Characteristics of Ag Etching using Inductively Coupled Halogen-based Plasmas

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Abstract

In this study, Ag thin films deposited on LCD-grade glass were etched using inductively coupled fluorine-based plasmas and the effect of various CF_4-based gas mixtures on the Ag etching characteristics were studied. When CF_4-based gas mixtures were used with N_2, due to the very low vapor pressure of etch products, etch products remained on the substrate after the etching. However, when CF_4 used with Ar, residue-free Ag etching could be obtained due to the removal of etch product by sputtering by Ar^+ ions.

1. Introduction

Silver(Ag) is a very attractive material in thin film transistor liquid crystal display(TFT-LCD), due to the lowest resistivity at room temperature and higher reflectance than aluminum by 10~15%. Also, it is one of the potential candidates for the intergrated circuit (IC) manufacturing [1].

Generally, Ag etching is performed using wet etching methods, however, due to the reduction of critical dimension of the lines, plasma etching is indispensable. However, there are many problems to be solved before Ag plasma etching to be applied. The main problems are the formation of involatile etch product, low etch rates, and high surface roughness after removing the etch products. For example, many works on Ag etching using halogen-based plasma etching were reported [2.3]. Even though these etch products could be removed by the resist wet strip process after the plasma etching, therefore by using two-step dry-wet processing, the rough sidewall of Ag etch profile was inevitable [4]. (Figure 1)

Therefore, in this study, Ag thin films were etched using inductively coupled fluorine-based plasmas, and the effect of additive gas such as N_2 and Ar on the Ag thin films etching was studied to investigate the possibility of Ag etch with higher etch rates and to reduce the Ag etch products.

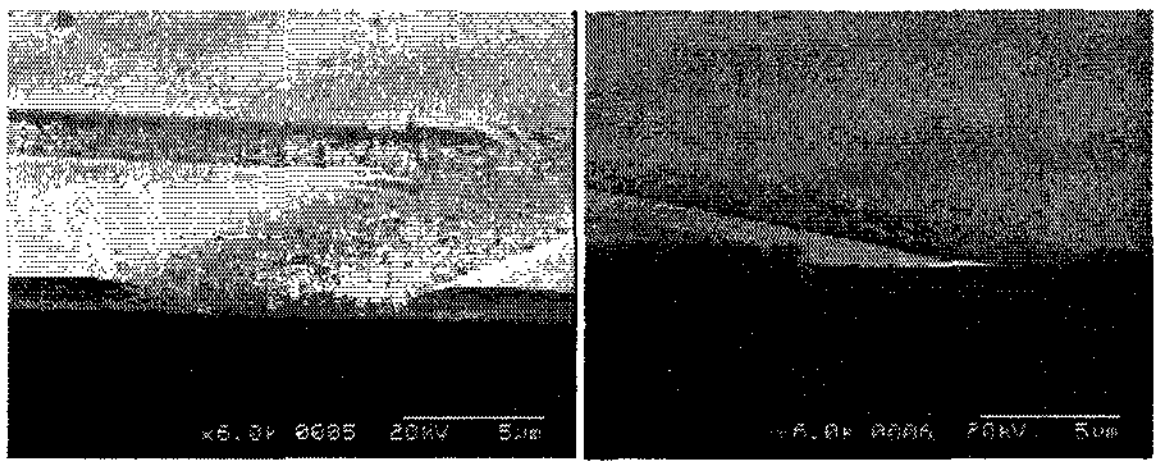


Figure 1 SEM micrographs of etched Ag with the photoresist pattern(left) and the etched Ag after the photoresist stripping(right) for pure Cl_2.

2. Experimental

To study the Ag etch characteristics, a magnetically enhanced inductively coupled plasma(MEICP) equipment was used. This equipment was composed of five-turn Au-coated copper coil located on the top of chamber and separated by a 1cm thick quartz window. To generate inductively coupled plasmas, the rf power of 13.56MHz was applied to the coil. Separate 13.56MHz rf power was also applied to the substrate to induce bias voltages to the wafer. 4 sets of permanent magnets having 2000Gauss on the magnet surface were installed around the chamber wall to increase plasma density and uniformity by confining the plasmas. Details of the MEICP system used in the experiment are described elsewhere [5].

Ag thin films(5000Å) were deposited on LCD-grade glass substrate with rf sputtering and 2.0㎛ thickness photoresist was used as the mask layer. CF_4 gas was used as the main etch gas to etch Ag thin films and N_2 and Ar were used as additive gases. And other etch parameters, such as the inductive power, the dc bias voltage, and the operational pressure were kept at 1500Watts, -150Volts, and 6mTorr respectively.

