Improvement in the Setup of the Inline Sputter System and the ITO Sputtering Process by Measuring and Controlling the Base Vacuum Level

Min Hyung Ahn**, Eou Sik Cho*, and Sang Jik Kwon*

Abstract

A DC-magnetron inline sputter was established, and the influence of the base pressure on the structural charact eristics of the ITO thin films was studied. When the inline sputter system was established and operated for ITO sp uttering, its initial vacuum level did not go below 5×10^{-6} torr. The vacuum leak test was conducted by measuring t he elapsed time until the vacuum level reached 1×10^{-6} torr.

The base pressure was successfully maintained at 1×10^{-6} torr for 900 min, and the uniformity of the ITO film that had been deposited at this pressure significantly improved.

Keywords : Inline sputtering, vacuum level, leak test, deposition

1. Introduction

In the fabrication of flat-panel display modules such as liquid crystal display (LCD) and plasma display panel (PDP), the sputtering method is one of the most important process steps as all the metal layers and all the transparent conductive layers are deposited using this method [1]. Since recently, for the use of a flexible substrate such as polyethylene terephalate (PET) instead of a glass substrate, the sputtering method is also being used for the deposition of the insulating layers, such as SiO_x of SiN_x, because of its lower process temperature compared with that of the other processes, such as chemical vapor deposition (CVD).

For the sputtering of the insulating materials and the transparent conductive materials, including the oxide materials, the reactive-frequency (RF) sputtering or magnetron sputtering methods have been used in various ways [2-4]. As the glass substrates of display panels become larger, it becomes increasingly difficult to control the uniformities of the sputtered layers, such as the thickness and the resistivity, and to remove the unpredicted particles on the glass substrate. To obtain high-quality sputtered layers, it is important to maintain a high vacuum level in the process chamber of the sputter equipment before the inflowing of Ar gas and before plasma discharge. It is not easy to create a high-vacuum condition, however, after each glass substrate is loaded onto the sputter, in terms of productivity [5].

A magnetron inline sputtering system was established in line with this study, and a second-generation-sized (370mm×470mm×1.1mm^3) glass substrate can be sputtered therein. An inline equipment was used to obtain high productivity in the manufacture, and the sputtering process was carried out during the movement of the glass substrate. To maximize the productivity, the vacuum level in the process chamber of the sputter system was systematically improved, and the indium tin oxide (ITO) layers were sputtered. The uniformities of the sputtered ITO layers were compared for the improvement of the vacuum level in the process chamber before the inflow of Ar gas and the plasma discharge [6-9].

2. Experiment

For the experiment, a DC magnetron inline sputter system was established, and the size of the ITO target that was used was 540×165×7 mm^3. The size of the glass substrate was 370×470×1.1 mm^3, and the substrate was transferred

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* Member, KIDS; ** Student Member, KIDS
Corresponding Author: Sang Jik Kwon
Department of Electronics Engineering, College of IT, Kyungwon University San 65, Kyuongwon Univ., Bokjeong-dong, Sujeong-gu, Seongnam City, Kyunggi-do 461-701, Korea
E-mail : sjkwon@kyungwon.ac.kr
Tel : 82-2-31-750-5319 **Fax** : 82-2-31-750-8696

using a transfer jig, to which the substrate was affixed using the roll-drive method. The process conditions were controlled according to the transfer speed of the jig during sputtering. For the partial vacuum formation pump, which uses the inline system, Edward's Oil Rotary Vane Pump (1,000 L/min) was used, and for high-vacuum formation, Osaka vacuum TMP (Turbo Molecular Pumps 2,400 L/sec) was used. The vacuum level measurement gauges that were used were Helix technology's Granville-Phillips mini-convection gauge 275 series and micro-ion gauge 354 series. The heating of the substrate was done using a heater, which conducts heating up to the maximum 300℃ possibility. Fig. 1 is a schematic diagram of the established inline sputter system.

It is possible to establish four sputter guns in front of the in-line sputter as shown in Fig. 1. Four other sputter guns can also be placed at the back of the equipment. One gun bay was affixed to the inline system that was used in the experiment, and the chamber caused defecation at the load-lock chamber and the process chamber. For the progress of the process at the time of the process chamber quick sputtering, a vacuum state must always be maintained because a quarantined isolation valve is used between the load-lock chamber and the process chamber. The equipment is stabilized after the establishment of the inline system to remove the moisture and impurities inside the chamber through vacuum formation, which leads to continuous pumping and where quicker vacuum formation is possible.

