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Effects of chemical stirring time on the physical properties for $LiNbO_3$ photonic film using of optical waveguide applications

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Abstract

Lithium niobate ($LiNbO_3$) structures are deposited on N-type silicon substrate by chemical sol-gel method. The chemical mixture was prepared with different time of stirrer (8 h, 24 h, 48 h) respectively. The nanostructures are deposited by spin coating at 3000 rpm for 30 sec and annealed 400 ^oC. They are characterized and analyzed by means of x-ray diffraction and Atomic Force Microscopy. The measurement results show that at increasing of mixing time, the photonic film start to crystallize to become a more regular, homogeneous distribution and Improving, which helps to use in the preparing of optical waveguide and the other of the Photonic and optoelectronics applications.

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1. Introduction

Lithium Niobate ($LiNbO_3$) is a very important optical material which is widely used by the photonics industry, mainly due to its excellent electro/acousto-optical properties[1, 2]. Lithium niobate is an important ferroelectric material because of its excellent piezoelectric, electrooptical, pyroelectrical and photo-refractive properties[3, 4]. It's a

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widely used as polar material for photonic applications[5, 6, 7]. It is a very attractive material for the fabrication of optical waveguide devices[8,9]. This crystal plays an important role as a high quality source material with low optical loss[10]. Integrated optics with lasers, modulators[11], and filters on a single $LiNbO_3$ wafer[12] are especially promising. On the other hand, polycrystalline lithium niobate films also have important technological applications for sensors, piezoelectric and pyroelectric devices due to its dielectric properties[13]. For Waveguide application therefore there are stringent requirements imposed on waveguide films Imperfections such as, porosity, refractive-index inhomogeneity[14,15], and surface roughness, which play an important role in device performance[16,17].

$LiNbO_3$ thin films were prepared using various experimental techniques such as sputtering[18], liquid phase epitaxial (LPE) [19], metal organic chemical vapor deposition (MOCVD) [20], soft- chemistry[21], hydrothermal methods[22], and pulsed laser deposition (PLD)[23].

This paper reports on the production of $LiNbO_3$ films by utilizing the Pechini route (Sol-gel). The phase evolution with the stirring time was studied by using XRD and AFM. These characterizations and studied is the main of our work and application on optical waveguides of nano and micro photonics $LiNbO_3$ thin films because of the purity of $LiNbO_3$, crystallization, homogeneity, grain size and surface roughness that parameters give us better work of optical waveguides. Optical waveguides of high index contrast enable small cross section dimensions and small bending radii of curved waveguides, a prerequisite for high density integrated optics

2. Experiment process

The preparation procedure for $LiNbO_3$ films by using Nb_2O_5 (ultra-pure, 99.99%), and citric acid (CA.) are used without further purification. The solution is prepared by mixing Li_2CO_3, Nb_2O_5, citric acid and Ethylene Glycol. The molar ratio between Li_2CO_3 and Nb_2O_5 was 1:1 in order to maximize the formation of $LiNbO_3$ stoichiometry phase. Firstly, the Li_2CO_3, Nb_2O_5, and citric acid were dissolved in ethylene glycol with heating and stirring at 90 ^oC for (8 h, 24 h, 48 h) hours, then mixed all together, with continued heating and stirring at the 90 ^oC for (8 h, 24 h, 48 h) hour. To obtain homogeneous and crack-free films of $LiNbO_3$, the precursor was deposited by spin coating technique on silicon substrates at a spinning speed of 3000 rpm for 30 sacs. Seven layers were prepared, the film was dried at the 120 ^oC for 5 min and calcined at 250 ^oC for 30 min in static air and oxygen atmosphere to remove the organics then it was annealing at 400 ^oC for 2 hours. The structural evolution of the as-prepared thin films was examined using a high-resolution X-ray diffraction (HR-XRD), (X'Pert Pro MRD PW3040 system diffractometer, PANalytical Company, Netherlands) system equipped with Cu-K α-radiation of wavelength λ = 0.15418 nm at 40 kV and 30 mA. The Atomic Force Microscope (AFM) (SPM-9600, Scanning Probe Microscope, Shimadzu, Japan) for investigating the roughness of LiNbO3. The optical properties were investigated using Photoluminescence (PL) spectroscopy system (Jobin Yvon model HR 800 UV system, Kyoto, Japan) at room temperature using He-Cd laser (λ=352 nm).

3. Results and discussion

3.1 structural properties

The XRD results of $LiNbO_3$ nanostructures deposited on Si substrates grown by sol–gel method is shown in Fig.1. The crystalline structure of $LiNbO_3$ nanostructures is found to have hexagonal structure. It is observed from Fig. 1 that the peaks at 2θ = 23.634, 32.637, 34.674, 48.355, 53.106, and 55.879 correspond to (012), (104), (110), (024), (116) and (122) planes. So, the crystalline structure will be more crystalline and more purity for $LiNbO_3$ by increasing the stirrer time. Where notes in Fig. 1 (c) for the disappearance of the peaks of Nb_2O_5, decline the intensities of the peaks for $LiNb_3O_8$, on the other hand increase in the intensities of the peaks of $LiNbO_3$. The measured structural properties of $LiNbO_3$ nanostructures are listed in Table 1. Crystallite size (D) was calculated using Scherrer's formula[24].

$$D = K\lambda / \beta \cos\theta \quad (1)$$