The application of rapid SIMS analysis for the identification of surface contamination in TFT-LCD manufacturing

*Been-Chih Liou, Yi-Hung Chou, Chien-Chih Chen, John A. Eccles**
TPO, Chu-Nan / Miao-Li, Taiwan, R.O.C.
**Millbrook Instruments Ltd., Blackburn, Lancashire, UK*

Phone: +886 (0)37 586393, E-mail: max.liou@tpo.biz, ivan.chou@top.biz, jack.chen@tpo.biz, a.j.eccles@millbrook-instruments.com

Abstract

Sodium is a serious contamination in LTPS TFT process. It causes the abnormal characteristics of TFT in operation. Contaminated areas can be seen in SEM images, but EDX measurements do not have adequate sensitivity to confirm the presence of superficial sodium residues. We employed SIMS as a fast analysis method to map the non-uniform distribution of sodium on the surface. SIMS can also indicate the thickness of the contamination.

1. Introduction

Because of its high sensitivity and ability to analyze the extreme surface atomic layers, secondary ion mass spectrometry (SIMS) is widely used in semiconductor technology and surface characterization [1]. We therefore chose it to solve the process issue in the LTPS TFT manufacturing. It is important that a rapid analysis can be performed on-site to give immediate feedback to the production process.

In this paper we focus on the issues of using SIMS in a manufacturing environment for (i) the detection and identification of contamination, and (ii) mapping the distribution of contamination.

2. Results

Experimental

Samples for analysis were prepared by TPO LTPS array process. These samples had been taken out during the array process and no further treatment was required before analysis.

Scanning Electron Microscope (SEM) images were performed using a Hitachi model S-4700 microscope fitted with HORIBA model 7200-H EDX spectrometer. Electron images were acquired using 15 keV beam voltage and 10 µA beam current.

SIMS analysis was performed using a Millbrook MiniSIMS desktop instrument [2]. The primary beam conditions were 6 keV, 3 nA Ga^+ incident normal to the sample surface. The secondary ions were separated by a quadrupole mass spectrometer.
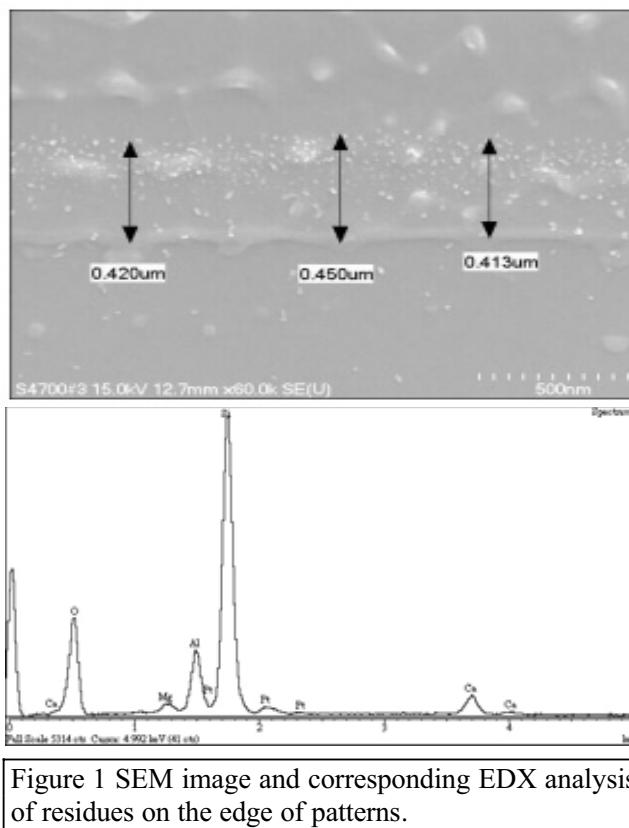