The leak test process must always be undertaken before operating all the vacuum equipment as all the impurities, such as moisture, can be pumped out through vacuum pumping, and as this will allow a high vacuum level to be

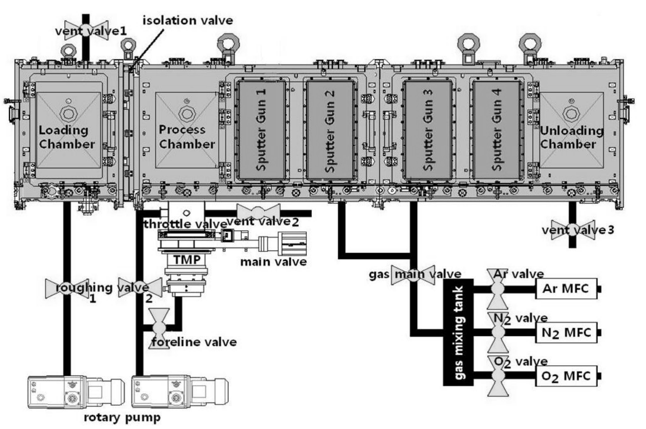


Fig. 1. Schematic diagram of the established inline sputter system.

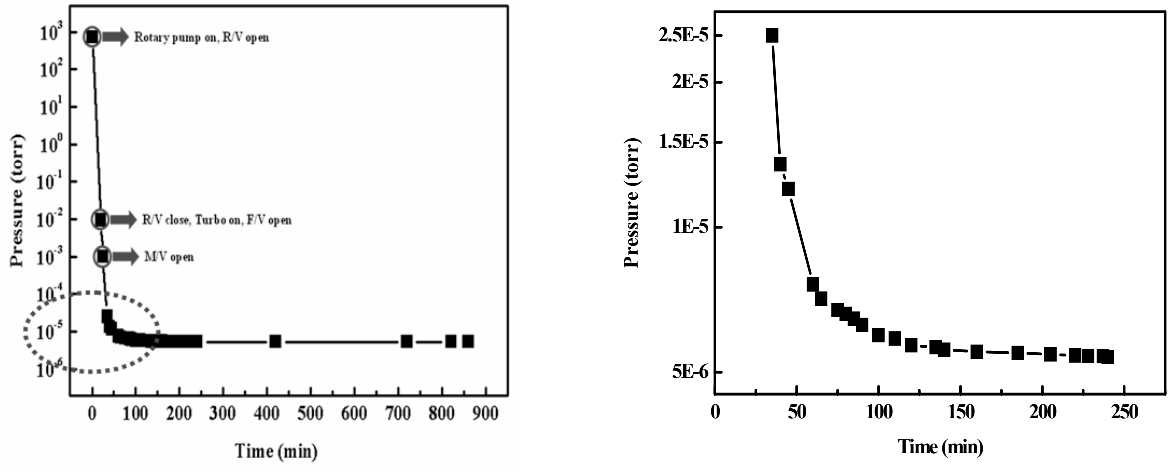
quickly obtained. Even if no leakage occurs before shipment, leakage may occur due to shock while the equipment is in transit. As such, the leak test process is necessary after the installation of the vacuum equipment. As the inline system is a mass production system, it requires the quick conduct of the leak test. Inline sputtering is an inline system that is made up of two parts: the load-lock chamber and the process chamber. During the sputtering process, however, the process chamber is sustained in a vacuum condition. It is known that the vacuum level depends on the volume capacity of the chamber and the exhaust capacity of the turbo pump. In this experiment, the pumping time was checked when the vacuum level of the process chamber was near the low 10^{-6} torr, at room temperature. The experiment results were then analyzed, and it was found that the parts that leaked used helium. After fixing the parts that leaked, the leak test was again conducted.