The step height of films before and after the etching was measured with stylus profilometry. A scanning electron microscope (Hitachi, S-2150 SEM) was used to observe as-etched Ag surfaces. Auger electron spectroscopy (AES, PHI-670) was used to analyze the reaction product remaining on the etched Ag surface.

3. Results and discussion

Figure 2 shows Ag etch rates as a function of gas mixture such as CF_4/N_2 and CF_4/Ar. As the operational condition, 1500Watts of inductive power, -150Volts of dc-bias voltage, and 6mTorr of operational pressure were used. As shown in the figure, when N_2 was added to CF_4, no noticeable increase of Ag etch rates was observed by increasing the additive gas. However, when Ar was added to CF_4, the Ag etch rate increased with the increase of Ar in the gas mixture. When N_2 was added to CF_4, the silver fluoride formed by CF_4 is involatile and dense, therefore, high Ag etch rates appear to be impossible as shown in the figure. However, in the case of Ar addition to CF_4, due to the enhancement of sputtering rate of silver fluoride by Ar^+ ions, high Ag etch rates could be obtained. Especially, when pure Ar was used to etch Ag, the highest Ag etch rate of about 3500 Å/min was obtained due to the high sputter yield of Ag(3.4atom/ion, by Ar^+ ion, 400eV) [6].

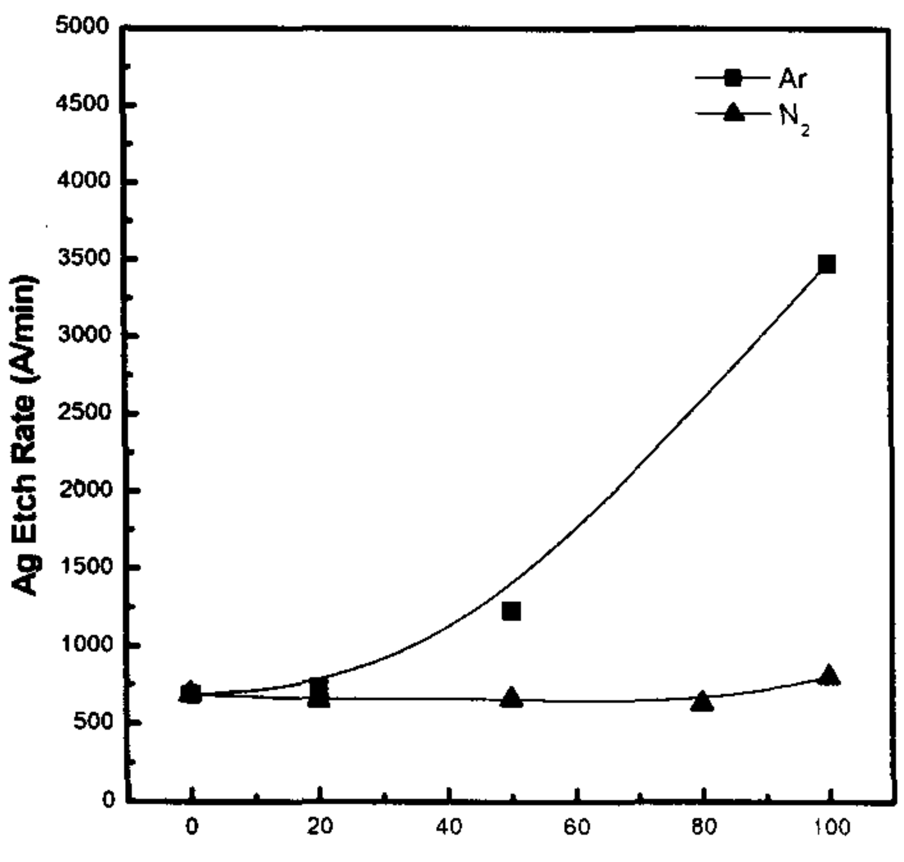
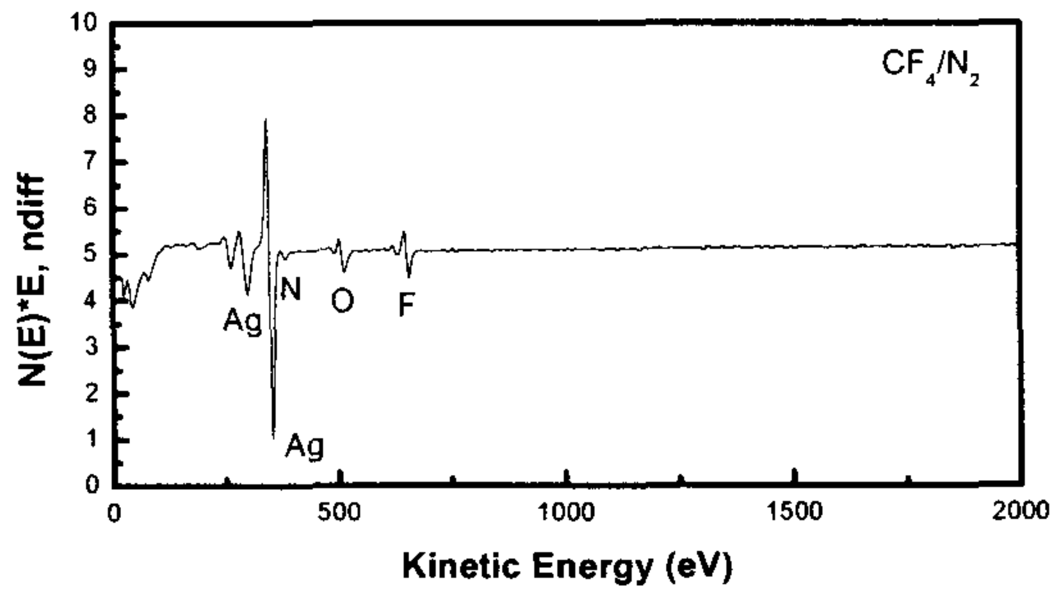


