

# **Determination of Spatial Uniformity by Ion Imaging with Secondary Ion Mass Spectrometry (SIMS)**

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# Determination of Spatial Uniformity by Ion Imaging with Secondary Ion Mass Spectrometry (SIMS)

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## ABSTRACT

This paper discusses some of the problems associated with applying secondary ion mass spectrometry (SIMS) to non uniform solar cell materials from the characterization viewpoint. Two examples are given: depth profile analysis of contacts on III-V materials, and “bulk” analysis of processed silicon materials.

## 1. Introduction

SIMS is frequently employed to provide depth distribution information of impurities, dopants, and matrix species in solar cell structures. Diffusion of these constituents is of major concern in multi layer structures where high growth and process temperatures are common. Because of its low detection limits (parts per trillion for some elements), SIMS is also used to measure solar cell material impurities and dopants in complement to traditional bulk characterization techniques [1].

## 2. Experimental

These experiments were carried out on a Cameca IMS-5F SIMS instrument. The primary ion beam ( $\text{Cs}^+$  or  $\text{O}_2^+$ ) is focused into a small spot ( $\sim 5\text{-}50\ \mu\text{m}$ ) and then rastered over an area generally between  $25\ \mu\text{m}\times 25\ \mu\text{m}$  and  $500\ \mu\text{m}\times 500\ \mu\text{m}$ . Typically, a  $60\ \mu\text{m}$ -diameter circular analysis area is used for rastered areas  $\geq 150\ \mu\text{m}\times 150\ \mu\text{m}$ . For secondary ion currents  $> 1\text{E}5$  counts per second (cps), direct ion imaging is obtained from a microchannel plate/fluorescent screen (MCP/FS) assembly. Figure 1 shows distribution of aluminum on the surface of poly-silicon by direct ion imaging.

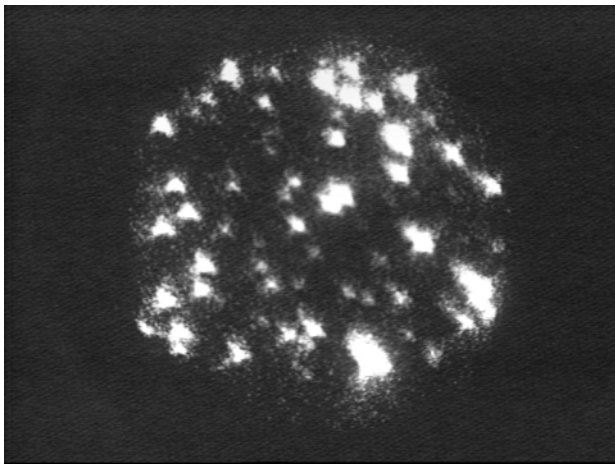


Figure 1. Direct ion image of **aluminum** (+) from the surface of a poly-crystalline silicon sample.  $150\ \mu\text{m}$  FOV.

For currents  $< 1\text{E}5$  cps, scanning ion images are obtained by the synchronization of the primary beam location (X & Y) and the secondary ion detector signal (Z). Lateral resolution of direct ion imaging, nominally  $72\ \text{nm}$  for a  $150\ \mu\text{m}$  field of view (FOV), is limited by the MCP size, pore spacing, and the FOV. Lateral resolution of scanning ion imaging is limited by the size of the primary beam spot, the trade-off being lower secondary ion intensity for a smaller spot size.

## 3. Example 1: Depth profiling Au contacts on GaAs

Samples of good and bad gold contacts on GaAs epitaxial layers were submitted for SIMS. Figure 2 shows depth distribution of Au through contaminated contact 1 and good contact 2. Depth resolution is limited by the primary beam mixing depth (nominally  $10.3\ \text{nm}$  with  $\text{Cs}^+$ ) and sample roughness. Differences in the two contaminated contact 1 profiles are the first clue to non-uniformity.