3. Results and Discussion

Fig. 2(a) shows the vacuum profile in the process chamber of the inline sputter system before sputtering, when it was established. The results show that it was not possible for the vacuum level of the chamber to reach a level lower than 10^{-6} torr in spite of long-time pumping after the main valve (M/V) was opened. Especially, the vacuum level was saturated from about 100 min and did not change despite further pumping, as shown in Fig. 2(b). For the improvement of the pumping process in the chamber, it was thought that there were some parts that leaked from the standpoint of the exhaust capacity of the turbo pump. Therefore, a leak test process was performed using helium gas.

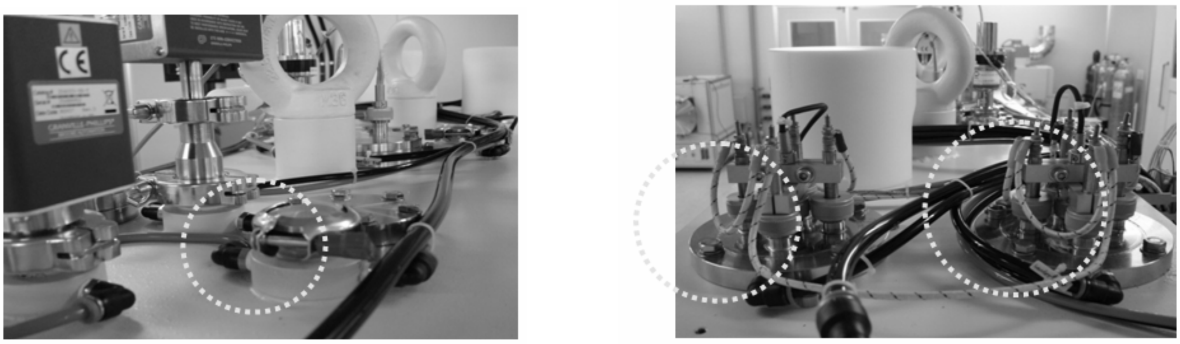
Fig. 3 shows the three places where leaks were found during the leak tests: (a) the spare ports for the vacuum gauge or thermocouple; (b) the heater and the thermocouple; and (c) the positions of (a) and (b) in the inline sputter system. The leakage problem was attributed to shock while in transit, for the establishment of the system. Therefore, the parts that leaked were fixed, and the vacuum test was again conducted. No further leaks were found when the vacuum profile was analyzed and when the leak positions were amended.

For the outgassing process, the chamber was heated up to 200℃ for 1 hr, and room temperature was reached. After the outgassing, it became possible to find a new leak again.



(a) (b)

Fig. 2. (a) A vacuum profile in the process chamber before sputtering. (b) The enlarged part of (a) between 30 and 250 min.



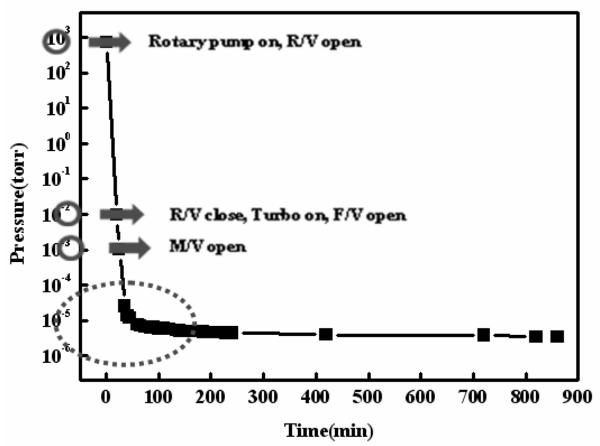
(a) (b)

(c)

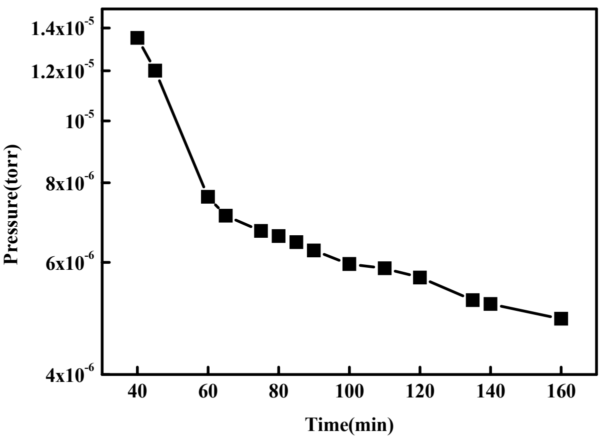
Fig. 3. The places where leaks were found during the leak tests: (a) spare ports, (b) heater and thermocouple, and (c) the positions of (a) and (b) in the inline sputter system.

