SENSITIVE MULTIELEMENT RIMS DEPTH PROFILING OF GENESIS SOLAR WIND COLLECTORS.*

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Introduction: In the NASA Genesis Mission [1], a spacecraft collected solar wind (SW) particles into a variety of ultra-pure materials [2]. The goal of the mission was to obtain a comprehensive set of solar elemental and isotopic abundances at significantly higher precision and accuracy levels than presently available [1]. However, the samples delivered by the mission present significant challenges for analytical techniques, in part due to severe terrestrial contamination of the samples on reentry, in part due to the low SW implant concentrations (ppm to ppt) which were implanted close to (within <100 nm) the surface. In addition, the collected SW elements appear to exhibit noticeable diffusion into the bulk and towards the surface [3], making it difficult to separate SW elements segregated to the surface from terrestrial surface contamination. However, the quality of scientific results from the Genesis mission critically depends on the ability of analytical techniques to accurately make this separation. Ion sputtering based surface analysis techniques such as Secondary Neutral Mass Spectrometry (SNMS) are the methods of choice to make this separation. At Argonne, we measure the concentration of metallic elements in Genesis collectors using Resonance Ionization Mass Spectrometry (RIMS) which is a variant of SNMS capable of detecting SW in samples with lateral dimensions of less than a few mm and at concentrations from above one ppm to a few ppt. The details of our instrument for Genesis sample analysis, SARISA, have been discussed previously [4]. In this paper, we report on first simultaneous RIMS measurements of Mg, Ca and Cr performed on Genesis samples #60179 (Si) and #60245 (diamond film on Si, DOS). We also describe the evolution of our analytical instrumentation and procedures that aimed and resulted in improved accuracy and precision of quantitative RIMS measurements of SW samples.

Experimental: Sputtered neutral atoms were measured, using Resonantly-Enhanced Multi-Photon Ionization (REMPI) with tunable Ti-Sapphire lasers to create photoions which were extracted into a TOF mass spectrometer (MS) for analysis. We developed new REMPI schemes (using 422.78nm, 369.63nm and 285.30nm light) that allowed us to simultaneously detect Mg, Ca and Cr, using only three tunable lasers. All laser beams were nearly collinear, which allowed a prism retro-reflector to be implemented returning the beams back into the photo-ionization region, for an extra (about a factor of two) signal enhancement. *Concentration versus depth* profiles were obtained by a sequence of alternating sessions of sputtering, using a raster scanned primary DC ion beam, and TOF MS analysis.

Results and Discussion: First, sample holders in our SARISA instrument were redesigned to minimize the variation in ion transmission when the analysis spot on the sample was changed. This resulted in nearly constant transmission from any point of the 25mm diameter sample.

Two types of samples were then depth profiled – ion implants to act as primary standards and Genesis SW samples. The standards were Si and DOS wafers implanted with Mg, Cr, and Ca at fluencies of 3×10^{13} at cm^{-2} and 1 keV/amu energies to emulate SW implants (Fig.1). The accuracy of our determination of SW fluencies was tested by comparing two Si standard samples. Quantification of one implant (acting as unknown, as if it would be a Genesis sample) based on using the other implant as a standard with a known fluence, demonstrated an accuracy within 5% for all three elements and greater than five orders of magnitude dynamic range for sputter depth profiling.

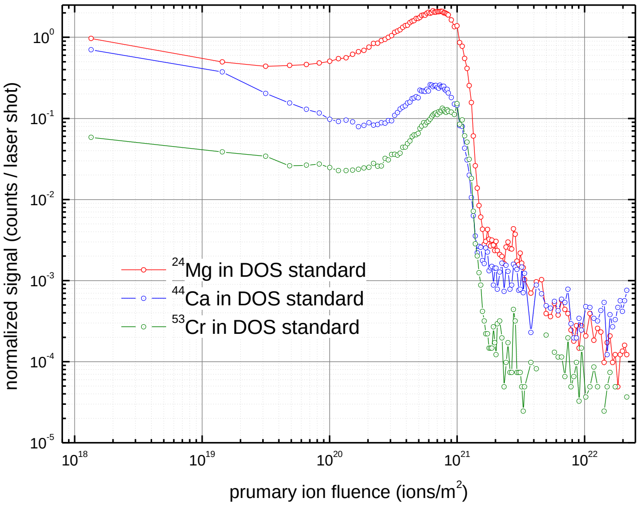

Fig.1 Three elements (Mg, Ca, Cr) RIMS depth profiles of DOS standards

However, once real Genesis samples were analyzed, it became apparent that further improvements in depth resolution were needed in order to distinguish the contamination from the SW implant. A series of experiments with Genesis DOS sample #60245 were performed. Three sputter depth profiling procedures (Fig.2) have been compared (1) an unrastered 10 keV pulsed ion beam was used to analyze only the center of the crater created by a 10 keV sputtering beam (top plot on Fig.2), (2) a 5 keV pulsed beam was raster scanned over the entire sputtered crater, with a gating signal used to make sure that only sputtered atoms from the central 50% of the area of the crater contributed in the detected signal (middle plot on Fig.2), (3) in the so-called "mesa" approach [5], prior to analyses, few micron deep "trenches" were sputtered around the outside of the analyzed crater in order to minimize the crater edge effect (bottom plot on Fig.2).