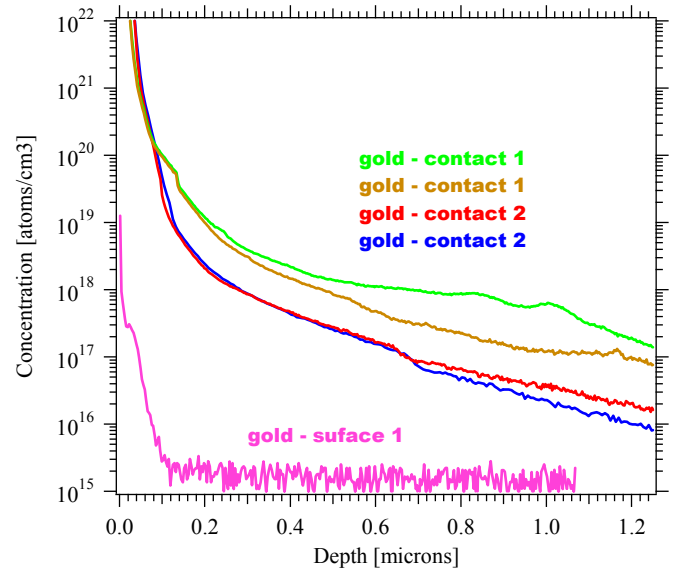


Figure 2. Depth profile of gold contact deposited on GaAs. Contamination of contact 1 influencing Au distribution.

Depth profiles of oxygen (Fig. 3) and carbon (Fig. 4) demonstrate contaminant non-uniformity. Figure 5 clearly shows contamination in particle form on the surface or embedded in the bad contacts. The results of these experiments were important in understanding why our gold deposition system was creating poor contacts.

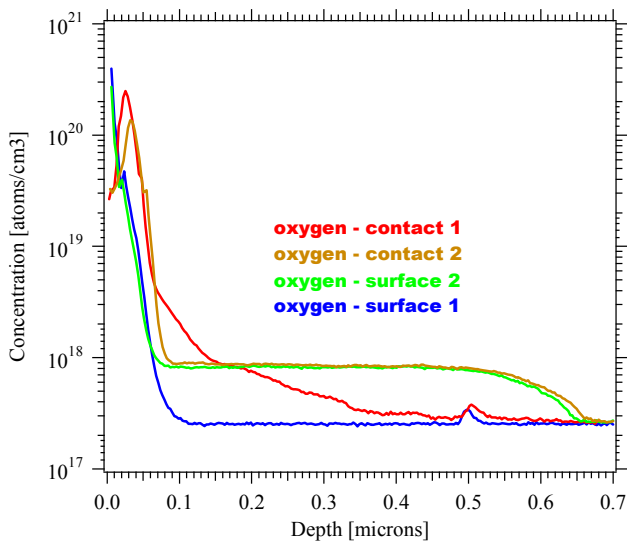


Figure 3. Comparison of oxygen distribution, bad (1) and good (2) samples, off-contact (surface) vs. on-contact. Also note interfacial contamination at 0.3 μm between GaAs and Au.

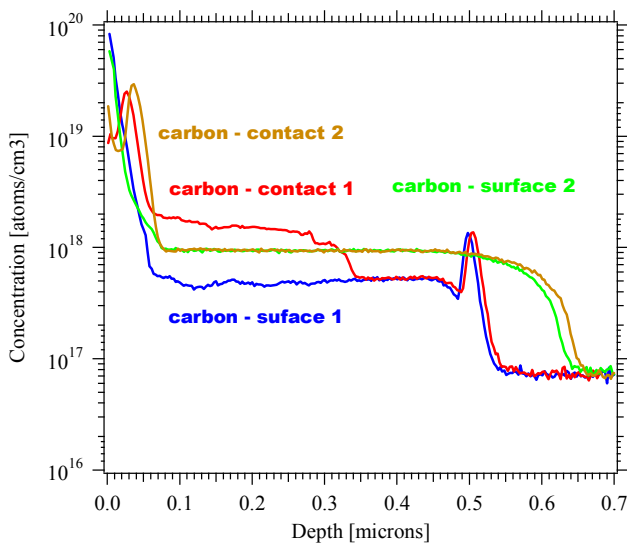


Figure 4. Comparison of carbon distribution, bad (1) and good (2) samples, off-contact (surface) vs. on-contact.