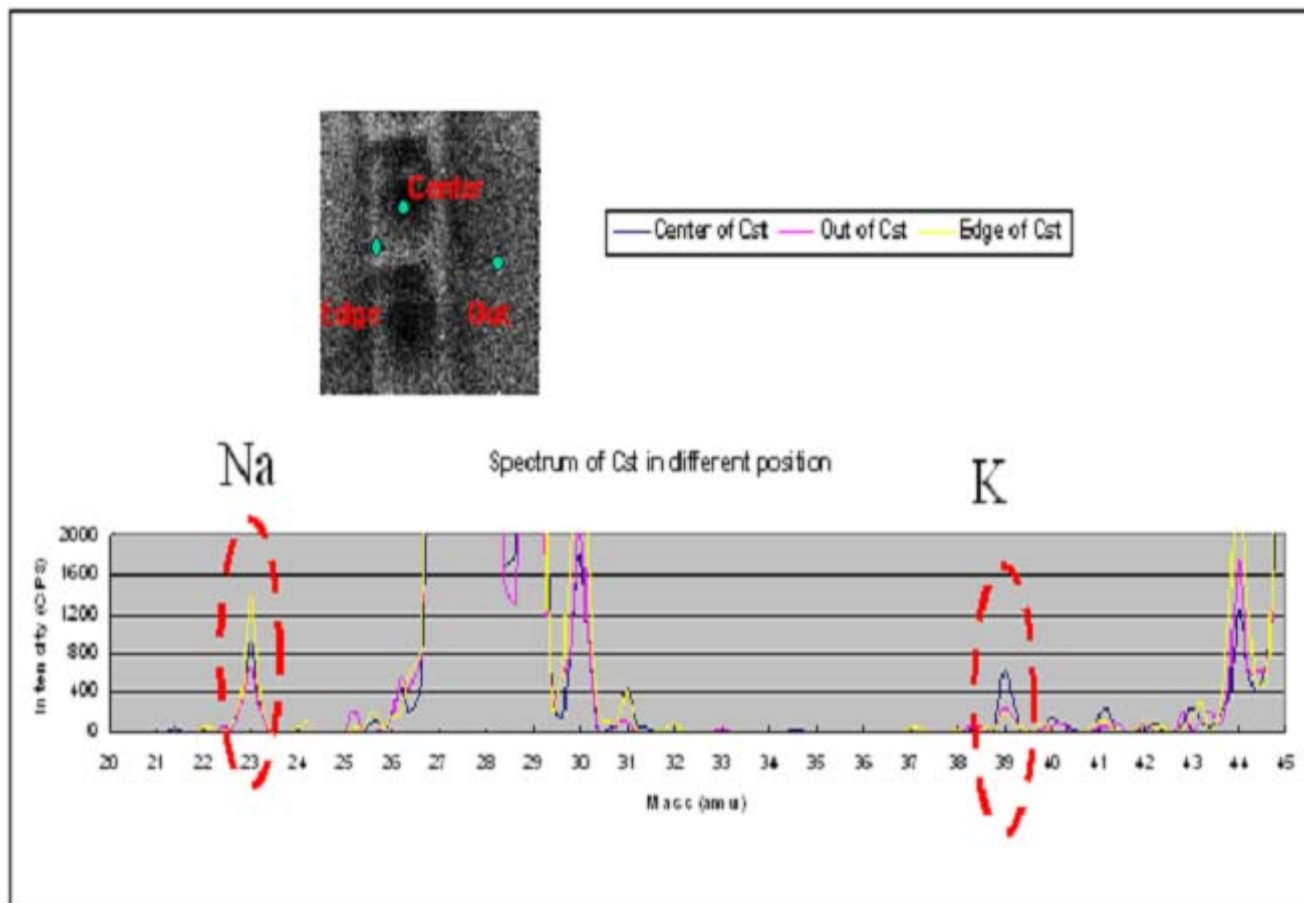Figure 1 SEM image and corresponding EDX analysis of residues on the edge of patterns.

Figure 2   Positive SIMS spectra acquired from different surface locations on the pattern.

3. Results

Residues on the edge of patterns were clearly visible in scanning electron microscope (SEM) images (Figure 1). However, attempting to verify the chemical nature of the residues by EDX showed only the elements expected in the array and no unexpected elements (Figure 1).

SIMS analysis of the residues was performed by analyzing in point mode (10 µm primary beam diameter) at different locations. The results of these localized positive SIMS spectra are shown in Figure 2. This shows that sodium concentration is low at the areas outside the pattern. The highest concentration is on the edge of pattern.

The comparative data between the different regions indicates the difference between the contaminated and non-contaminated areas of the sample. Absolute quantification of sodium concentration is not possible without the use of matched standards, but the surface concentration is estimated as below 1E12 atoms cm^{-2}.

