

# ***PROGRAM AND PROCEEDINGS***



## **NCPV Program Review Meeting 2000**

**April 16-19, 2000**

**Adam's Mark Hotel**

**Denver, Colorado**



## NOTICE

This report was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

Available electronically at <http://www.doe.gov/bridge>

Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from:

U.S. Department of Energy  
Office of Scientific and Technical Information  
P.O. Box 62  
Oak Ridge, TN 37831-0062  
phone: 865.576.8401  
fax: 865.576.5728  
email: [reports@adonis.osti.gov](mailto:reports@adonis.osti.gov)

Available for sale to the public, in paper, from:

U.S. Department of Commerce  
National Technical Information Service  
5285 Port Royal Road  
Springfield, VA 22161  
phone: 800.553.6847  
fax: 703.605.6900  
email: [orders@ntis.fedworld.gov](mailto:orders@ntis.fedworld.gov)  
online ordering: <http://www.ntis.gov/ordering.htm>



# SIMS Characterization of Amorphous-Silicon Solar Cells Grown by Hot-Wire Chemical Vapor Deposition on Stainless Steel

R.C. Reedy, Q. Wang, H. Moutinho, E. Iwaniczko, A.H. Mahan

National Renewable Energy Laboratory

1617 Cole Blvd., Golden, CO 80401

## ABSTRACT

This poster is intended to be an overview of some of the challenges that must be overcome when characterizing amorphous-silicon solar-cell devices by the secondary ion mass spectrometry (SIMS) technique.

### 1. Introduction

SIMS is a mass-spectrometry technique that is highly prized for its sensitivity and ability to provide depth information. It is also one of the few techniques that can detect hydrogen. Much work has been performed with this technique to improve the quality of a-Si:H i-layers deposited by hot-wire chemical-vapor deposition (HWCVD) [1]. SIMS is also very useful in the characterization of a-SiGe:H materials [2,3]. Figure 1 shows a typical depth profile of a a-Si:H n-i-p device grown on a stainless-steel (SS) substrate at the National Renewable Energy Laboratory (NREL). The profile is actually a composite of three separate depth profiles. Hydrogen, carbon, and oxygen data were obtained by sputtering with our Cs<sup>+</sup> source at an impact energy of 14.5keV, analyzing negative secondary ions. Phosphorous data was obtained under similar conditions with the secondary optics optimized for high-mass resolution. Boron data was obtained by sputtering with our O<sub>2</sub><sup>+</sup> source at an impact energy of 8keV, analyzing positive secondary ions.

SIMS depth profiles provide evidence of boron contamination in the n-layer and phosphorous in the p-layer

which can most likely be attributed to the deposition of these materials in the same chamber. More important is the diffusion of dopants into the i-layer. Ideally, the growth of a-Si:H layers would conform to the substrate surface, and the sputtering during SIMS depth profiles would reproduce the original device surface. Since these ideal conditions are never completely met, it is important to determine the contribution of roughness to the apparent diffusion.

### 2. Mass Interferences

Mass interferences are common in SIMS because of the variety and intensity of the atomic and molecular ions species that are generated [4]. Mass resolution,  $m/\Delta m$ , is required to distinguish between two ions that have the same nominal mass,  $m$ , but differ in mass by a small value,  $\Delta m$ . The magnetic sector design of the dynamic SIMS instrument will normally provide unity-mass resolution,  $m/\Delta m = 300$ . High-mass resolution is achieved by physically limiting the amount of ions through the mass spectrometer by a set of mechanical slits. The mass resolution of the Cameca dynamic SIMS instrument can be varied up to 10,000, although transmission under these conditions is severely limited. Phosphorous requires a mass resolution of 3957 to separate <sup>30</sup>Si<sup>+</sup>H and is especially difficult in a-Si:H materials due to the high levels of hydrogen. While detection limits of 1E14 atoms/cm<sup>3</sup> can be easily achieved for boron under low-mass resolution, phosphorous background limits of 1E16 atoms/cm<sup>3</sup> require instrument parameters of the utmost precision.