This comparison revealed the the "mesa" approach [5] produces the widest dynamic range and best depth resolution for the implant standard. The direct comparison between results on Genesis is more complicated because each analysis spot had different surface contamination. The calculations of SW fluencies of ^{24}Mg for first and second procedures produced 1.9x10^{12} and 1.5x10^{12} at/cm^2, which is somewhat lower than previously reported (2.5x10^{12} at/cm^2) [6].

Since the last LPSC meeting, we have made significant improvements both in instrumentation and methodology for RIMS analyses of Genesis samples. In particular, we demonstrated that the "mesa" approach produces superior results. We will continue to use this approach for SW fluence determination using multielement RIMS analyses.

References: [1] Burnett, D. S., et al. (2003) Space Science Rev., 105, 509-534. [2] Jurewicz, A. J. G., et al. (2003) Space Science Rev., 105, 535-560. [3] King, B. V. et al. (2008) Appl. Surf. Sci, 255, 1455-1457. [4] Veryovkin, I. V., et al. (2004) Nucl. Instr. Meth. B, 219-220, 473-479. [5] Gillen, G. (2004) Surf. Int. Anal., 18, 777-780.[6] I.V. Veryovkin et al., (2008) *LPS XXXIX*, Abstract #2396.

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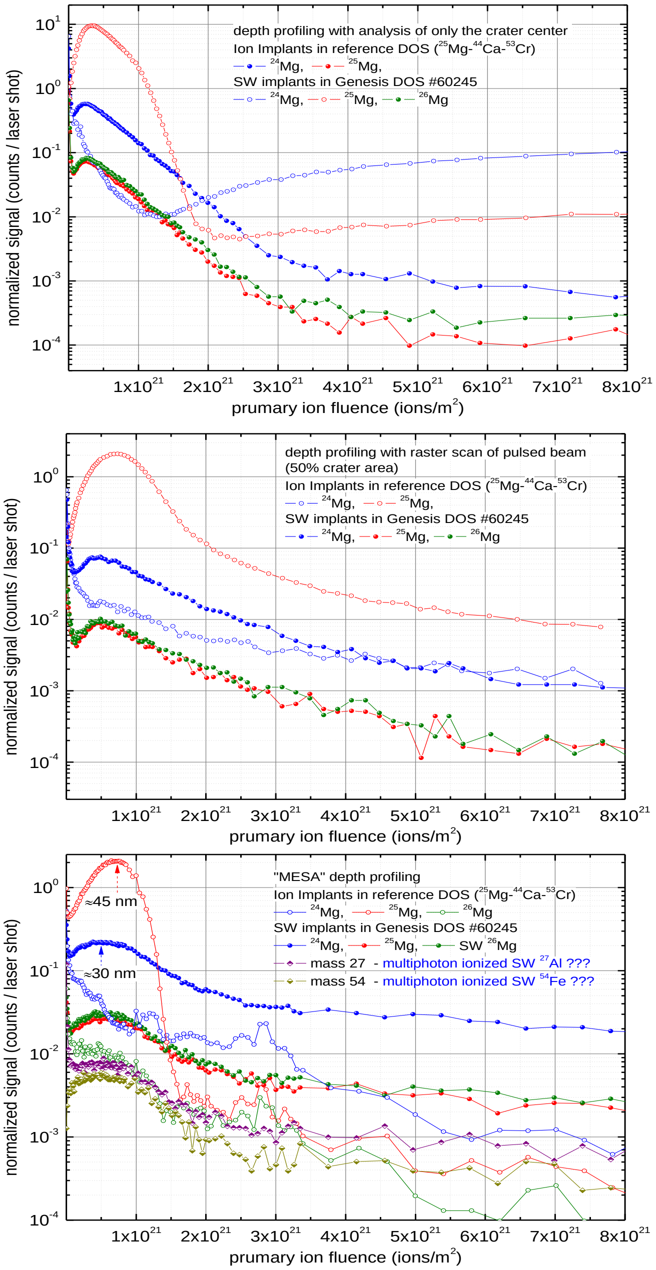

Fig.2 Comparison between three different approaches to depth profiling.