Preparation Technique of AlN Piezoelectric Thin Film

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Abstract— AlN piezoelectric thin films were prepared by DC magnetron reactive sputtering. A good *c*-axis orientation is essential for obtaining high piezoelectric coefficients. Therefore, the experiments were designed about the four parameters of the sputtering power, volume ratio of N_2 and Ar, gas pressure, and substrate temperature, in order to make sure the deposition parameters of the *c*-axis orientation AlN film. The crystal structure and full width at half maximum (FWHM) of the thin films were analyzed by X-ray diffraction (XRD). The results show that the optimal process parameters were the sputtering power of 200 W, volume ratio of N_2 and Ar of 2 : 8, gas pressure of 3.75 mT. The results provide the experiment evidence and process base for the next study.

1. INTRODUCTION

Aluminum nitride (AlN) is a wide band gap III-V Piezoelectric material with high CMOS compatibility. AlN piezoelectric thin films have excellent properties of physical and chemical, such as good chemical stability, high piezoelectric coefficient, high band gap, and high dielectric constant and so on which led to widespread concern [1–3]. AlN materials are widely used in the ultraviolet range of the light-emitting diode (LED), short-wavelength detectors, field emission displays, and integrated circuit packaging, dielectric isolation and insulation, and other fields.

The lattice orientation of AlN films has great influence on the center frequency and electromechanical coupling coefficient of acoustic wave devices. Control piezoelectric film growth direction along the *c*-axis is very important (002), because only when propagate along the surface of AlN thin films that have high lattice *c*-axis orientation, the surface acoustic wave will have fastest phase speed, meanwhile the film can shows the most excellent piezoelectric properties, so as to achieve a higher electromechanical coupling coefficients [4, 5]. Thus control piezoelectric film growth direction along the *c*-axis (002) is very important. In order to obtain high-quality AlN films, we need to understand the impact factors of the thin films growth and control the behavior of thin films.

Almost all of the deposition techniques, including reactive sputtering [6, 7], chemical vapor deposition [8] and molecular beam epitaxial [9], have been used to deposit aluminum nitride film. In these techniques, the magnetic reactive sputtering has advantages of a simple operation, low equipment cost, low deposition temperature and deposition rate. thus it is the most common method.

2. EXPERIMENT PROCEDURES

There are many methods to prepare AlN films; in this paper we choose DC magnetron reactive sputtering method. Reactive magnetron sputtering has advantages of a simple operation, low equipment cost, low deposition temperature and deposition rate. The aluminum nitride thin films with a typical thickness of about 200 nm were deposited on Pt-covered Si (100) substrate, and using nitrogen as a reaction gas by a chemical reaction. And substrate temperature set 300 degree. Prior to deposition the wafers were cleaned with acetone and deionised water. The deposition chamber was filled with a gas composition consisting of a mixture of N_2 and Ar. The aluminum target, with a purity of 99.999% had a diameter of 50.8 mm. After evacuation of the deposition chamber below 5×10^{-6} mbar, argon gas was introduced to pre-sputter the target for 10 min prior to each film deposition for purification purposes.

3. RESULTS AND DISCUSSION

X-ray diffraction (XRD) technique was used for phase analysis. Figure 1 shows the XRD patterns of samples deposited with different sputtering powers. As can be seen from Figure 1, when sputtering power are 100 W, 150 W and 250 W, films growth orientation is (110), and films growth orientation is (002) only when sputtering power is 200 W. Table 1 lists FWHM of the (002) peak for the AlN films deposited at various sputtering powers. From Figure 1 and Table 1, Summed up that 200 W is the best sputtering power to the preparation of high c-axis orientation of AlN films.

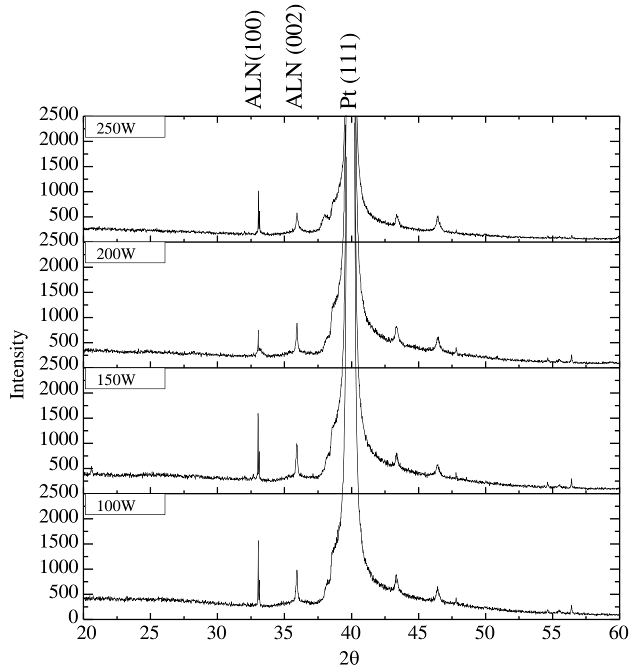

Figure 1: XRD patterns of samples deposited with different sputtering powers.