Fig. 4 shows the vacuum profile after outgassing at 200℃. Compared with Fig. 2, the vacuum level did not improve in spite of the leak test after outgassing. Therefore, it was thought that new leakages occurred after outgassing. The leak test was thus conducted one more time.

Fig. 5(a) and Fig. 5(b) show the heater on the unload section of the inline sputter, where a leakage was found, and the position of (a) in the sputter system, respectively. After changing the heater, it became possible for the vacuum level to reach 10^{-6} torr, and it took less time to reach such vacuum level compared with the precious vacuum profiles. For the contamination of the base vacuum, indium tin oxide (ITO) films were deposited at 1×10^{-5} and 1×10^{-6} torr. The surface profiles of the deposited ITO films were then compared, as shown in Fig. 7(a) and Fig. 7(b). In the sputtering process, the Ar and O_2 gas flows were fixed at 50 sccm and at 1 sccm, respectively. The working pressure and DC power were 5 mtorr and 1 kW, respectively. From the results, it was apparent that the uniformity of the ITO films that had been deposited at a lower base vacuum was superior and less rough than that which had been deposited at a higher base vacuum.

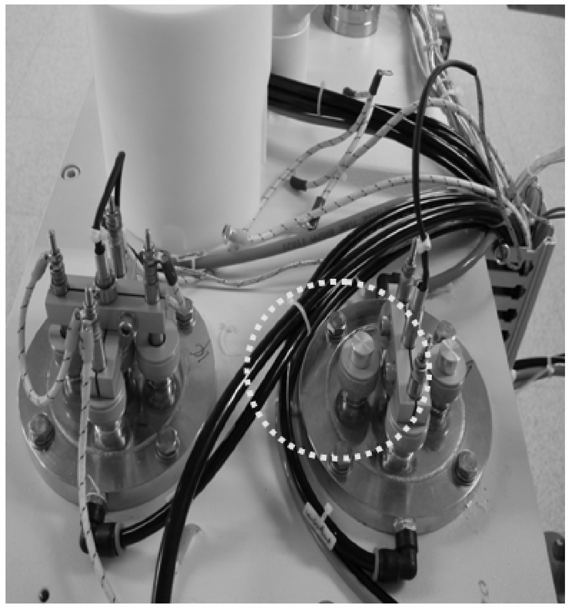


(a)



(b)

Fig. 4. (a) A vacuum profile of Fig. 2(a) after the leak test and repair. (b) The enlarged part of (a) between 40 and 160 min.



(a)

(b)

Fig. 5. The places where leaks were found during the leak tests: (a) heater, and (b) the position of (a) in the inline sputter system.

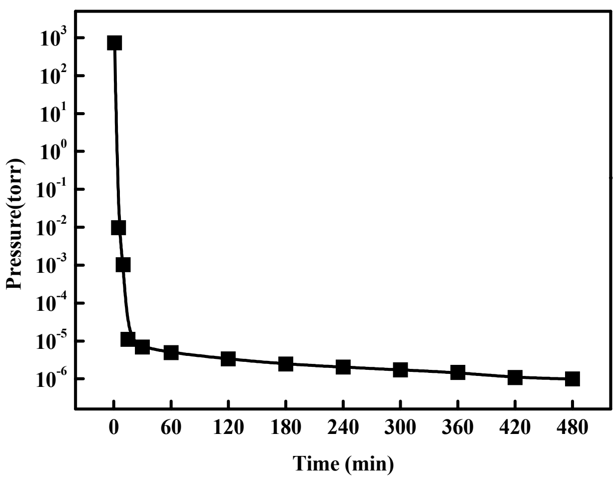


Fig. 6. A vacuum profile of Fig. 2(a) after the second leak test and repair.