The imaging function of SIMS is a powerful tool to visualize the contamination distribution. A chemical image is generated by tuning the quadrupole to a specific mass corresponding to the element of interest and scanning the primary beam across the sample. Typical analysis times are 15 seconds per image.
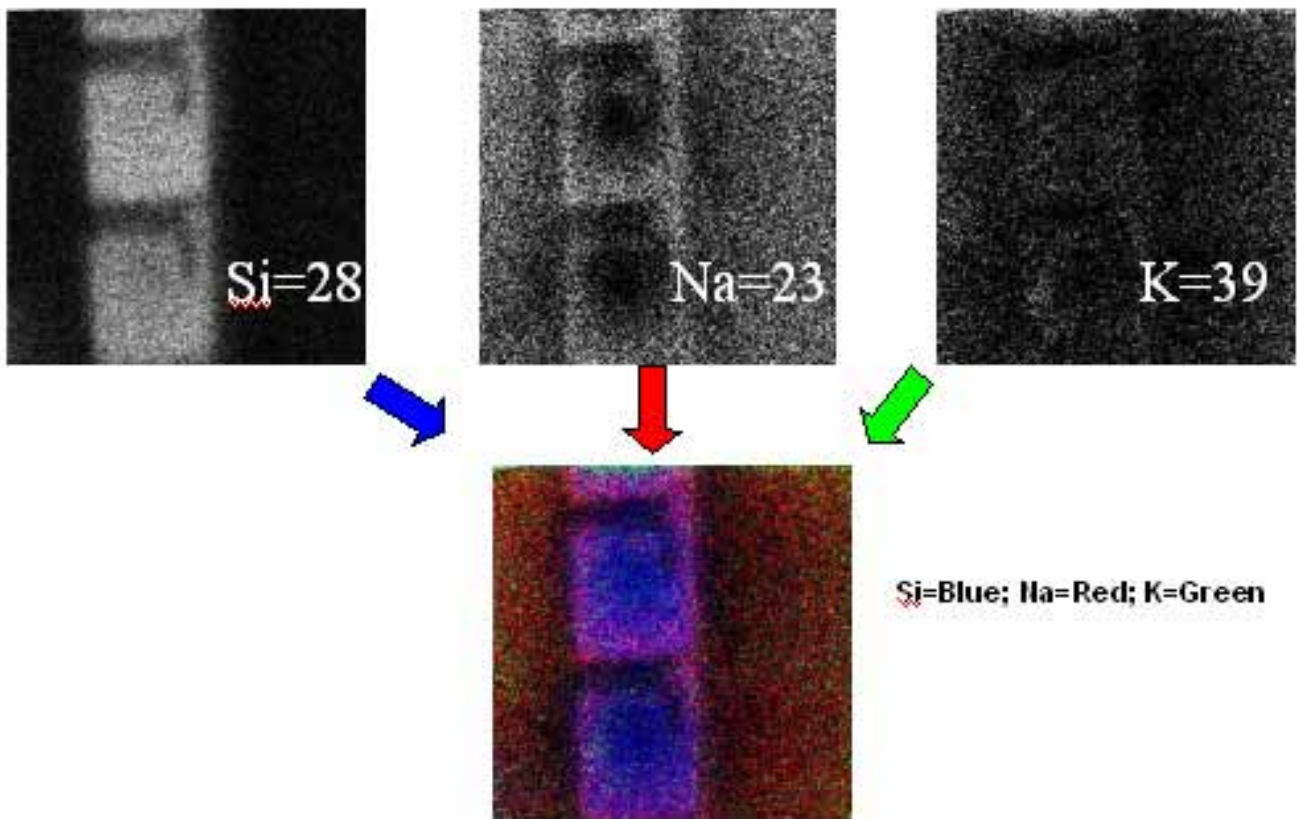
Figure 3 Secondary ion images of the contaminated area. Image size is 150 μm x 150 μm.
The images are also shown as a false-colour overlay.

The results for sodium (Na$^+$, m/z 23) potassium (K$^+$, m/z 39), and silicon (Si$^+$, m/z 28) are shown in Figure 3. The sodium image shows a different distribution of intensity to the silicon image of the substrate, confirming that the high concentration of sodium is located only on the edge of pattern

Prolonged SIMS analysis times of several minutes lead to controlled etching of the sample. At the same time, the change in intensity of selected secondary ions can be monitored to investigate the composition beneath the original surface. It is therefore possible to assess the thickness of contamination and determine whether the sodium is present as a superficial contaminant on the surface, or as a contaminant in the near surface layers of the device itself.