#### 4. “Bulk” analysis of polycrystalline silicon

The silicon solar cell community is actively working to solve its feedstock dilemma. SIMS has been frequently used to study processed silicon materials. Characterization of AstroPower Silicon-Film™ material by ICP-MS, GDMS, and SIMS has shown that impurities exist in good and bad samples [2]. SIMS is the only technique that can provide low detection limits with decent spatial information. Figure 6 demonstrates a deep depth profile in AstroPower poly-Si, where a cluster of contamination is seen near the surface.

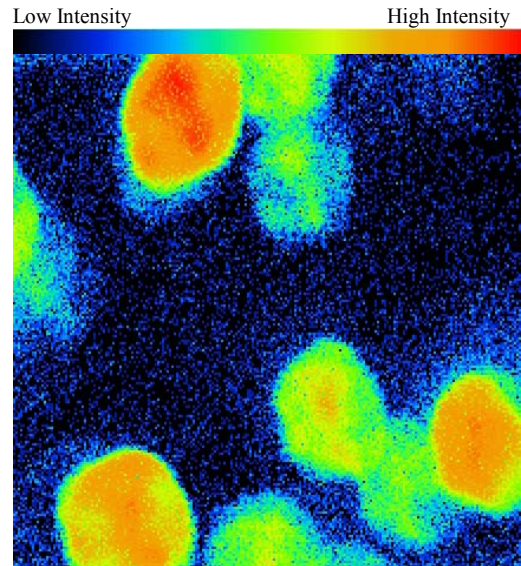


Figure 5a. Surface distribution of carbon from contaminated (contact 1) sample. Field of view is 125μmX125μm.

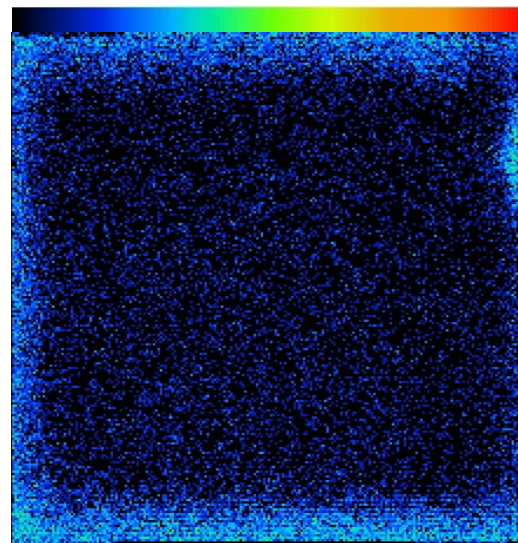


Figure 5b. Surface distribution of carbon from non-contaminated (contact 2) sample. Field of view is 125μmX125μm.

For the same spot size, faster sputtering can be obtained with  $O_2^+$  vs.  $Cs^+$  and is necessary for the detection of transition metals. Scanning ion images (Figs. 7a and 7b) of this analysis area prior to the depth profile show that the sample is indeed non-uniform, as well as the association of C with Al, Cr, and Fe. Aluminum particles also appear independent. The primary beam spot was about 50  $\mu m$  in diameter while taking this image. The results of these experiment helped to identify the location of impurities and their associations in AstroPower materials as a function of process conditions.

