

The Influence of Charged Static Electricity on LCD Glass and Neutralization Characteristic by Soft X-ray

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Abstract

We observed that static electricity has an influence on the etching uniformity of dry etching process. When the static electricity was applied from −200[V] to −1000[V] on glass substrates, the etching rate uniformity was changed to 1.5%~15%. In this experiment, the soft X-ray to neutralize static electricity was adopted as one of neutralization methods. As an experimental result, soft X-ray irradiation improved neutralization capability on the surface of LCD glass substrate within the short time, about 15~30sec. The difference of etching rate uniformity was below 0.5%.

Keywords : Static electricity, TFT-LCD, soft X-ray, neutralization, decay time

1. Introduction

In fabrication of the TFT-LCD, the generation of static electricity has been one of the major factor in yield and reliability of final products and a grave impediment in raising the device integration. In the TFT-LCD process, as the LCD glass progresses toward large size, static electricity inevitably is occurred by handling in the manufacturing process. These charges on the glass cause two impediments. One is the particles which are introduced by electrostatic force. These particles make dislocation or point defect. The other is that TFT is damaged by electrostatic discharge [1-2]. Therefore, the neutralization of charged static electricity is indispensable to increase the yield and reliability in LCD manufacturing process.

In dry etching process, it was shown that the static electricity also had a serious influence on uniformity of etching surface profile and etching rate. Until now, various methods are introduced as an anti-static technology [3-4].

In this experiment, the soft X-ray was adopted as one of methods for neutralization [5]. The neutralization capability and characteristics of soft X-ray were studied according to temperature, humidity, air flow rate, the irradiation distance, angle and chamber ambient of soft X-ray exposure.

2. Experimental set-up

2.1 The influence of static electricity in dry etching process

The plasma etcher is for 300x350mm^2 LCD glass(Japan PSC Co, DES-A325E). It is mainly used for a-Si and Ta etching process in manufacturing line. This is the parallel electrode type to have anisotropic etching characteristic. For the experiment, two kinds of LCD glass samples were prepared. The size of them was 10x10cm^2 and 2x3cm^2 respectively. On the glass samples, 1000Å thick a-Si layer was deposited by LPCVD. Because of two kinds of glass sample size, two kinds of Al-meshes were prepared for artificially making the static electricity. The pattern of Al-mesh was made by hexagonal holes like a honeycomb. To make the static

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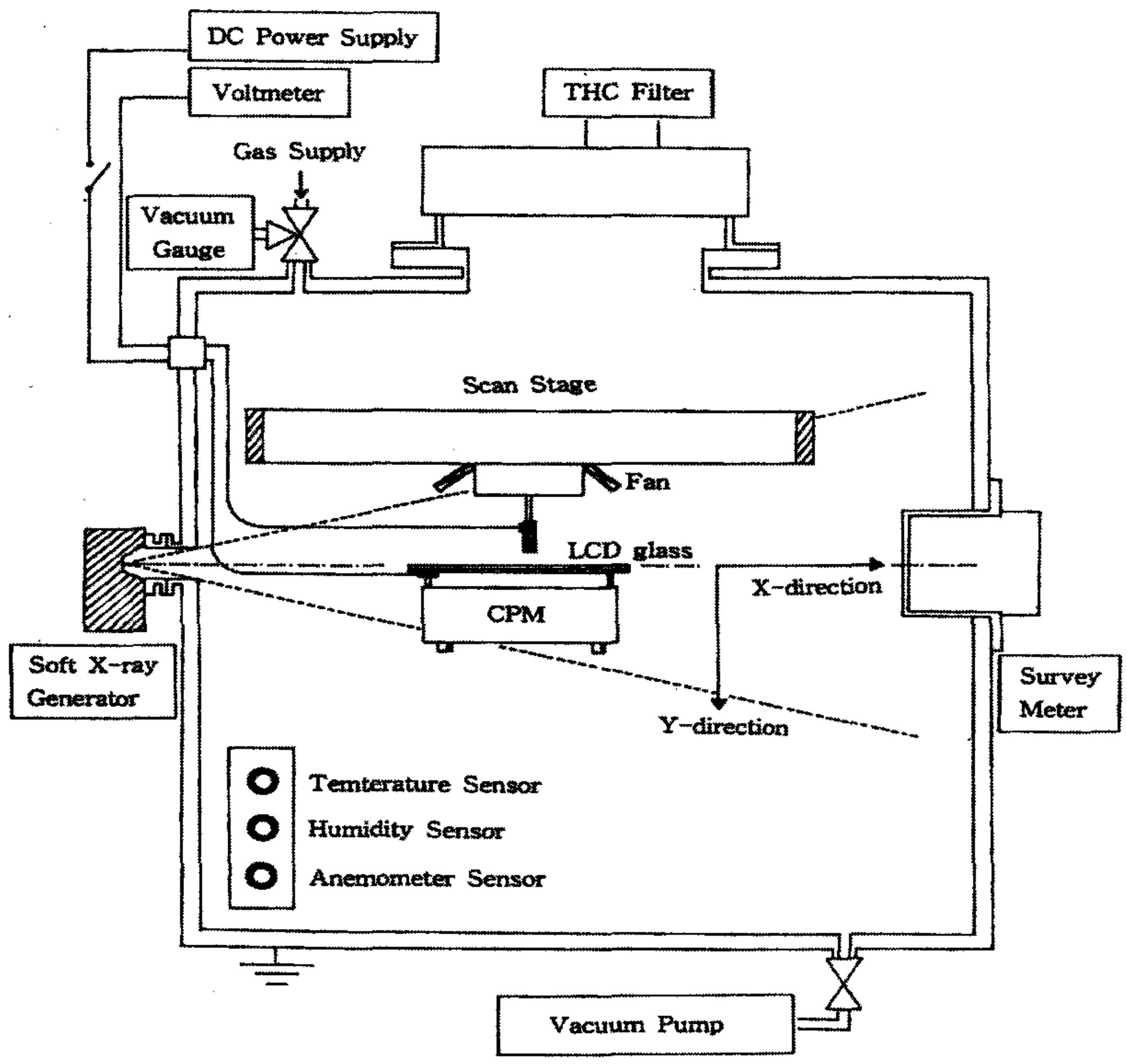

Fig. 1. The experimental equipment's schematic diagram for neutralization experiment.