Table 1: FWHM of the (002) peak for the AlN films deposited at various sputtering powers.

Sputtering power	**FWHM**
100 W	0.15290
150 W	0.15484
200 W	0.15325
250 W	0.23614

Figure 2 show the XRD patterns of samples deposited with different volume ratio of N_2 and Ar. As can be seen from Figure 1, only when volume ratio of N_2 and Ar is 3 : 7, films growth orientation is (002). Table 1 lists FWHM of the (002) peak for the AlN films deposited at volume ratio of N_2 and Ar. The FWHM is smaller, the lattice orientation of films is better. As a result, when volume ratio of N_2 and Ar is 3 : 7, high c-axis orientation of AlN films can be obtained.

Table 2: FWHM of the (002) peak for the AlN films deposited at volume ratio of N_2 and Ar.

volume ratio of N_2 and Ar	**FWHM**
3 : 7	0.12575
4 : 6	0.1388
5 : 5	0.14638
6 : 4	0.14644
7 : 3	0.19923

Figure 3 shows the XRD patterns of samples deposited with different gas pressure. As can be seen from Figure 3, the intensity of the (002) peak more than the (100) peak when gas pressure is 3.75 mT. And FWHM is lowest when gas pressure is 3.75 mT. So 3.73 mT is the best pressure to obtain high c-axis orientation of AlN films.

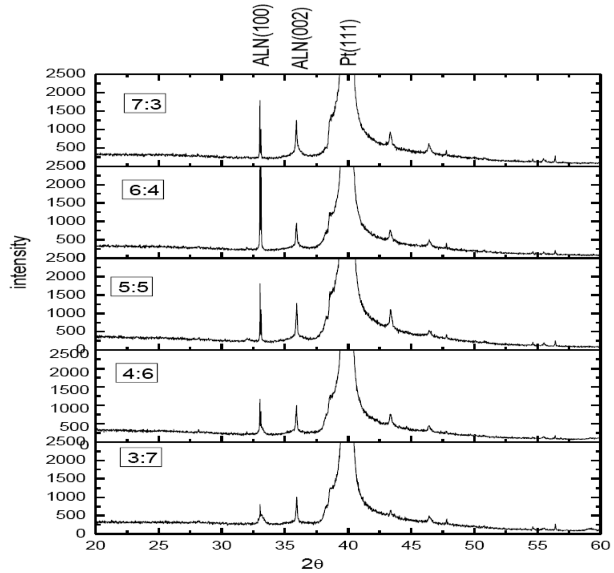

Figure 2: XRD patterns of samples deposited with different volume ratio of N_2 and Ar.

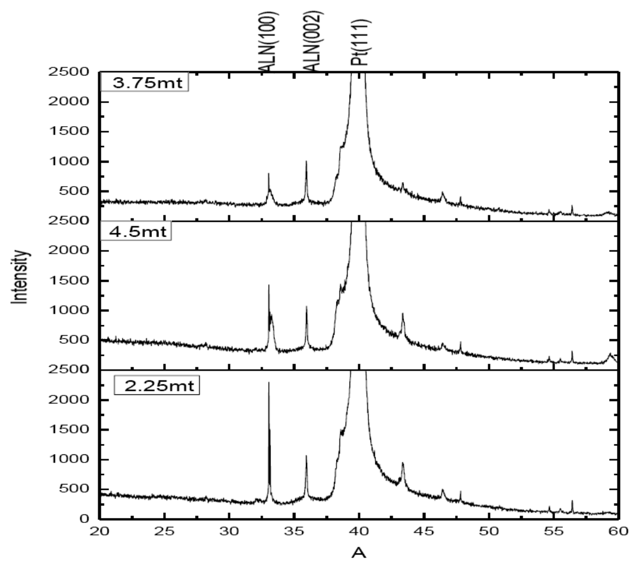

Figure 3: XRD patterns of samples deposited with different gas pressure.

Table 3: FWHM of the (002) peak for the AlN films deposited at various gas pressure.

gas pressure	FWHM
2.25 mT	0.14581
3.75 mT	0.12923
4.5 mT	0.12923

4. CONCLUSIONS

In this work, the film samples were prepared under different conditions for performance testing. According to the results of XRD patterns and FWHM of samples, AlN thin films with a high *c*-axis orientation can be obtained well when the sputtering power of 200 W, volume ratio of N_2 and Ar of 2 : 8 and gas pressure of 3.75 mT.

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