ($MgCl_2 \cdot 6H_2O$) were dissolved in deionized water and used as precursor solution. We used this precursor for the first time for the deposition of MgO film.

The air flow with a pressure of 0.2 MPa was used to transport dispersed precursor particles onto the heated substrate. The diameter of the nozzle is 0.2 mm. The distance between the nozzle and the heated substrate surface was equal to 15 cm. The substrates temperature during the obtaining of films was measured using a chromel-alumel thermocouple. The substrate temperature range for synthesis of the films was chosen from T_s = 640 K to 690 K with step Δ10 K. The procedure of obtaining oxides films has been described more detailed in [10]

The thickness of the samples was determined using a probe Profilers Dektak XT. In order to increase accuracy, three measurements of each sample were held.

The optical properties (transmittance, absorption and band gap energy) were measured at room temperature of the MgO films were determined by using 721G visible spectrophotometer in the wavelength range from 320 to 1000 nm.

III. Results and Discussion

Established that the average thickness of the samples ranged from 0.8 μm at T_s = 640 K to 2.2 μm at T_s = 690 K and increases with increasing substrate temperature.

Transmittance spectra of magnesium oxide film, deposited on glass substrate, are presented in Fig. 1. As can see from the figure the transmittance of films obtained at substrate temperature T_s = 620 and 630 K are lower than films deposited at higher temperature T_s.

The absorption spectrum of the film is required to calculate the band gap material E_g. Absorption spectra were determined from the spectral transmittance using the next equation:

$$\alpha = 1/d \cdot \ln(1/T) \quad (1)$$

where d is the film thickness and T is the transmittance [11-12].

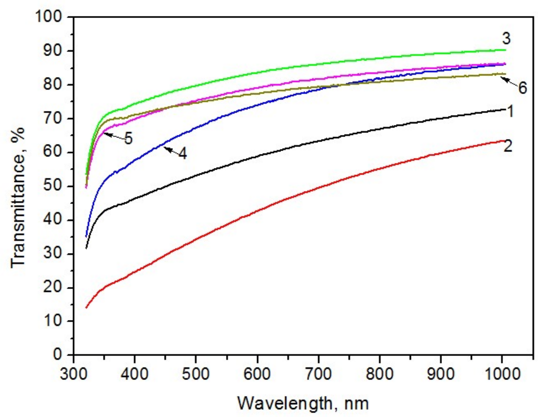

Fig. 1. Transmittance spectra of magnesium oxide film, deposited at substrate temperatures T_s = 620 K (1), 630 K (2), 640 K (3), 650 K (4), 660 K (5), 670 K (6)

$$\alpha h\nu = A(h\nu\text{-}Eg)^{n/2}, \quad (2)$$

where n is a number that depends on the nature of the transition.

In this case, its value was found to be 1 because MgO is direct gap semiconductor. Figure 2 shows calculated absorbance spectra.

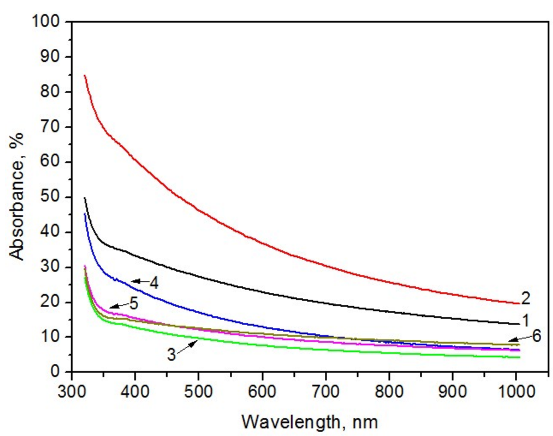

Fig. 2. Absorbance spectra of magnesium oxide film, deposited at substrate temperatures T_s = 620 K (1), 630 K (2), 640 K (3), 650 K (4), 660 K (5), 670 K (6).

Figure 3 is a typical Tauc plot, which shows $(\alpha h\nu)^2$ versus $h\nu$ for the magnesium oxide film obtained at substrate temperature T_s = 660 K. The intersection of the straight line with the $h\nu$-axis determines the optical band gap energy E_g [12]. It was found to be about 3.69 eV which is much lower than the bulk band gap of the MgO crystal. The same values of band gap energy were found for samples obtained at T_s = 670 - 690 K (Eg=3.63 – 3.69 eV). A few fewer values were found for sample deposited at T_s = 640 K and 650 K were 3.56 and 3.36 eV, respectively.

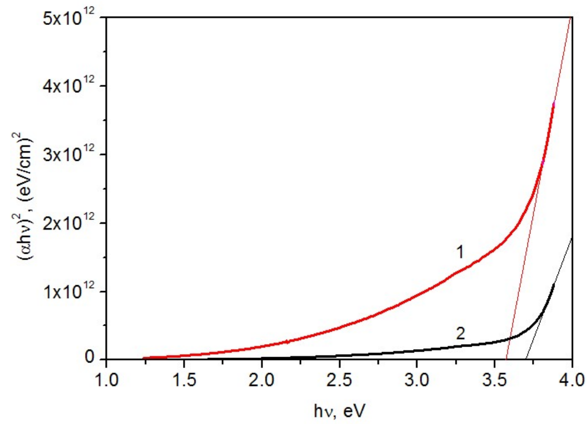

Fig. 3. E_g for the magnesium oxide film obtained at substrate temperature T_s = 640 K (1), 650 K (2),

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