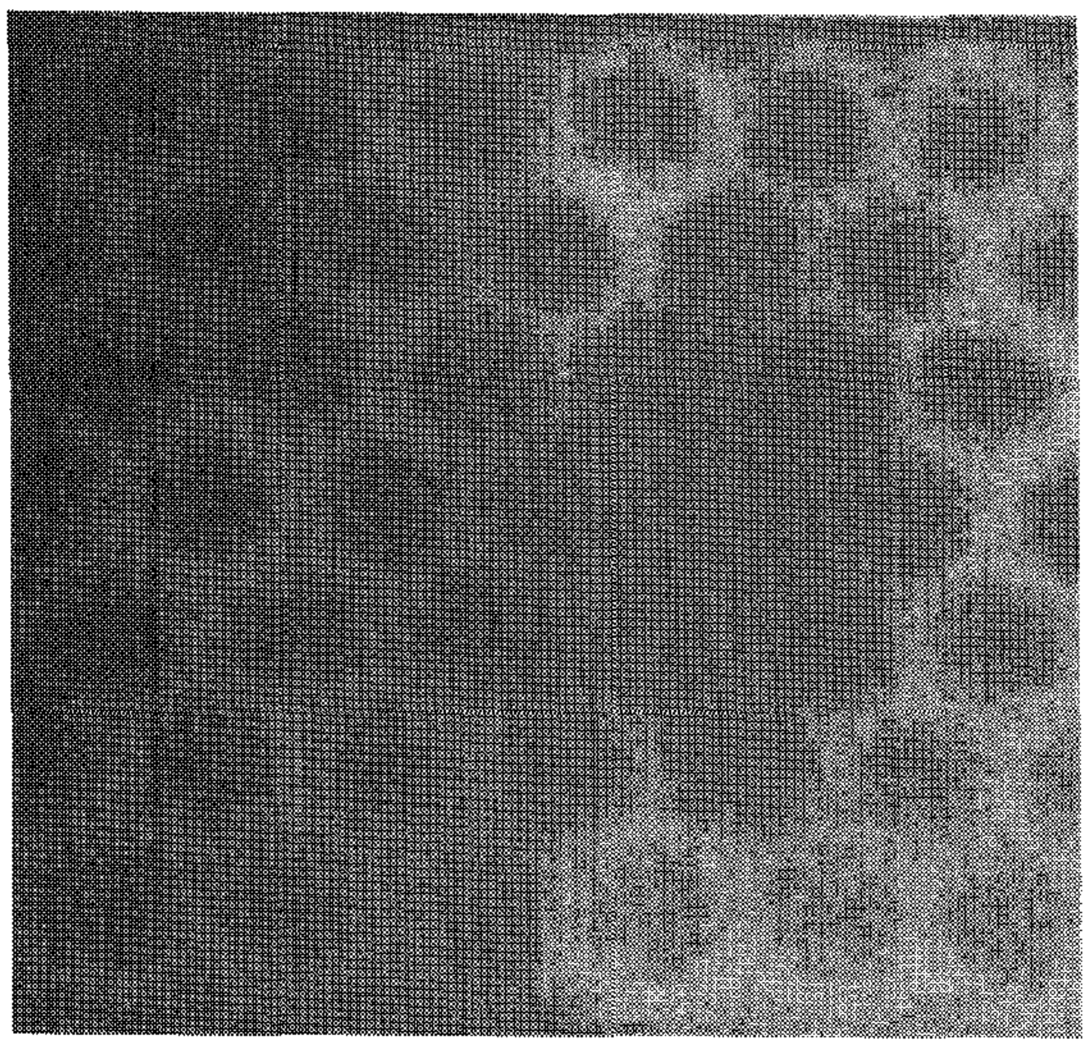

Fig. 2. The etching process result of charged glass surface.

electricity, the Al-mesh was contacted under the glass sample. In experimental procedure, the each sample was fixed on 300x350mm^2 LCD glass panel. The naturally made static electricity on the samples was completely eliminated by soft X-rays exposure. Samples were artificially charged from −200V to −100V through the contact of the AL-meshes. Finally, samples were transferred to the reaction chamber by the robot arm for dry etching process. Before the experiment, we measured natural disappearance of the artificially made static electricity on the sample according to the time. It was confirmed the static electricity was naturally discharged from initial applied voltage to 60%-70% value during transfer from cassette to reaction chamber. The conditions of etching process were following these. Charged static electricity was -1kV and sample size was 10x10cm^2.

2.2 Neutralization of charged static electricity with soft X-ray irradiation

The soft X-ray is generated when the electron beam with several kV strikes a metallic target. The soft X-ray is irradiated to the vicinity of a charged substrate and generates many ions and electrons. Both of them are used for neutralizing charged LCD glass. Fig. 1 shows the experimental set up for neutralization. This chamber (SUS, thickness=15mm, size = 700x700x700mm) is designed for pumping down to about 1x10^{3}Torr. The soft X-ray generator(Japan RAYON Co, SXE-610-SP) and

