ION BEAM REMOVAL OF SURFACE CONTAMINATION IN GENESIS SAMPLES.

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Introduction: High purity silicon wafers were exposed to the solar wind for 852 days and then returned to Earth in the NASA Genesis mission. We have previously used resonance ionization mass spectrometry (RIMS) [1] to profile particular solar wind elements, such as Mg, in Si collectors. However the Genesis capsule crashed on re-entry so the wafer surfaces were contaminated with material from other wafers as well as by terrestrial contaminants [2], making it difficult to separate, using RIMS, solar wind atoms, which are typically buried 50nm below the surface at a few parts-per-billion or lower concentrations, from the surface contamination.

There are a variety of analytical and process techniques which can be used to analyze and treat surfaces to both measure and remove contamination, enabling better measurement of solar wind fluence. In this paper we use four analytical techniques to investigate the use of the process technique, giant cluster ion beam (GCIB) irradiation, to remove contamination from Genesis surfaces. GCIB are beams of gaseous elements, such as Ar, comprising 1000 or more atoms in individual clusters [3]. They have been used to gently remove atomic layers from surfaces with much less damage than the conventional atomic beams in sputter depth profiling.

Experimental: Genesis samples 60476 and 60179 were analysed by atomic force microscopy (Veeco Dimension 3100 AFM) and white light interferometry (MicroXAM surface profiler) before being irradiated with GCIB (10keV Ar_{1000}) at the University of Hyogo. Part of the sample was masked so that irradiated and unirradiated regions on the same sample could be measured.

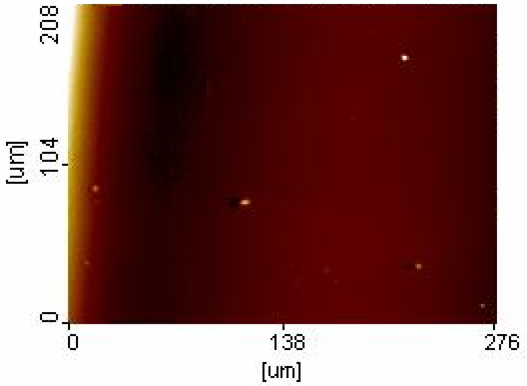

Figure 1 White light interferometer image of Genesis 60179 surface at low magnification showing distribution of micron sized particles.

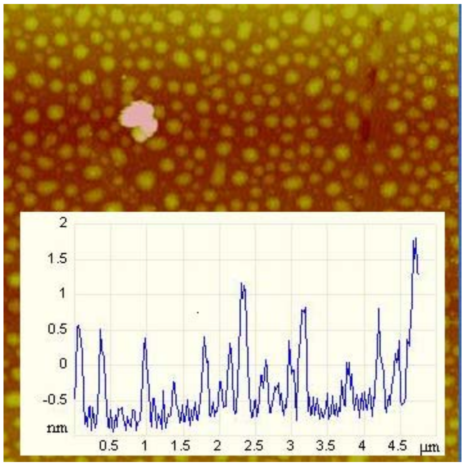

Figure 2 AFM image of Genesis 60179 surface at high magnification (5 µm x5µm) with line scan. The regular features on the surface are up to 2nm high and separated by, on average, 100nm

The samples were then again analysed using interferometry to determine surface topography, total X-ray fluorescence (TXRF) to determine heavy element (Z>13) surface contamination and sputter depth profiling using resonant ionization mass spectrometry (RIMS) to determine impurity concentrations in the top few microns of the surface.

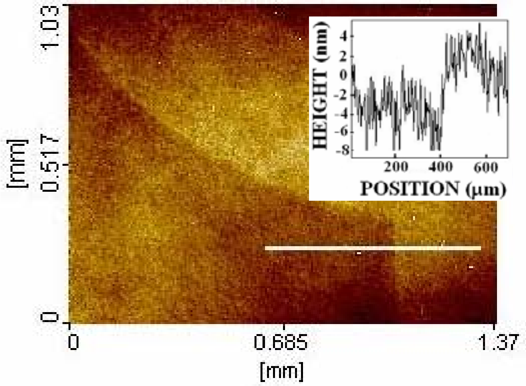

Figure 3 White light interferometry image of irradiated (dark) and unirradiated (white) areas of Genesis sample. A line scan of surface height (white line and insert) shows that 8nm of surface was removed.

