



Etch characteristics of indium zinc oxide thin films using inductively coupled plasma of a Cl_2/Ar gas

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ABSTRACT

Inductively coupled plasma reactive ion etching of indium zinc oxide (IZO) thin films masked with a photoresist was performed using a Cl_2/Ar gas. The etch rate of the IZO thin films increased as Cl_2 gas was added to Ar gas, reaching a maximum at 60% Cl_2 and decreasing thereafter. The degree of anisotropy in the etch profile improved with increasing coil rf power and dc-bias voltage. Changes in pressure had little effect on the etch profile. X-ray photoelectron spectroscopy confirmed the formation of InCl_3 and ZnCl_2 on the etched surface. The surface morphology of the films etched at high Cl_2 concentrations was smoother than that of the films etched at low Cl_2 concentrations. These results suggest that the dry etching of IZO thin films in a Cl_2/Ar gas occurs according to a reactive ion etching mechanism involving ion sputtering and a surface reaction.

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1. Introduction

Transparent conducting oxides (TCO), such as indium tin oxide (ITO), zinc oxide (ZnO), and tin oxide (SnO_2), which have high electrical conductivity and optical transparency, have been widely used as transparent electrodes in flat panel displays, touch panel displays, organic light emitting diodes, and photovoltaic cells [1–6]. ITO thin films have been generally used in these applications but they first need to be heat-treated at temperatures above 300 °C during or after deposition in order to obtain high transmittance and low resistivity [1]. High temperature annealing of ITO films limits the possibility of fabricating devices on plastic substrates.

Recently, a number of studies have attempted to exploit the potential of indium zinc oxide (IZO) thin films to serve as a novel transparent electrode because these films show high transmittance in the visible region, low resistivity, and good surface morphology without heat treatment at high temperatures after deposition [1,4]. Due to these unique properties, IZO thin films can be applied as a transparent electrode in flexible displays and solar cells as well as in conventional devices requiring TCO films.

The deposition process of IZO thin films has been studied extensively and various deposition methods including chemical vapor deposition, sputtering, pulsed laser deposition, and sol-gel techniques have been reported. From these studies, IZO films with excellent properties with respect to a variety of applications have been obtained. To realize sophisticated and high density devices using IZO films, the patterning and etching processes of the films should be simultaneously developed. In recent studies, dry etching of IZO

thin films was performed using Ar/Cl_2 , $\text{Ar}/\text{CH}_4/\text{H}_2$, IBr and BI_3 plasmas [7–9]. However, the etch characteristics, such as the etch rate and etch profile as well as the etch mechanism, were not evaluated under various etch parameters in an Ar/Cl_2 gas chemistry.

In this study, inductively coupled plasma reactive ion etching (ICPRIE) of IZO thin films patterned with a photoresist (PR) were examined in terms of the etch rate and etch profile using Cl_2/Ar gas. X-ray photoelectron spectroscopy (XPS) and atomic force microscopy (AFM) were used to determine the etch mechanism of IZO thin films.

2. Experimental details

IZO thin films were prepared on a Si substrate by radio frequency (rf) magnetron sputtering (Flexlab System 100, A-Tech system, Korea). The target was composed of In_2O_3 and ZnO at a 9 to 1 wt.% ratio. The 1500–2500 Å thick films were patterned by a conventional lithography process using a 1.2 μm thick photoresist (AZ1512).

In this study, the etching of IZO thin films was carried using commercial ICPRIE equipment (Etch-100 M, A-Tech system, Korea) that can generate a high density plasma. The ICPRIE system is composed primarily of two parts, a main process chamber and a load lock chamber. A 13.56 MHz rf power supply was connected to a coil installed on the top of the main process chamber to generate high density plasma. Another 13.56 MHz rf power source was capacitively coupled to the substrate susceptor, inducing a self dc-bias voltage to control the ion energy in the plasma. The main process chamber was evacuated to a base pressure of $1\text{--}2 \times 10^{-6}$ Torr using a turbomolecular pump. The substrate susceptor was maintained at a constant temperature of 15 °C using a chilled fluid and the substrate was cooled by cold helium gas filled between the substrate and susceptor.

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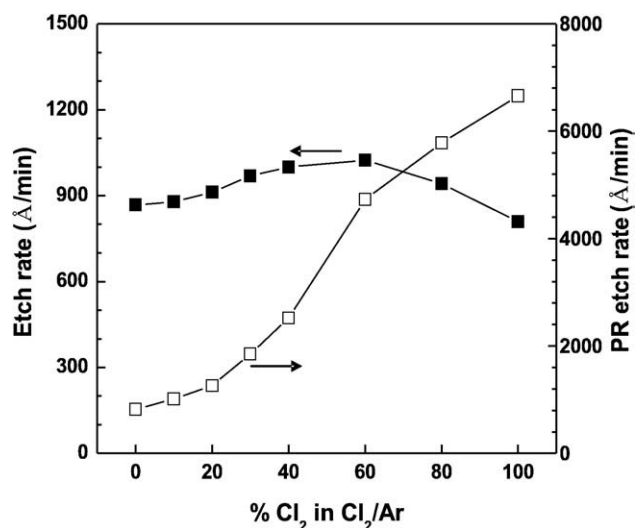
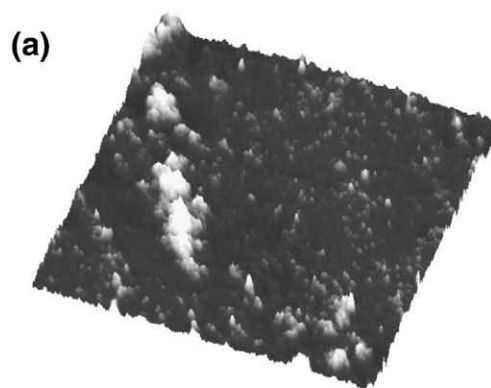
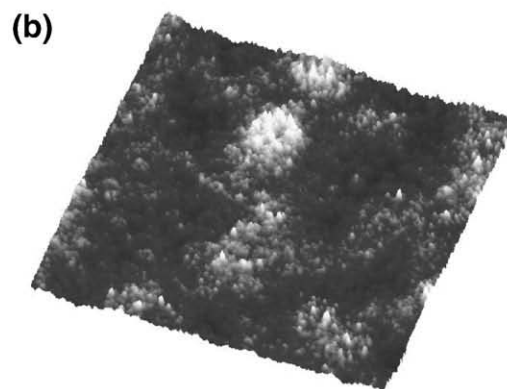


