DISCRIMINATION AND QUANTIFICATION OF IMPLANTED SOLAR WIND IN GENESIS COLLECTOR SHARDS USING GRAZING INCIDENCE SYNCHROTRON X-RAY TECHNIQUES: NEW DETECTOR INITIAL RESULTS K. Kitts[1], Y. Choi[1], P. Eng[2] , S. Sutton[2, 3], S. Ghose[2], D. Burnett[4], [1]Department of Geology & Environ. Geosciences, Northern Illinois University (Davis Hall 312, Normal Rd, DeKalb, IL 60115; kkitts@niu.edu), [2]Consortium for Advanced Radiation Sources and [3]Department of Geophysical Sciences (University of Chicago, Chicago, IL 60637), [4]Geology & Planetary Sciences, Caltech (MS 100-23, Pasadena, CA 91125).

Introduction: Accurate knowledge of the composition of the Sun provides a baseline, which allows an understanding of how the solar system has evolved over time and how solar processes and solar wind mechanics behave. Unfortunately, the errors in photospheric abundances are too large for many planetary science problems and this hampers our understanding of these different processes. Analyses of solar wind implanted in meteorites or lunar soils have provided more precise data [e.g. 1 and references therein] but the extent to which alteration processes on these bodies complicate such information is only now being determined [2, 3]. Therefore, in order to obtain pristine solar wind samples, NASA developed and launched the Genesis Discovery Mission. Unfortunately, the probe crash-landed shattering the 300 collector plates into 15,000+ pieces complicating the analysis and necessitating the development of new analytical techniques and equipment.

Thus, shards from the Genesis collector array and their appropriate flight spares are currently being characterized via grazing-incidence synchrotron x-ray techniques at the Advanced Photon Source at Argonne National Laboratory. The goals are (1) determine solar wind fluences of the elements Ca-Ge by grazing-incidence angle-resolved x-ray fluorescence (XRF) and x-ray reflectivity, (2) improve data reduction via the development of XRF spectral deconvolution routines and develop modeling algorithms for reflectivity and fluorescence yield analysis in order to determine element specific depth profiles from which absolute concentration may be extracted and (3) designing and developing a new multi-element silicon multi-channel (SMCD) detector system. These improvements will increase our sensitivity by a factor of three or more, reduce measurement time at a given sensitivity to one-eighth and the minimum detection limit would be reduced by a factor of 3 to ~3 x 10^8 atoms/cm^2.

Materials and Methods: The Curatorial Staff at Johnson Space Center and the Genesis Team have provided two flown shards of Si on single crystal sapphire (60234 and 60326), the appropriate implant standards and flight spare. These were analyzed using x-ray reflectivity and grazing incidence XRF at APS (GSECARS sector 13 Newport General Purpose Diffractometer). The x-ray beam was derived from an APS undulator with the gap set to supply 11.5 keV photons at the undulator fundamental. A cryogenic Si (111) double-crystal monochromator was used to narrow the energy bandwidth of the beam. A combination of focusing mirrors in a Kirkpatrick-Baez geometry and slits resulted in an x-ray beam size of 20 x 500 μm (H x V) that is collimated to less than 1mdeg (in the reflection direction) and contains ~ 10^{12} photons/sec.

The samples and spares were mounted on the diffractometer with the normal in the horizontal plane enclosed in a helium-flow sample chamber containing a thin (5 μm) Mylar window. A scintillation detector was used to measure the intensity of the reflected x-ray beam and a Vortex® silicon-drift energy-dispersive detector mounted in direct contact with the Mylar window was used to collect XRF spectra. X-ray reflectivity measurements were collected by performing θ-2θ trajectory scans with an angular sampling interval of 2 millidegrees (θ) spanning a range well below and above the critical angle (θ_C) of both the film and the substrate. Full XRF spectra were collected at each angle and were subsequently processed via a peak fitting routine to produce background subtracted fluorescence yield profiles (peak intensity vs. angle) for each detected XRF peak between 2 and 11 keV [4].

In our initial investigations [5], we used a single element SII NanoTechnologies Vortex® silicon multichannel detector (SMCD) to energy resolve the x-ray fluorescence spectrum during grazing incidence yield measurements. This detector has an excellent energy resolution (< 136 eV @ 6 keV), a large active area (~50 mm^2) and high deadtime corrected total count rate (> 500 kcps). Through the use of this detector, we were able to achieve a minimum detection limit of $1x10^9$ atoms/cm^2 for Fe with a 40 second integration time per incidence angle point. From these data, we showed that (1) grazing incidence XRF is an efficient and non-destructive technique that can be used to differentiate the embedded solar wind component from surface contamination and collector background signature and (2) that the initial solar Fe abundance in the flown sample D30554 determined by this technique was only slightly higher than the predicted Fe fluence of 2 X 10^{12}/cm^2 [6].