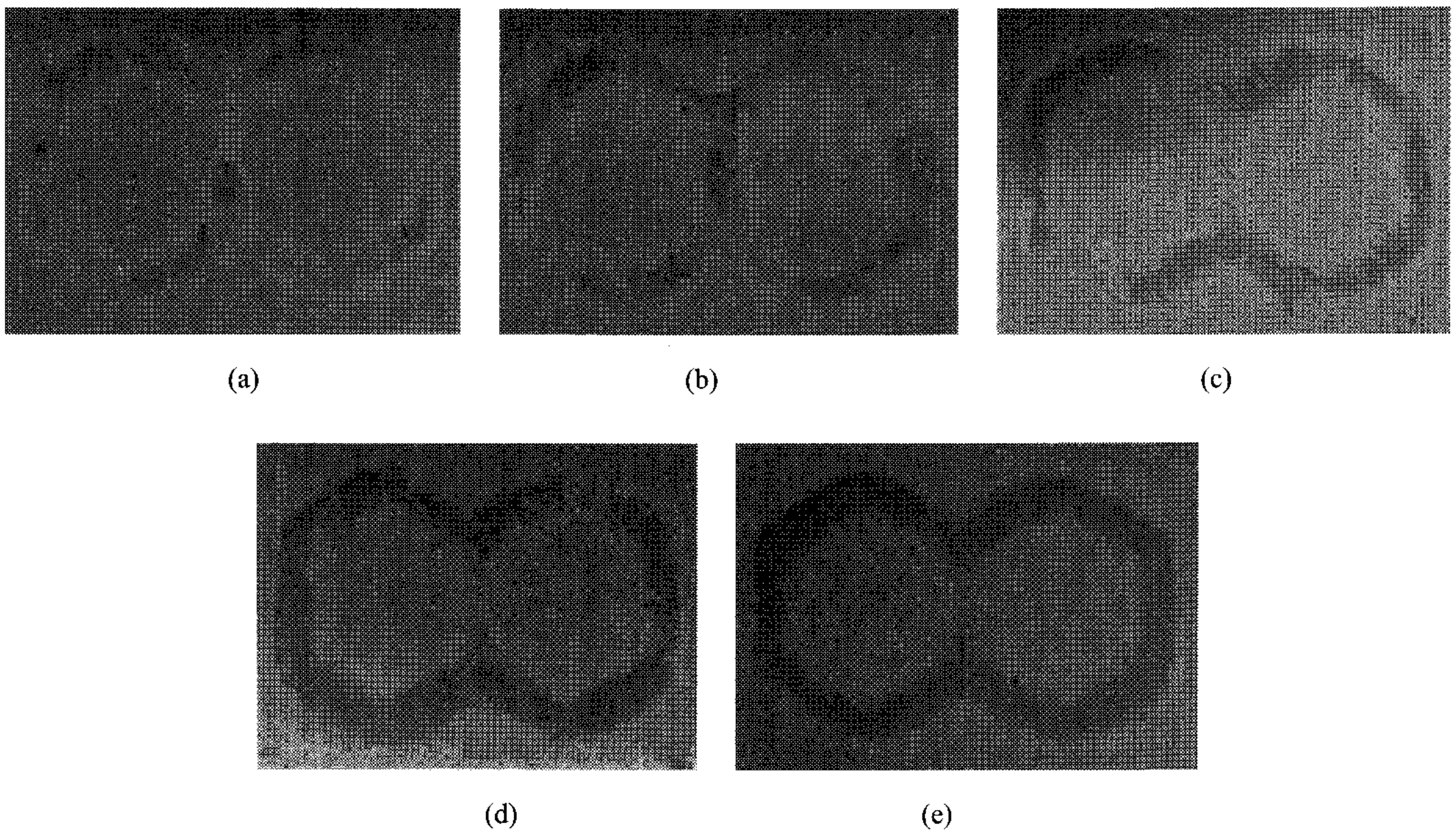

Fig. 3. The glass surface etching pattern by the static electricity of various supplied potential.

the survey meter(Japan ALOKA Co, ICS-311) are placed on the opposite side of the same axis. The survey meter is to measure the ion generation rate after the soft X-ray exposure. To control the moisture and temperature into the chamber, THC(Temperature Humidity Controller, Japan RASCO Co, B022) is set up. And the gas inlet is placed at the upper side of the chamber and LCD glass gets to be charged intentionally through the feedthrough. CPM(Charged Plate Monitor, Japan SHISHIDO Co, H0601) is placed below the LCD glass for monitoring the ion unbalance on the LCD glass. The static electricity sensor (Japan SIMCO Co, EVL-5R type) scans on the LCD glass with being hanged from the scan stage with 3-axis actuators and sensors for measuring the air flow rate and temperature are placed into the chamber.

3. Experimental Results and Discussion

Fig. 2 shows the etching result of charged glass surface. The pattern of charged static electricity was reappeared on the glass. This sample was charged to about –1kV. The sample size was 10x10cm^2. 50sccm SF_6 was introduced into the chamber. RF power was 300[W]. Each pressure and temperature was 60mTorr, 20°C Etching time was 30sec. The white area in the Fig. 2 was the charged area. It was observed this charged area had higher etching rate. Fig. 3 shows the etching patterns resulted by the static electricity for different applied potentials. The Al-mesh for intentionally charging had two jointed hexagonal holes like a honeycomb. The etching pattern on the glass sample was same with the Al-mesh pattern. The samples were charged to (a): -200V, (b): -400V, (c): -600V, (d): -800V and (e): -1000V, respectively. The size of all samples was 2 x 3 cm^2. The etching process condition was the same with that of Fig. 2. The black area in Fig. 3 was the charged area, and had higher etching rate. The comparison of etching rate between charged area and no charged area is shown in Fig. 4. No-charged areas of each sample had lower etching rate than charged areas. The etching rate of these areas was increased according to supplied electrostatic potentials. When the static electricity was charged from –200[V] to –1000[V] on glass samples, the charged area had higher etching rate about 1.5%~15% than that of no charged area. In case of the static electricity was charged positively, the difference of etching rate between the charged area and the no charged area was little.

On the basis of the neutralization experiment, the etching rate unifomity results is shown in table1. As the negative electrostatic force is generated on the LCD glass by the positively supplied electrostatic potential, the negative electrostatic force attracts ionized atoms forward samples during the plasma. Therefore, charged area has higher etching rate than no charged area. But positive electrostatic does not influence etching rate.

We confirmed that the charged static electricity on LCD glass affected the dry etching process. For more reliable device manufacturing process, the neutralization of static electricity is indispensable. As contents of experiment for neutralization with soft X-ray irradiation, various neutralization capability was shown according to humidity, temperature, air flow rate, the radiation distance and angle of soft X-ray exposure, additionally chamber ambient. The decay time is when the electrostatic potential of LCD glass is reduced to 0[V]. The decay time is used to be an index for measuring the neutralization capability of soft X-ray.

TABLE 1. The comparison of etching uniformity

Experimental condition	Etching rate difference
Etching rate uniformity without neutralization by soft X-ray exposure	1.5%~15%
Etching uniformity with neutralization by soft X-ray exposure	<0.5%