Figure 2 Ag etch rate as a function of gas mixture such as CF_4/N_2 and CF_4/Ar.



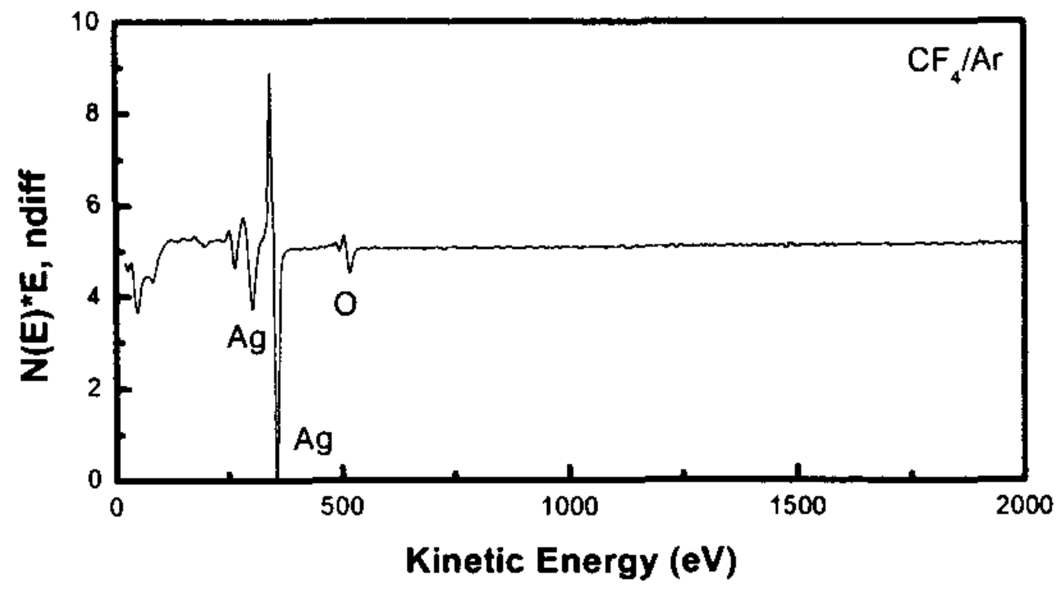


Figure 3 AES data on the composition of the Ag substrate as a function of gas mixture such as CF_4/N_2 and CF_4/Ar.

However, if pure Ar is used for Ag etching, all the sputtered Ag will be deposited all over the chamber in addition to the redeposition to the patterned photoresist sidewall. Especially, when high density plasmas are used, the deposition of conductive layer on the dielectric window for electromagnetic transmission will be a serious problem. Therefore, pure Ar cannot be used with high density plasma equipments for the etching of Ag. The characteristics of the etch products were investigated using AES and the results are shown in Figure 3. 5000 Å thick blank Ag thin films were exposed to $50\%CF_4/50\%N_2$ and $50\%CF_4/50\%Ar$ plasmas for the same time. In the case of $50\%CF_4/50\%N_2$ plasma, fluorine was detected on the Ag substrate, due to the formation of silver fluoride. However, in the case of $50\%CF_4/50\%Ar$ plasma, fluorine was not detected, because the silver fluoride was sputtered by Ar^+ ions.