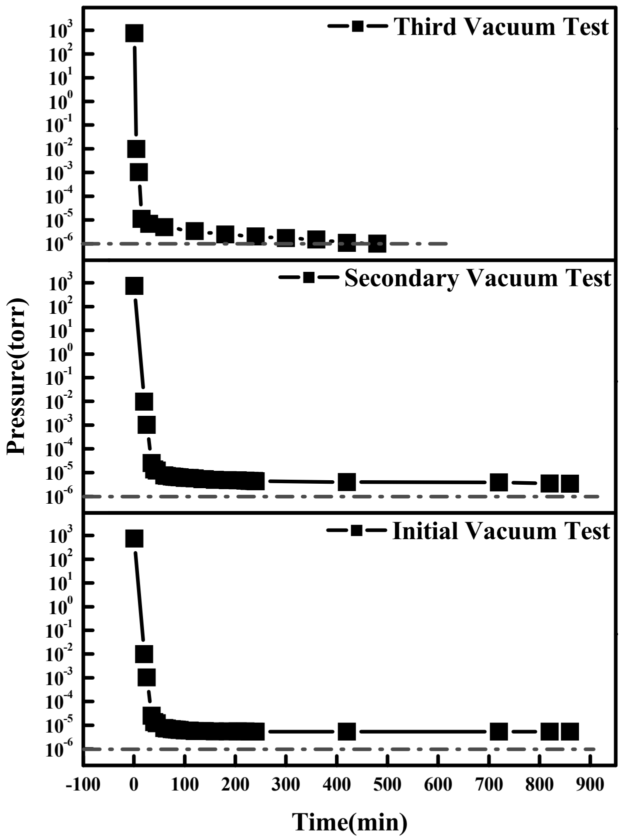
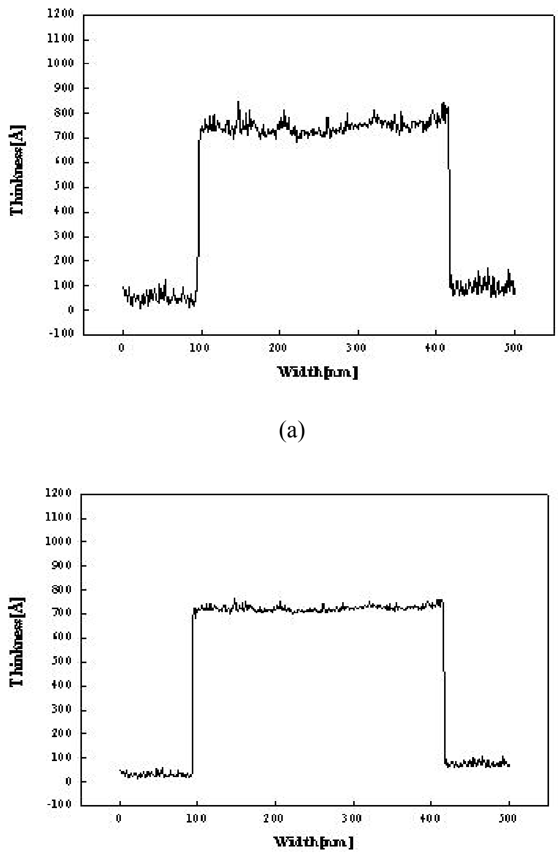


Fig. 7. The relationship between the base vacuum levels of the process chamber and the times required by the vacuum level obtained from Fig. 2(a), Fig. 4(c), and Fig. 6.



(a)

(b)

Fig. 8. Surface profiles of the sputtered ITO films with base vacuum levels of (a) 10^{-5} torr and (b) 10^{-6} torr.

4. Conclusions

The initial vacuum level of the inline sputtering system was controlled at a sufficiently low level. The surface profile of the ITO films measured by the alpha-step profilometer showed that the films that had been deposited at 1×10^{-6} torr showed much enhanced uniformity compared to those that had been deposited at 5×10^{-6} torr.

A high vacuum level is very important for the inline sputter. This is because the vacuum level has a direct effect on the mean free path of the primary particle, on pollution prevention from other gases (oxide or nitride will be generated when the pure metal is deposited), and on the reduction of the threshold voltage of the emission electron from the conductive target surface. (In the atmosphere, the breaking voltage is always higher than 20 kV, but it is 0.6~1 kV when the vacuum is lower than ~mtorr.)

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