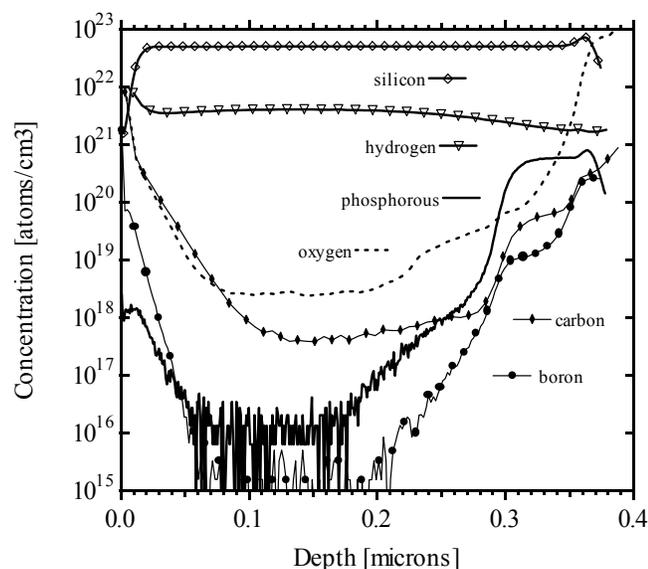


Figure 1. SIMS depth profile of a-Si:H n-i-p device deposited on unpolished stainless steel. Note the amount of boron in the n-layer and phosphorous in the p-layer.

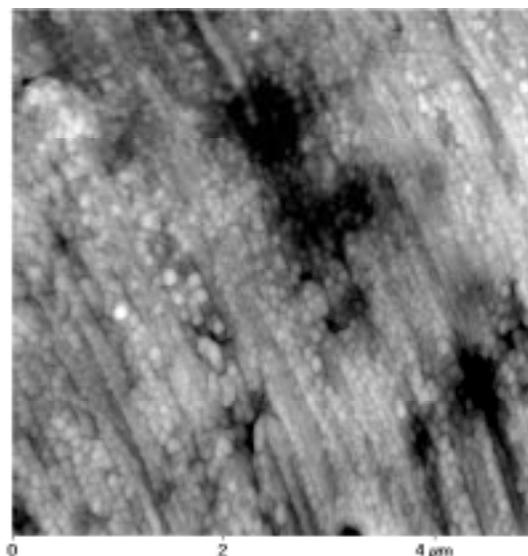


Figure 2. AFM image of standard stainless-steel surface roughness. Note that the typical SIMS analysis area has a diameter of 60 μm.

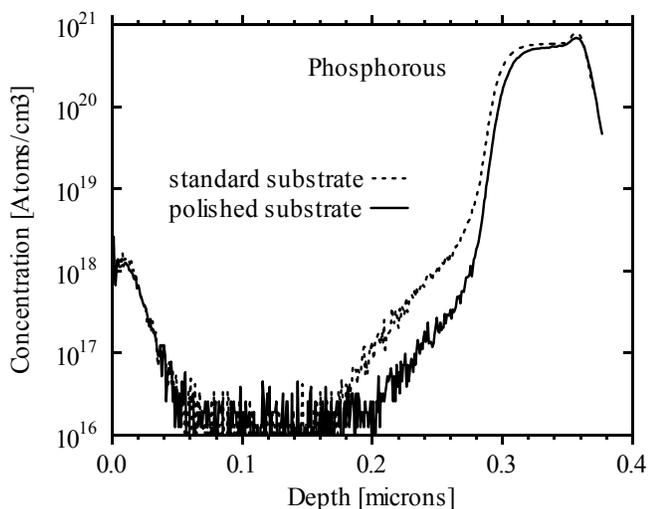


Figure 3. SIMS depth-profile comparison of phosphorous profiles, polished vs. standard SS substrates.