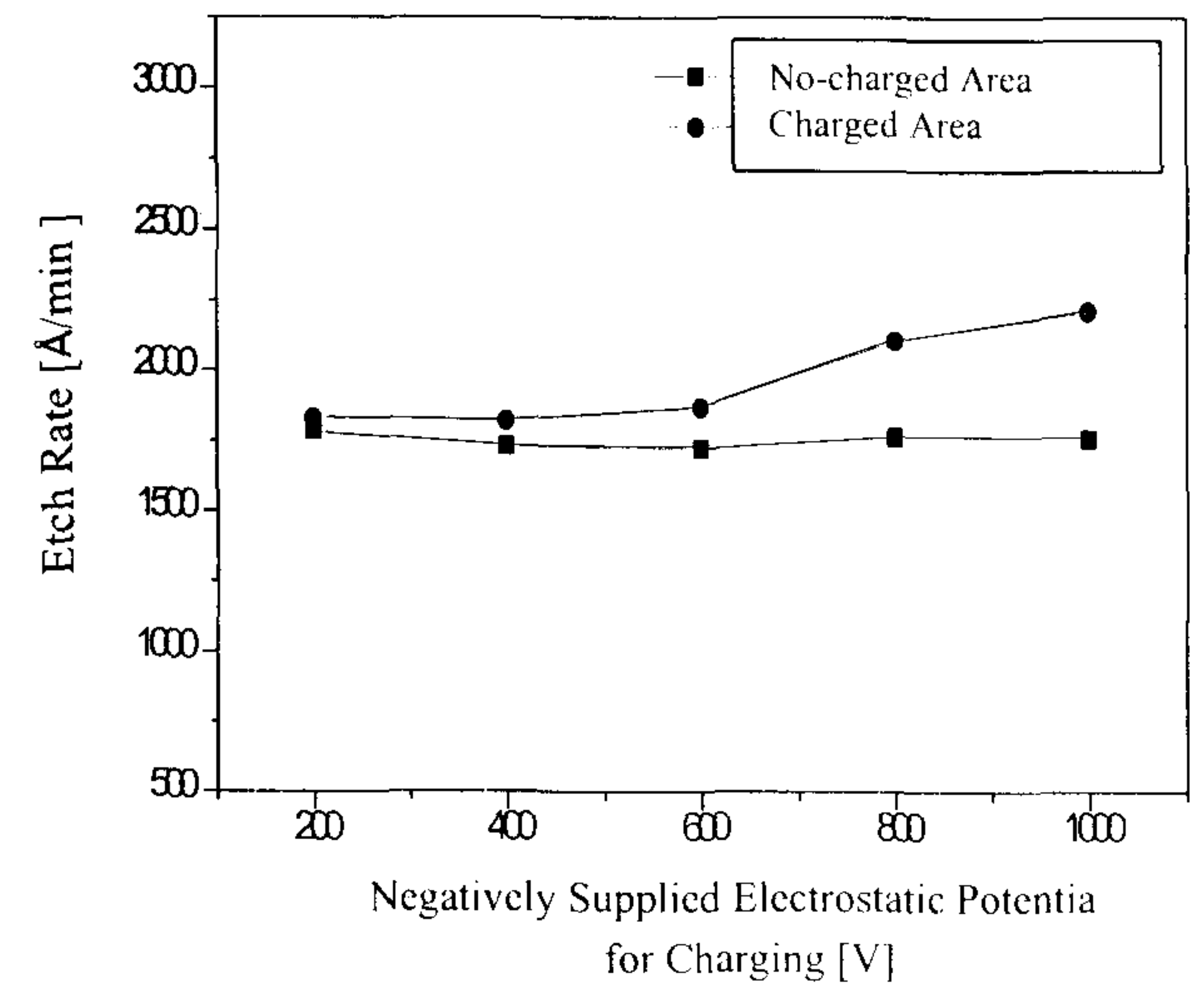

Fig 4. The comparison of etching rates between charged area and nocharged area.

Fig. 5 shows the discharge time of the electrostatic potential of LCD glass charged with ±1kV according to the humidity into the chamber. As the humidity in the chamber increases, moisture is attached on the LCD glass and promotes the ion mobility along with the surface. Therefore, the surface resistance of LCD glass decreases and electrostatic potential decreases.

Fig. 6 shows the decay time of LCD glass charged with ±1kV as a function of the temperature. Temperature of the glasses was changed from 15°C to 30°C. Air flow rate and humidity is 0m/s, 40%. Fig. 6 shows that temperature does not affect the decay time, and thus neutralization characteristics. Even though raising temperature into the chamber makes molecular in air more activated, the mobility of electrons and ions is enough faster than that of molecules. In addition, ionized atom spreads out widely. Therefore, neutralization capability increment induced by molecular activation effect is not achieved.

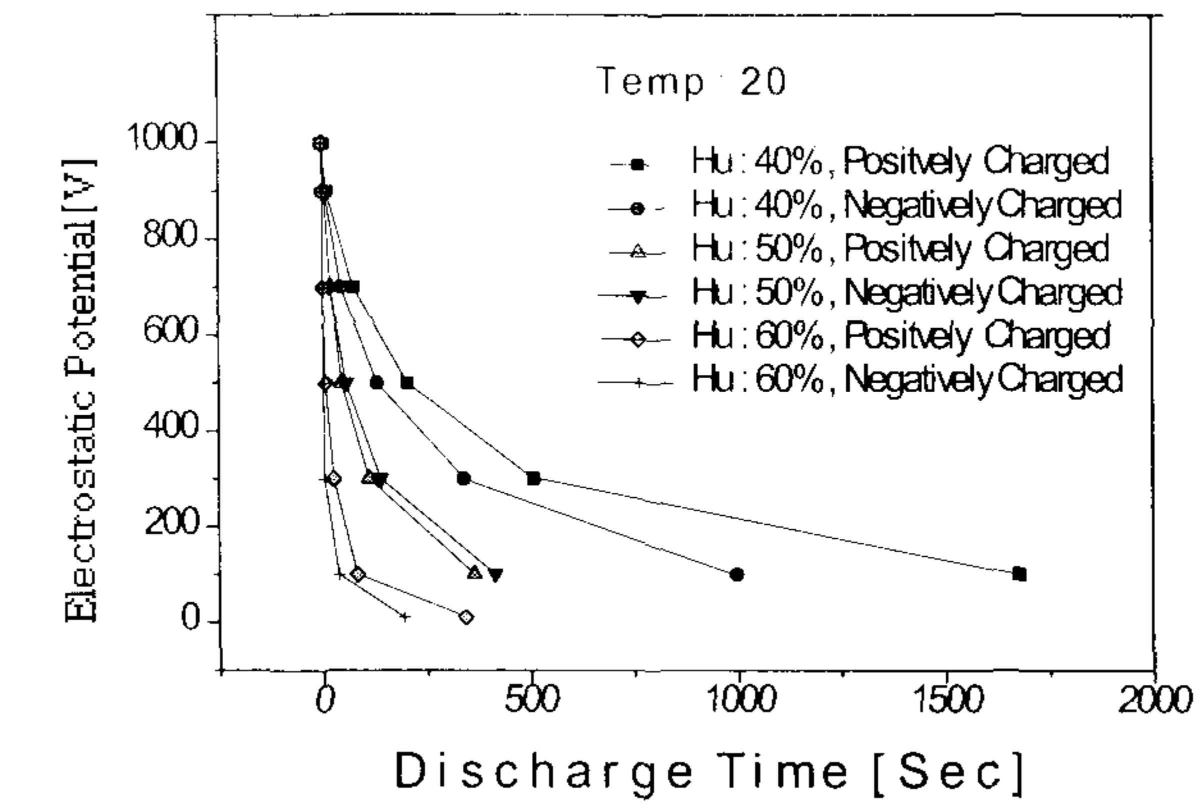

Fig. 5. The discharge time of the electrostatic potential on LCD glass according to the humidity