A depth analysis (Figure 4) was performed by etching an area 100 μm x 100 μm near the edge of the pattern, in a region shown as having high sodium concentration at the surface. Under these conditions, the average etch rate is approximately 1 nm in 10 seconds. Gallium is implanted in the sample by the bombarding beam, and this quickly reaches a steady state as monitored by the Ga$^+$ ion (m/z 69). It can be seen that the intensity of the Na$^+$ ion (m/z 23) signal rapidly falls to the background level. Sodium has a high ionization probability and this result can therefore not be attributed to the change in matrix composition with depth. Instead, the conclusion is that the sodium is only present superficially on the surface.
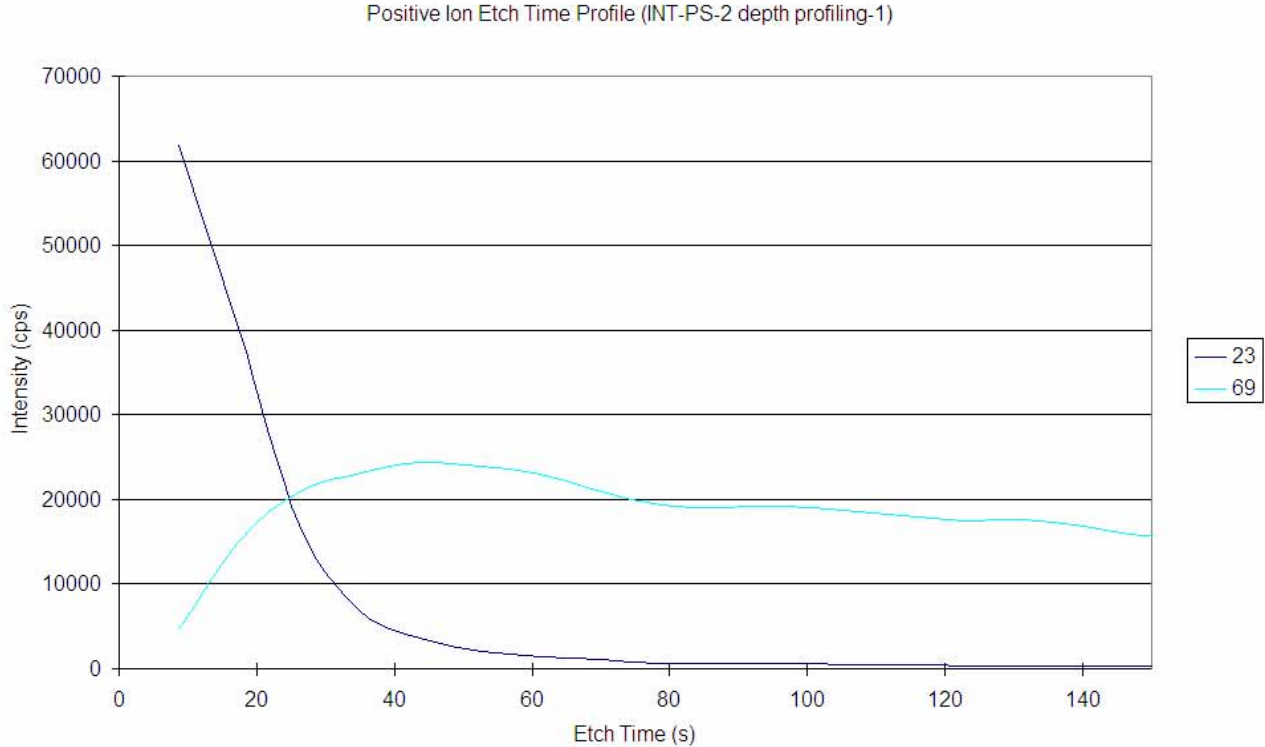
Positive Ion Etch Time Profile (INT-PS-2 depth profiling-1)

Figure 4 Positive secondary ion positive depth analysis. Crater size 100 μm x 100 μm.

3. Conclusion

SEM/EDX and SIMS give complementary information for process monitoring. SIMS can resolve process issues in this type of case where the contamination levels are too low or the residues are too superficial to be detected by EDX.

The use of a desktop SIMS instrument allows a routine analysis to be performed on-site, with total analysis times of less than 15 minutes per sample. The low capital and running costs together with the ease of use of this type of automated desktop instrument allows analysis that would not be cost-effective with the more sophisticated instrumentation conventionally associated with SIMS.

4. Acknowledgements

This work was supported by TPO.

5. References

[1] R.G. Wilson, F.A. Stevie & C.W. Magee SIMS: a practical handbook for depth profiling and bulk impurity analysis, John Wiley & Sons, New York, (1989)

[2] A.J. Eccles & T.A. Steele, p.229 Proceedings SIMS XII, Eds. A. Benninghoven et al., Elsevier Amsterdam (2000)