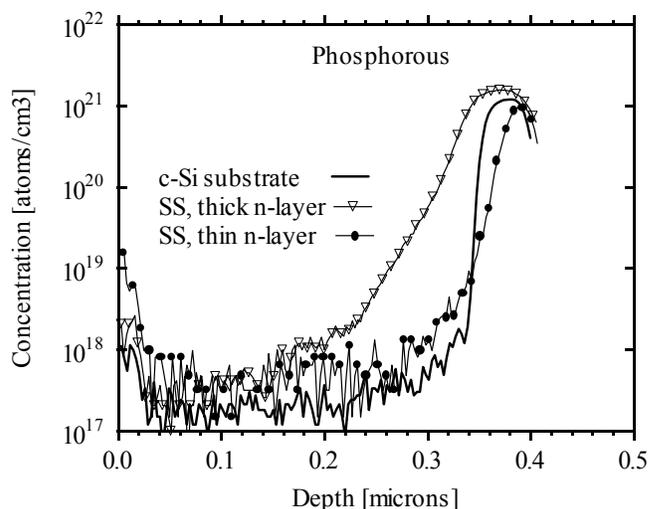


Figure 4. SIMS depth profile comparison of phosphorous profiles, single crystal silicon vs. SS substrates.

### 3. Roughness Issues

Substrate and surface roughness play a large role in affecting the depth resolution of SIMS depth profiles. Figure 2 is an atomic force microscopy (AFM) image taken from a typical NREL SS substrate. An attempt was made to polish a sample of substrate material and compare the SIMS depth profiles of a-Si:H n-i-p structures grown next to a standard substrate. Visually, the polished substrate appeared to be smoother than the standard, however the average roughness of both substrates, measured by AFM, was nearly identical at 80Å. Figure 3 is a comparison of phosphorous profiles and it clearly shows an improvement in depth resolution.

Comparisons can be made between smooth substrates e.g., glass and single-crystal silicon (c-Si). However, problems occur with adhesion to c-Si and charging effects associated with insulators. The thermal properties of different substrate materials may also influence growth of a-Si:H. Figure 4 is a comparison of a-Si:H n-i-p structures grown on SS and c-Si. There is evidence of approximately 1000Å of P diffusion in the c-Si substrate sample from the n to i-layer.

### 4. Summary

SIMS is a very powerful tool in the characterization of solar cell devices. Compromises are almost always necessary in detection limits, background levels, and depth resolution. It is imperative to understand the artifacts in measurements and sample preparation to determine the validity of resultant processed data.

### REFERENCES

- [1] A.H. Mahan; R.C. Reedy; E. Iwaniczko; Q. Wang; B.P. Nelson; Y. Xu; A.C. Gallagher; H.M. Branz; R.S. Crandall; J. Yang; and S. Guha: "H Out-Diffusion and Device Performance in n-i-p Solar Cells Utilizing High Temperature Hot Wire a-Si:H i-Layers", Materials Research Society Symposium Proceedings, Vol. 507, pp. 119-124 (1998).
- [2] R.C. Reedy, A.R. Mason, B.P. Nelson, and Y. Xu, "SIMS Characterization of Amorphous Silicon Alloys Grown by Hot-Wire Deposition", Conference Proceedings of the 15<sup>th</sup> NCPV Photovoltaics Program Review, AIP 462, pp. 537-541
- [3] B.P. Nelson, Y. Xu, J.D. Webb, A.M., R.C. Reedy, L.M. Gedivals, and W.A. Lanford, "Techniques for measuring the composition of hydrogenated amorphous silicon-germanium alloys", Journal of Non-Crystalline Solids, 5204, Article 6755 (2000).
- [4] R.G. Wilson, F.A. Stevie, and C.W. Magee: "Secondary Ion Mass Spectrometry, A practical Handbook for Depth Profiling and Bulk Impurity Analysis", John Wiley & Sons, New York (1989).