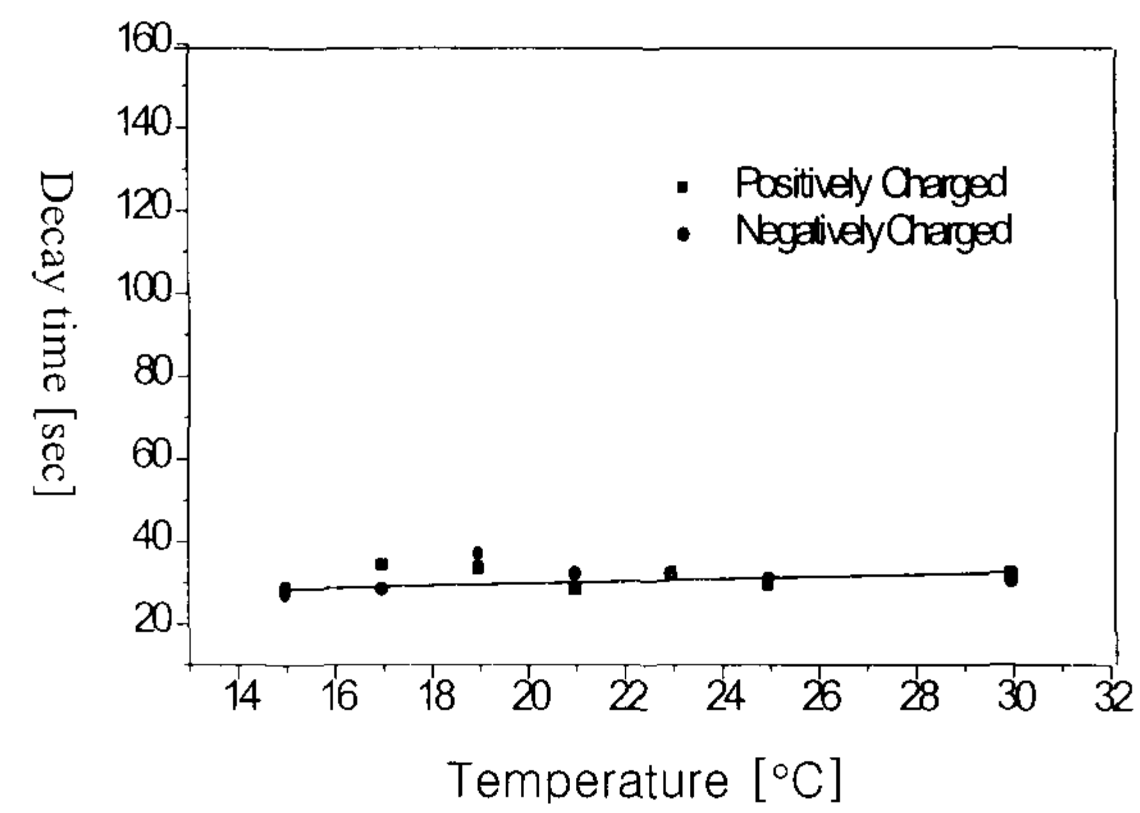

Fig. 6. The decay time of LCD glass charged with ± 1kV according to the temperature.

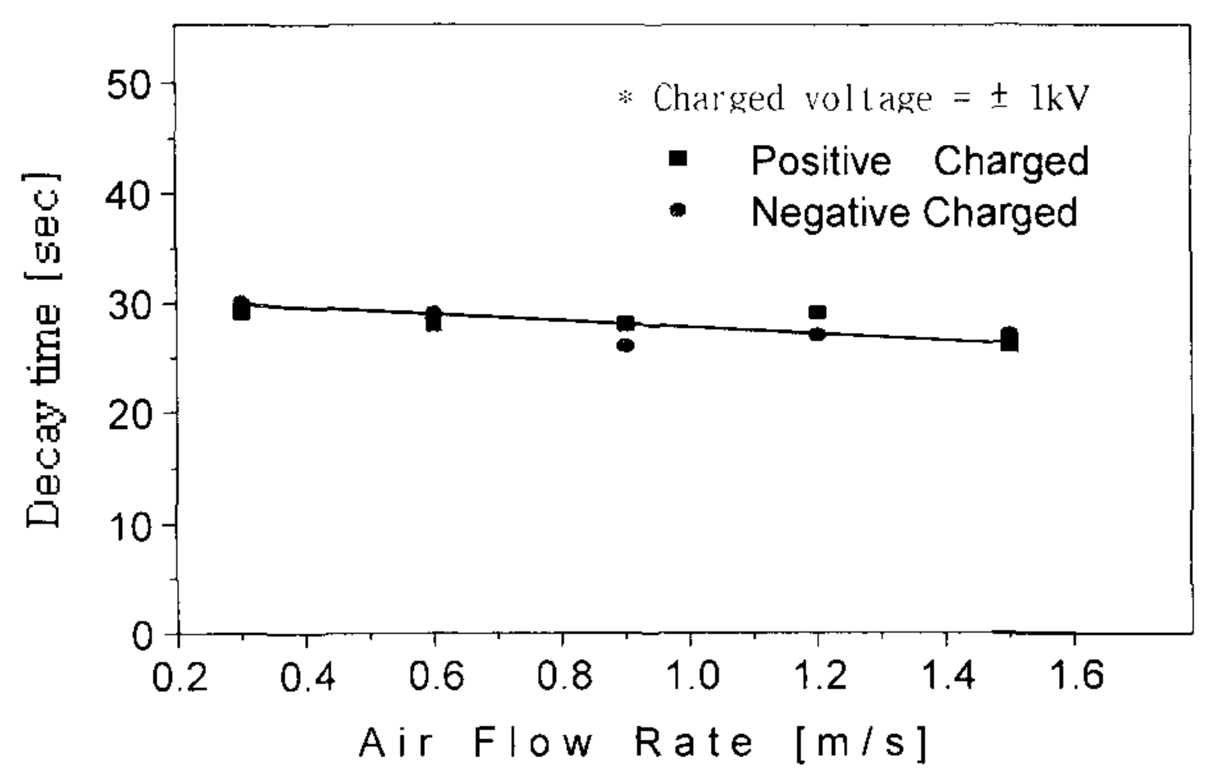

Fig. 7. The decay time of LCD glass charged with ± 1kV according to the air flow rate.

Fig. 7 shows the decay time of LCD glass charged with ±1kV as a function of the air flow rate. Air flow rate was changed from 0.05m/s to 0.4m/s. Measuring point on the glass is fixed. Humidity is 40%. The decay time increase in some degree when air flow rate increases in this figure. Air flow does not contribute the neutralization greatly because soft X-ray generator places near the charged LCD glass and its neutralization capability is more effective.