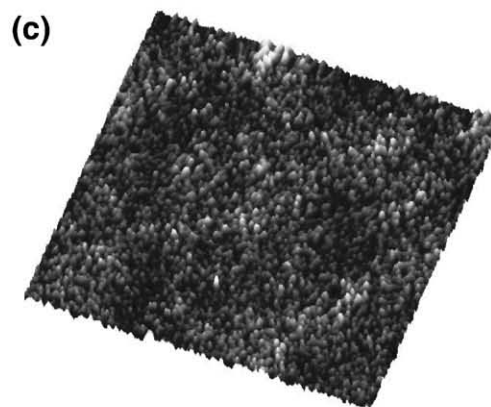
Fig. 1. Etch rate of IZO thin films under varying Cl₂ concentrations in Cl₂/Ar gas; coil rf power of 700 W, dc-bias voltage of 200 V, gas pressure of 5 mTorr.



RMS : 0.874 nm



RMS : 0.678 nm



RMS : 0.463 nm

Fig. 3. AFM images of IZO thin films etched at (a) pure Ar, (b) 10% Cl₂/Ar, and (c) 60% Cl₂/Ar; coil rf power of 700 W, dc-bias voltage of 200 V, gas pressure of 5 mTorr.

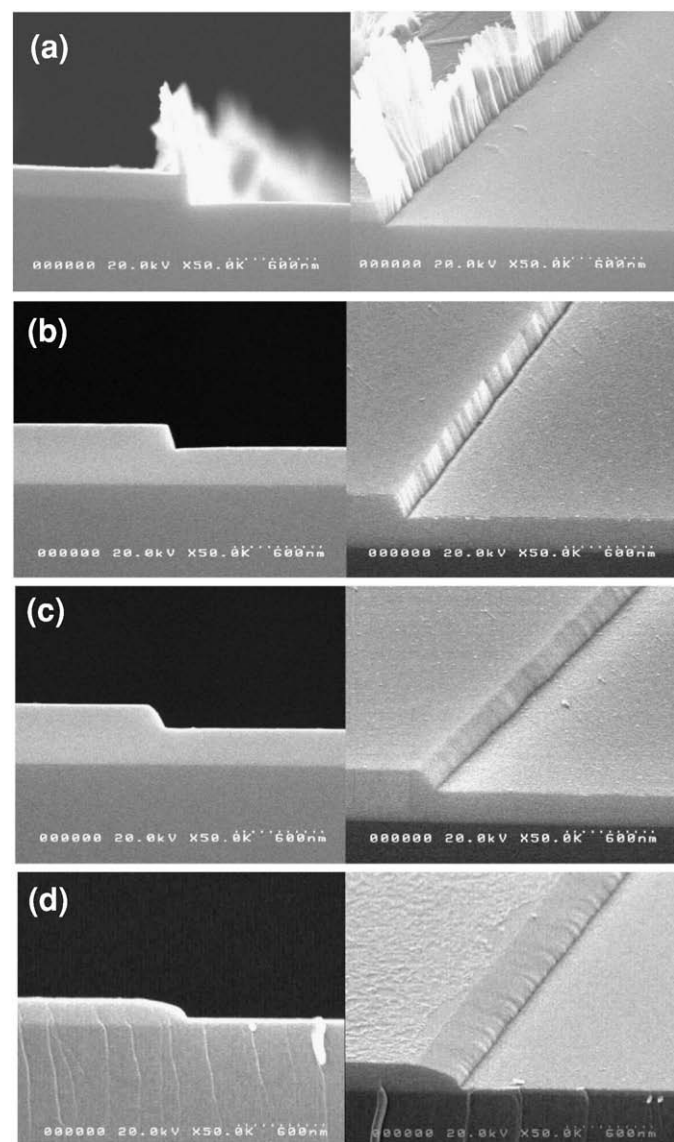


Fig. 2. FESEM micrographs of IZO thin films etched at (a) pure Ar, (b) 10% Cl₂/Ar, (c) 30% Cl₂/Ar, and (d) 60% Cl₂/Ar; coil rf power of 700 W, dc-bias voltage of 200 V, gas pressure of 5 mTorr.

Cl₂/Ar gas was used as the etch gas and was fed into the main chamber at a flow rate of 30 sccm. The etch rates and etch profiles of the IZO thin films were examined at various Cl₂ concentrations. In addition, the effects of the etch parameters such as coil rf power, dc-bias voltage to substrate, and gas pressure were investigated. An alpha step (Tencor P-1) was used to measure the etch rates. The etch profiles were observed by field emission scanning electron microscopy (FESEM; Hitachi S-4300). In addition, XPS (Thermo Scientific K-Alpha) was used to examine the etch products generated during etching of the IZO films in Cl₂/Ar plasma. The surface morphology of the etched films was examined by atomic force microscopy (AFM; NS4A).

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