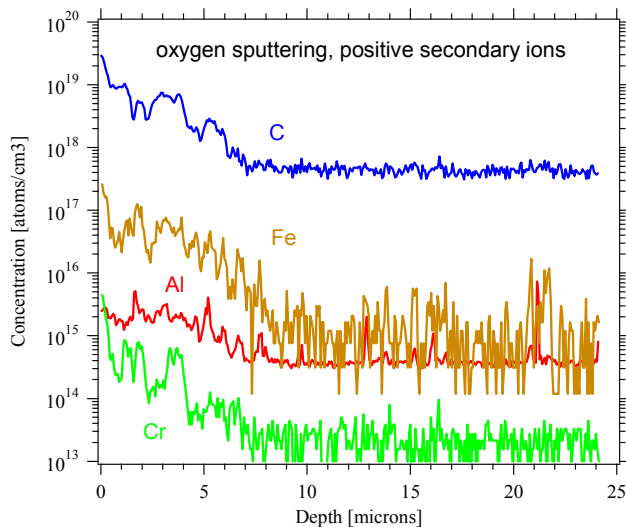


Figure 6. Depth profile of AstroPower Silicon-Film™ sheet material. Between multiple profiles, the size and location of contaminants was not consistent.

## 5. Conclusion

Multiple depth profiles should be performed on samples as this is the first clue to sample non-uniformity. Low sputter rate ion imaging can be employed to avoid areas of surface contamination, with minimal loss of surface information. Ion imaging techniques are instrumental in identifying artifacts in depth profile analysis, as well as providing spatial information on impurities in photovoltaic materials.

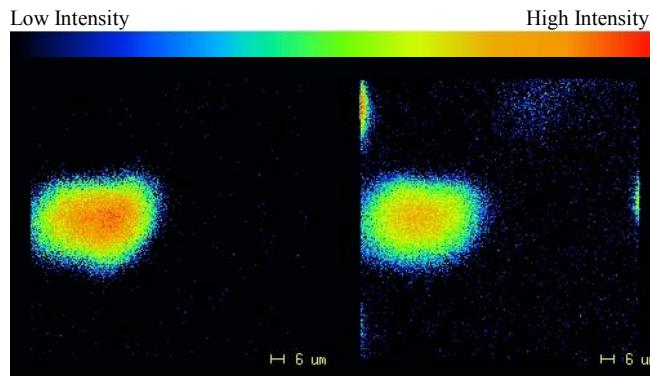


Figure 7a. Scanning ion images of  $^{12}C$  (left) and  $^{27}Al$ .

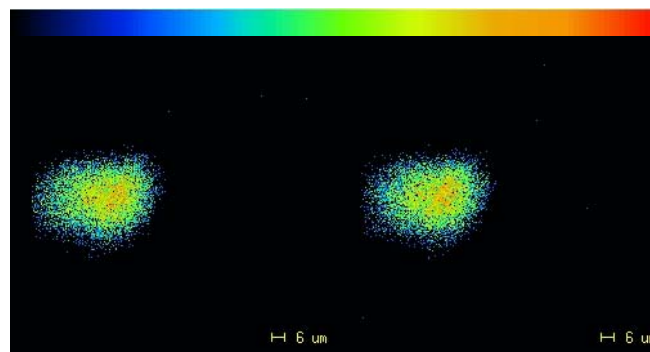


Figure 7b. Scanning ion images of  $^{52}Cr$  (left) and  $^{54}Fe$ .

## 6. Acknowledgements

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- [1] R. Wilson, F. Stevie, and C. Magee. Secondary Ion Mass Spectrometry – A Practical Handbook for Depth Profiling and Bulk Impurity Analysis,” (John Wiley & Sons) 1989.
- [2] J. Rand, G. Rozgonyi, and R. Reedy. "Characterization of Silicon-Film™ Sheet Material” *Proceedings of the 29th IEEE PV Specialists Conference, May 18–25, 2002, New Orleans, LA.*

# REPORT DOCUMENTATION PAGE

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