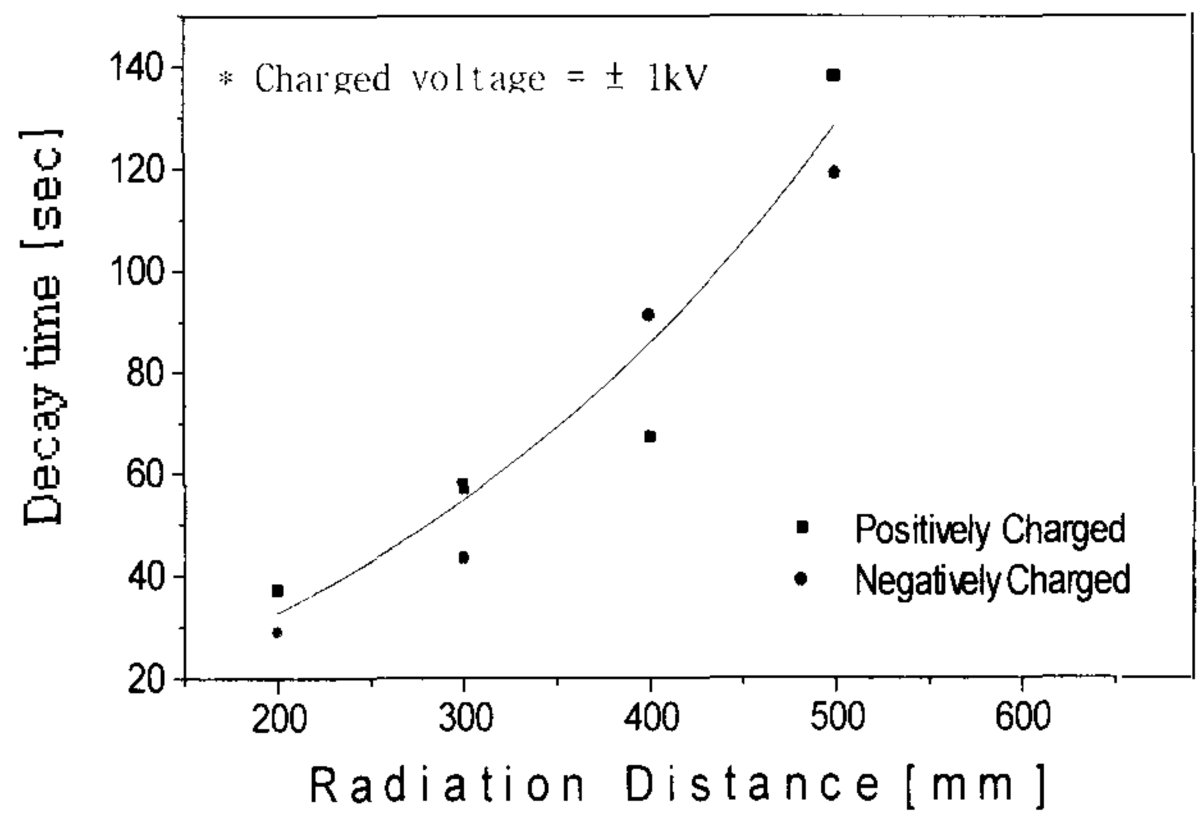

Fig. 8. The decay time when the distance from the soft X-ray generator was varied fro 200nm to 500mm along with X-axis.

Fig. 8 shows the decay time when the distance from the soft X-ray generator was varied from 200mm to 500mm along with X-axis. Air flow rate and humidity is 0m/s, 40% and temperature is 20°C. As the distance between the charged plate and ionized space increases, recombination rate of ionized atom is high. So the neutralization capability of soft X-ray decreases rapidly. This experimental result shows that the neutralization capability of soft X-ray generator depends upon the distance.

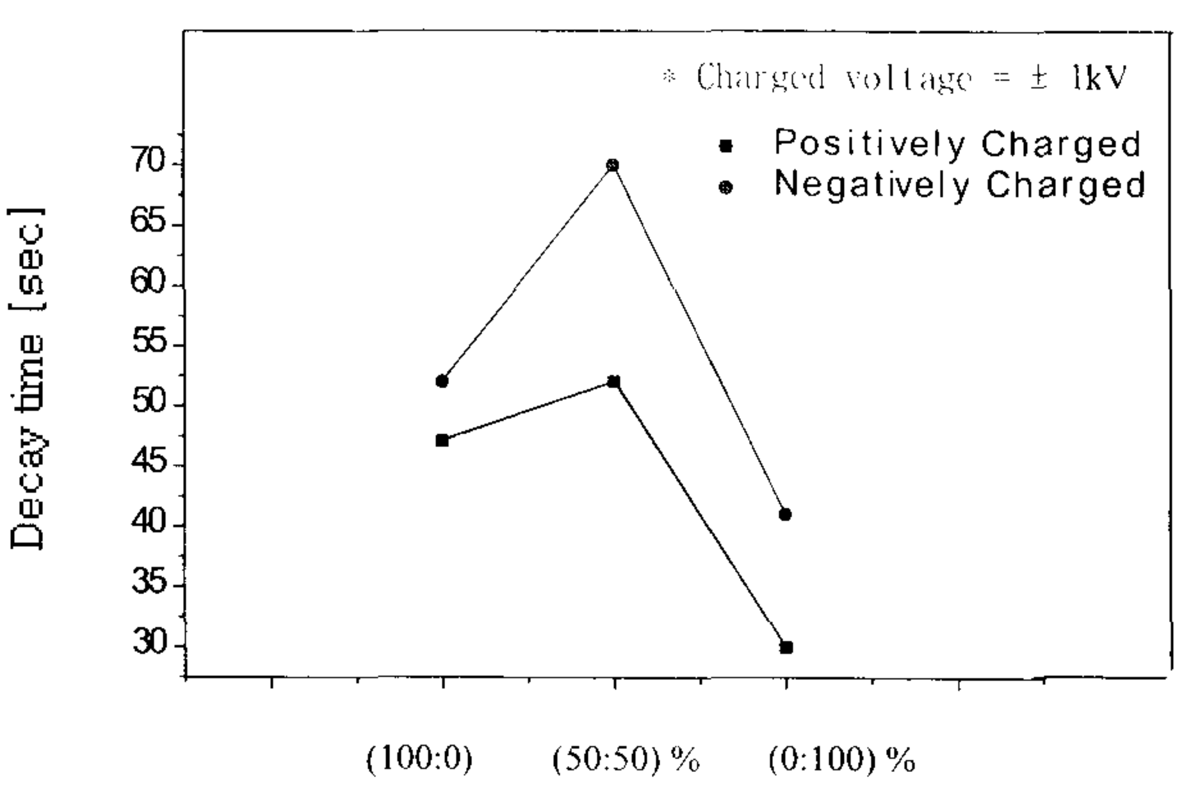

Fig. 9. The neutralization characteristic of soft X-ray under N_2, O_2 gas mixture ambient

Fig. 9 shows the neutralization characteristic of soft X-ray under N_2, O_2 gas mixture ambient. The photon energy for ionizing N_2 is over 15.6 eV. On the contrary, photon energy for O_2 is over 6.1 eV. Therefore, O_2 is ionized easily and the ionized rate of atom increase rapidly more than N_2. The neutralization capability under O_2 gas is more effective than that of N_2 gas.