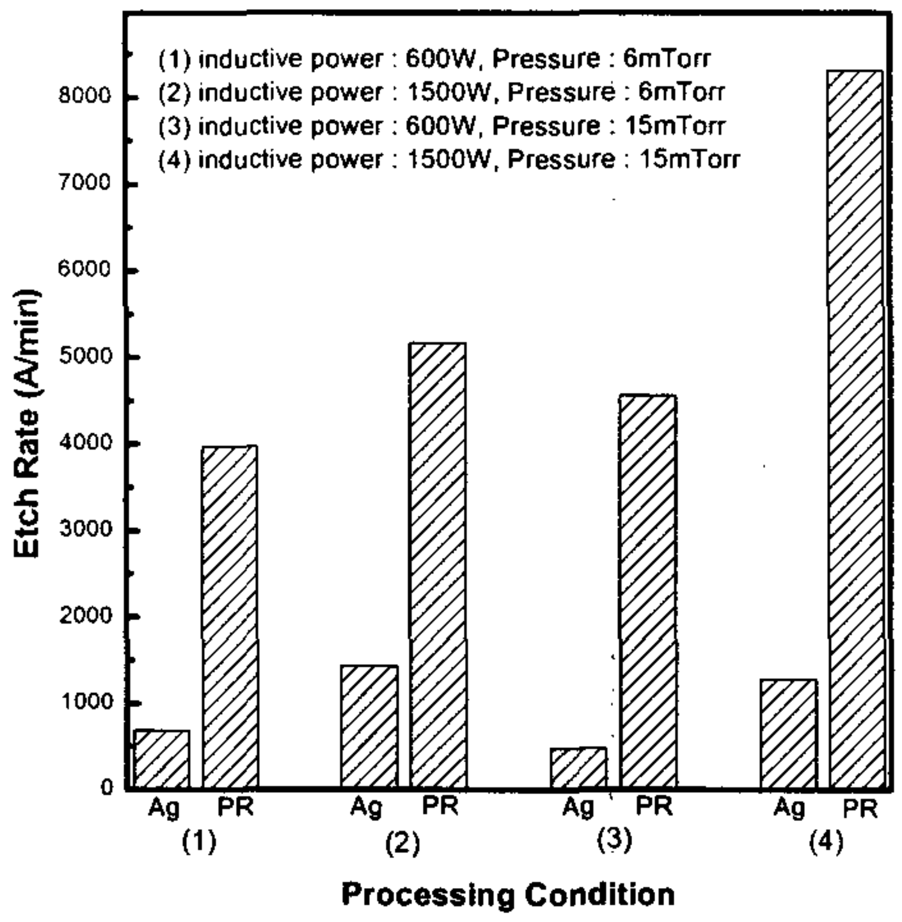


Figure 4 Ag and photoresist etch rates as a function of inductive power and operational pressure.

Figure 4 shows the effect of inductive power and operational pressure on the Ag and photoresist etch rate. DC bias voltage was maintained at –150Volts. As shown in the figure, the increase of inductive power increased Ag and photoresist etch rates. The increase of Ag etch rates with inductive power appears to be from the increase of plasma density, therefore, from the increase of sputter etching of silver fluoride by increasing the ion density. However, the increase of operational pressure decreased Ag etch rates. The decrease of Ag etch rate appears to be related to the increase of F radical density with the increase of operational pressure, therefore, to the formation of more involatile silver fluoride as mentioned before. Therefore, the variation of Ag etch rate with inductively power and operational pressure could be easily explained by the relation between the formation and removal of silver fluoride by F radical density and Ar^+ ion density and energy, respectively.

Figure 5 shows SEM micrographs of the etched Ag with the potoresist pattern(left) and the etched Ag after the photoresist stripping(right) for 50%CF_4/50%Ar. Other etch parameters were 1500Watts of inductive power, -150Volts of dc bias voltage, and 6mTorr of operational pressure. As shown in the figure, no etch product such as silver fluoride could be observed after the etching Ag(left)

Figure 5 SEM micrographs of etched Ag with the photoresist pattern(left) and the etched Ag after the photoresist stripping(right) for 50%CF4/50%Ar.

when 50%CF_4/50%Ar was used and the sidewall of the Ag etch profile was smooth as shown in the figure after the photoresist stripping(right).

4. Conclusion

In this study, Ag thin films applied to TFT-LCD metal layers were etched using CF_4-based inductively coupled plasmas and the effects of various processing conditions on the Ag etching characteristics were studied. The variation of Ag etch rates with inductively power and operational pressure could be easily explained by the relation between the formation and removal of silver fluoride. Therefore, the residue-free and high etch rate Ag etching mechanism for CF_4-based gas mixed with 50%Ar is the formation of involatile silver fluoride by F radicals and simultaneous removal of the formed silver fluoride by sputtering by Ar^+ ions.

5. Acknowledgements

This work was supported by the Samsung Electronics Co. and the National Research Laboratory Program (NRL) by the Korea Ministry of Science and Technology.

6. References

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