Results and Conclusions: Here, we present our initial test results of a new four-channel silicon multicathode detector. This prototype detector is made up of four elements tightly packed into a detector snout with specifications similar to the single element detector.

Due to this compact design, the elements can be situated directly normal to the beam optimizing the suppression of any elastically scattered x-rays and thereby significantly reducing the background.

As expected, Figure 1 shows a total count rate increase slightly greater than a factor of four for the four vs. one element detector when configured to operate at the same energy resolution. Thus, the four-element detector increases our sensitivity, reduces measurement time and lowers our minimum detection limit.

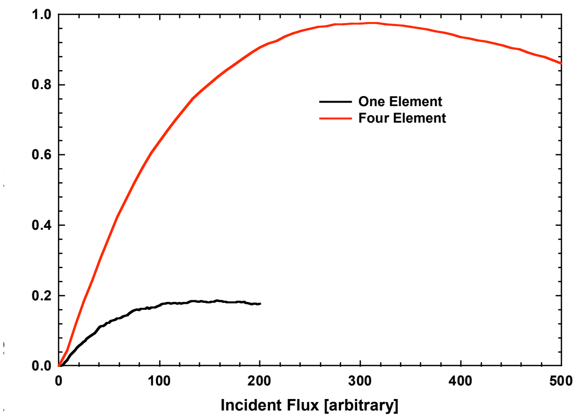

Figure 1: Comparison of count rate performance of the one and four element silicon multi-cathode detector operating at the same energy resolution.

From these initial experiments, we have been able to show that the standing wave can be deconvolved for the elements of Fe, Ni, Mn, Cr and Ca in the flown Genesis samples. Figure 2 shows measured Ni fluorescence that exhibits angle-dependent oscillatory behavior as a result of the standing wave within the Si film layer and the bulk sapphire substrate.

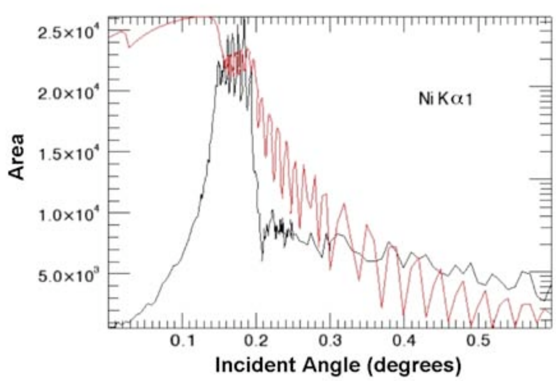

Figure 2: The red line is total reflectivity and the black line is the fluorescence yield of the Ni Kα line of the implanted solar wind in a Si on sapphire sample (60230) as a function of incident x-ray angle in degrees.

xp

The final series of plots demonstrate how the standing wave can be modeled to the necessary precision for elemental abundance determinations. Slight variations in the implanted element concentration depth profile strongly modify the standing wave pattern. This technique has the resolution to observe these variations and by using standards of known concentration with depth, absolute abundance depth profiles can be determined. The black line is calculated using a model concentration profile (based on an implant standard) and is in excellent agreement with the actual solar wind Fe data represented by the blue circles.

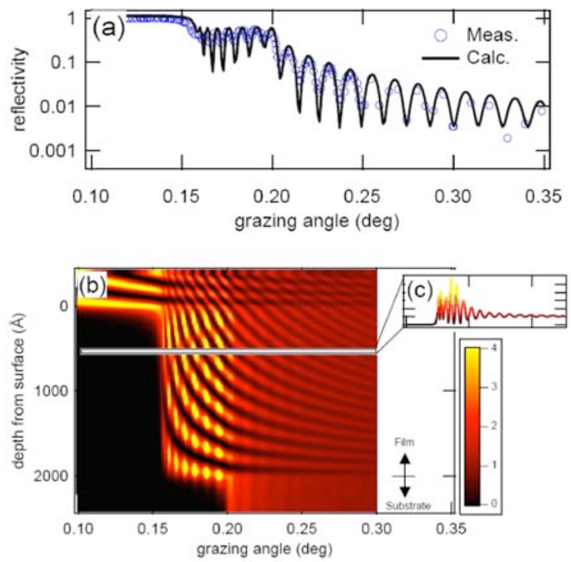

Figure 3: (a) Measured and calculated x-ray reflectivity curves for sample 60230. (b) The calculated x-ray standing wave intensity variation inside the film as a function of the incident x-ray angle at various depth positions. (c) Calculated fluorescence yield from implanted atoms.

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