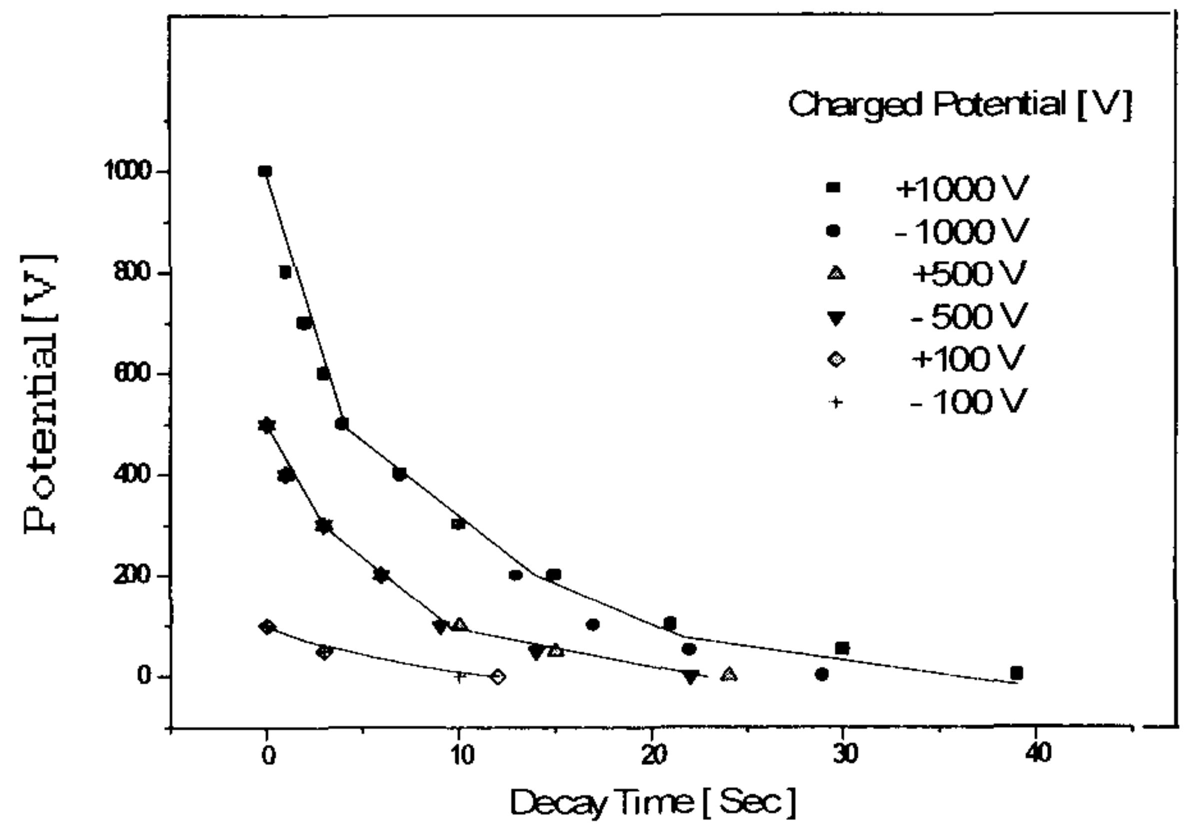

Fig. 10. The decay time of glass potential according to initial charged electrostatic potential.

Fig. 10 shows the decay time of glass potential according to initial charged electrostatic potential. Initial charged voltage is ±1000[V], ±500[V], ±100[V] respectively. The slope of decay time is almost same value. When the electrostatic potential on the LCD glass is high, the number of ionized atom introduced on the LCD glass increase. On the contrary, if the potential is low, the number of ions and electrons introduced on the LCD glass decrease because of the increase of recombination of ion and electron. Therefore, there is no outstanding difference in the decay time even though initial charged potential is different.

Fig. 11(a) shows the decay time of the natural neutralization. Fig. 11(b) shows the decay time of neutralization after soft X-ray exposure. Initial charged voltage is ±1kV. The decay time is measured simultaneously with pumping down. The required time for neutralizing to 0[V] is 40min. But, the required time for neutralization with soft X-ray is about 15sec. In case of soft X-ray irradiation, the neutralization capability with soft X-ray in vacuum decreases rapidly due to absence of molecular. But, if neutralization is accomplished simultaneously with pumping down, neutralization effect increase can be expected.

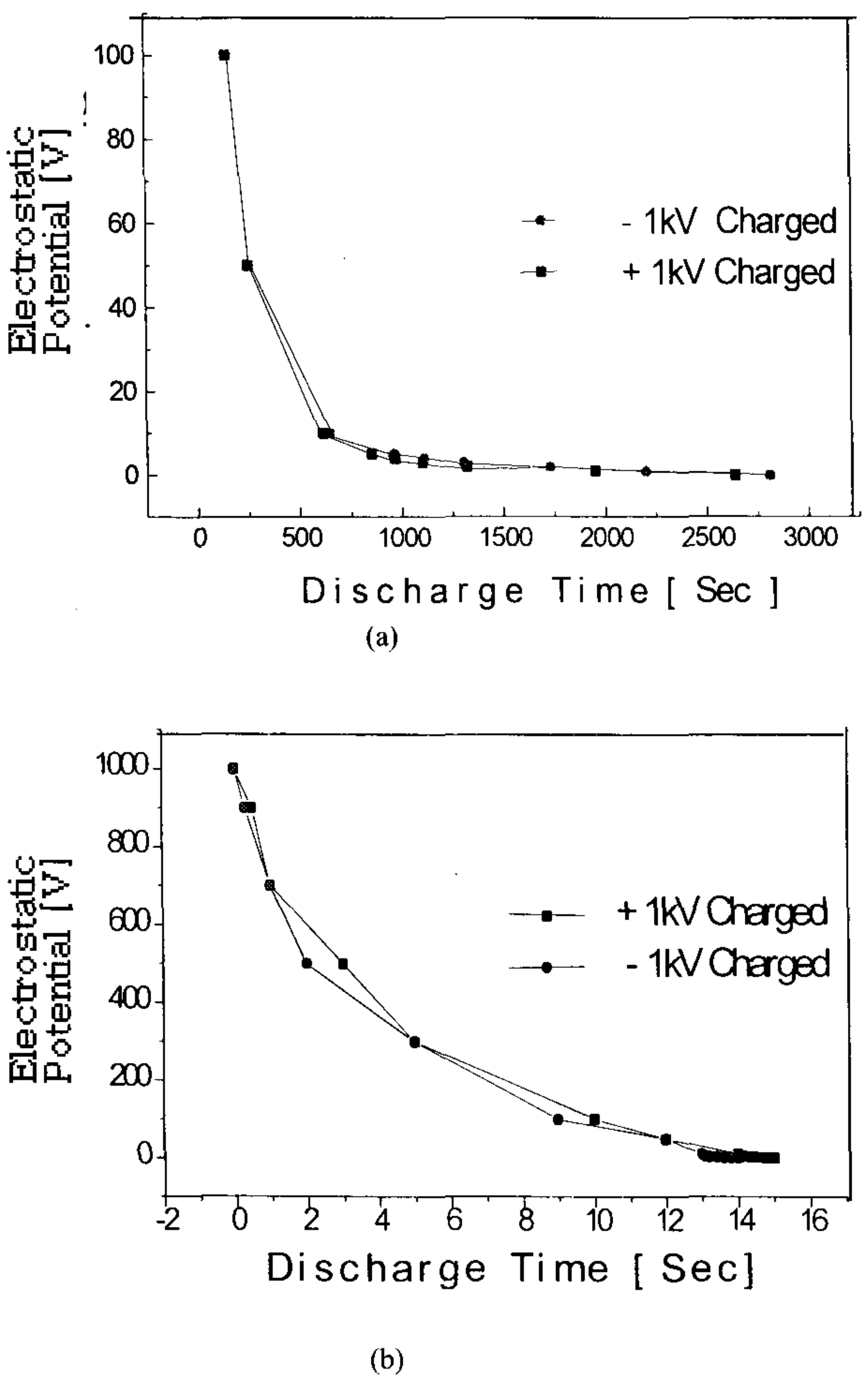

Fig. 11. (a) The neutralization characteristic under natural neutralization (b) The neutralization capability of soft X-ray in vacuum ($1x10^{-2}$) according to initial charged electrostatic potential

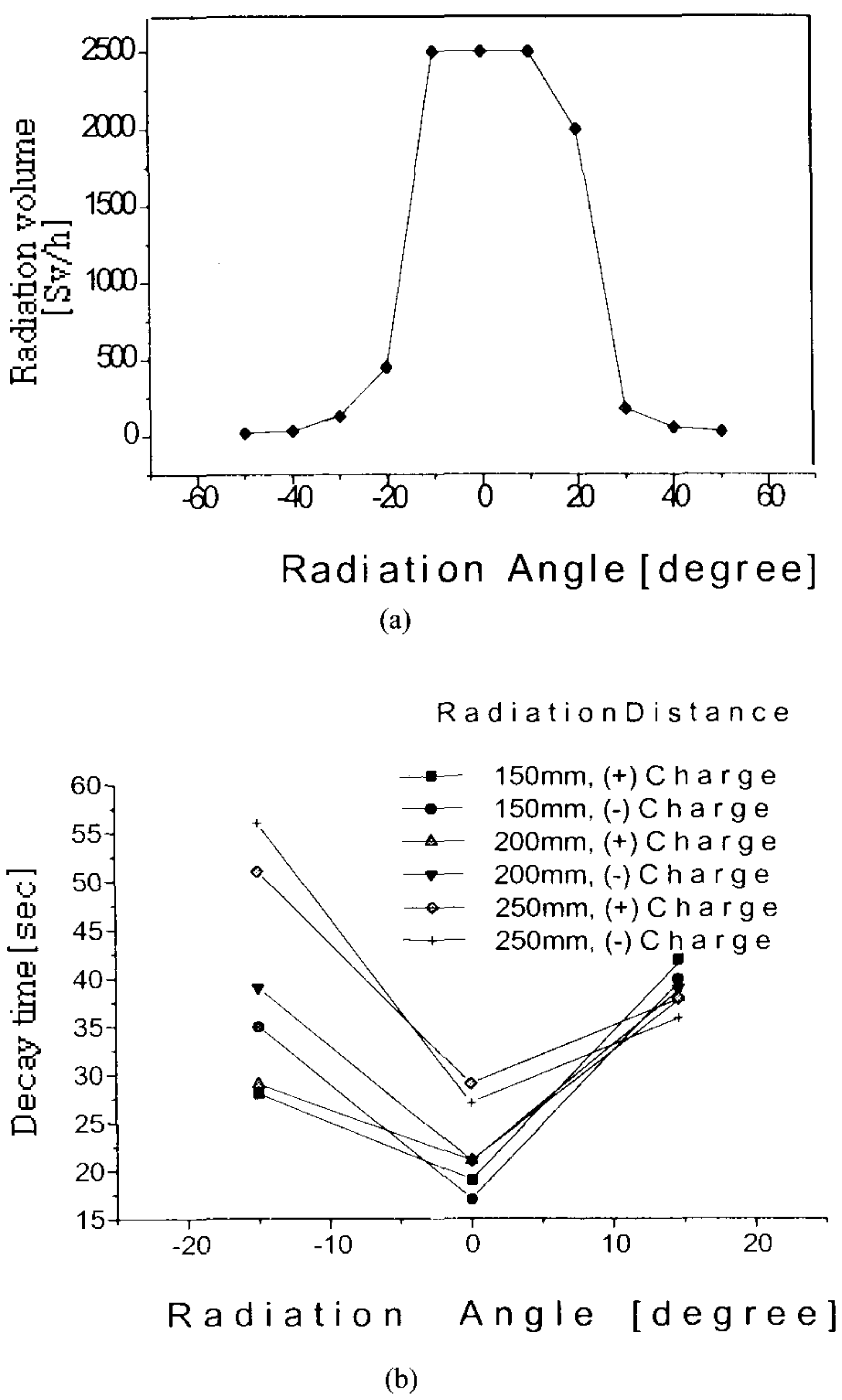

Fig. 12. The radiation volume and decay time according to the exposure angle of soft X-ray.

Fig. 12 (a) shows the radiation volume about the exposure angle of soft X-ray. Fig. 12 (b) shows the decay time about it. Air flow rate and humidity is 0m/s, 40% and temperature is 20°C. The decay time of LCD glass charged with ±1kV was measured. This is caused by the difference of the ion concentration rate generated after soft X-ray exposure. Ionization of air molecular by soft X-ray at the center is greater than that of other region. When the charged LCD glass places at the center of soft X-ray generator, the neutralization effect increases because the neutralization capacity of LCD glass is the highest on the center.

4. Conclusion

We confirmed that the charged static electricity on LCD glass affected the dry etch process. Through our experiment on the static electricity, it was verified that the static electricity on LCD glass caused the etching rate difference. The charged region has higher etching rate about 1.5%~15% than that of no charged region.

The static electricity generation is unavoidable in TFT-LCD manufacturing process and also should be neutralized for better yield and reliable manufacturing process.

In our experiment, the neutralization capability of soft X-ray irradiation was studied as a new advanced and clean manufacturing technology. The neutralization capability of soft X-ray irradiation was not influenced by temperature and initial electrostatic potential. Even though humidity and air flow rate affect the neutralization in some degree, the result was not effective in the neutralization. The neutralization capability of soft X-ray irradiation decreases under the absence of gas molecular. But, the soft X-ray are effective in air or O_2 gas.

Especially, the neutralization capability of soft X-ray showed the close relationship with the distance and angle of irradiation. In the experiment of neutralization characteristic as a function of the distance and exposure angle, ion generation rate rapidly decrease with the increasing distance. The radiation volume difference also was outstanding according to the angle. Therefore, in order to increase neutralization capability of soft X-ray, the charged LCD glass has to be placed within the appropriate irradiation area. if soft X-ray irradiation module is attached, the better effective neutralization can be achieved in short time of 15-30sec. The etching uniformity is improved from 1.5-15% to 0.5%. The neutralization capability of soft X-ray is the greatest under the humidity of 60%, air flow rate of 1.5m/s and O_2 gas ambient of 50%. The distance for neutralization is effective when the charged LCD glass places close from the soft X-ray irradiator and at the center of soft X-ray generator.

As an advanced and clean neutralization technology, the soft X-ray is very promising in current TFT-LCD fabrication. And TFT-LCD manufacturing equipment has to establish the soft X-ray exposure module system for solving the static electricity problem. In case of loadlock chamber with the loading and unloading system inside, if soft X-ray irradiation module is attached, the better effective neutralization can be expected.

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