Results and Discussion: Figure 3 shows an interferometric measurement of the surface topography and indicates that 8nm of surface was removed by the GCIB irradiation. Such measurements were repeated randomly over the entire surface with consistent results.

TXRF [4] analysis of irradiated and nonirradiated areas on the same Genesis sample show peaks due to the Si substrate (1.73keV), the Mo X-ray source (above 15 keV) as well as a number of surface impurity peaks in the X-ray energy range from 7 to 15keV. In all cases the impurity peaks in the spectrum from the irradiated area are less than those from the unirradiated area.

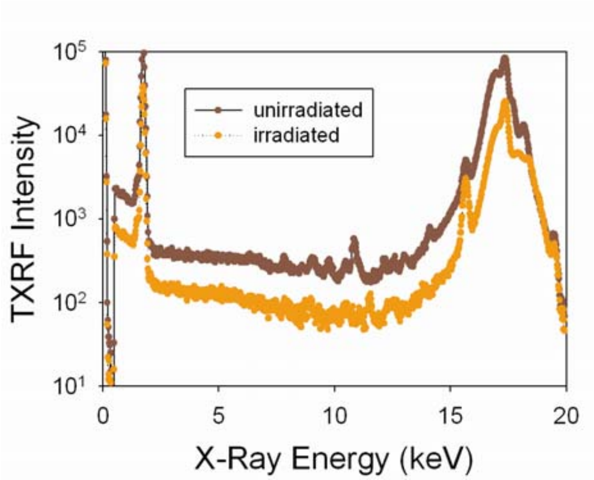

Figure 4 Total X-Ray Fluorescence spectrum of the irradiated and unirradiated areas of the Genesis sample.

RIMS depth profiling of Mg and Ca impurities in the Genesis sample (fig 5) shows that the signals from both elements have decreased by about an order of magnitude in the irradiated sample, and that this decrease is more pronounced at the surface, confirming the TXRF results. However the implanted solar wind ions, expected to be at a depth of 50-100nm are only marginally more visible in the irradiated samples compared to the unirradiated samples. Clearly, a greater thickness of material needs to be removed by the GCIB process to allow better quantitation of the solar wind implants.

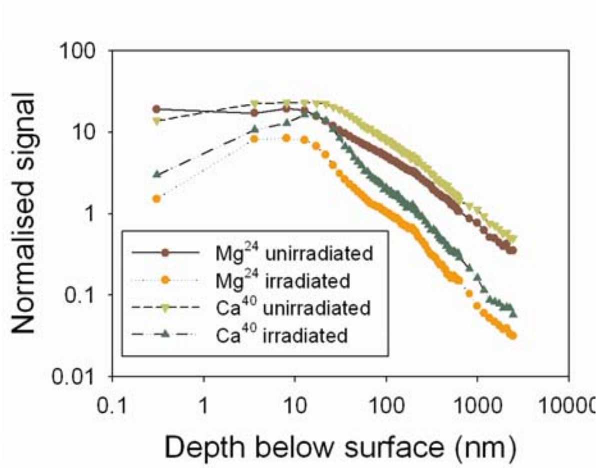

Figure 5 RIMS depth profiles of Mg^{24} and Ca^{40} from Genesis sample 60476 either irradiated with the GCIB or unirradiated.

Conclusions: Genesis samples 60179 and 60476 have been shown to have surface contamination on both micron and nanometer scales. Giant cluster ion beams have been shown to be effective in removing surface contamination, but more material needs to be removed by this process to allow solar wind implants to be clearly measured by RIMS depth profiling.

References:

[1] I.V. Veryovkin et al., (2008) *LPS XXXIX*, Abstract #2396 [2] J.H. Allton et al. (2007) *LPS XXXVIII*, Abstract #2138 [3] I. Yamada et al. (2003) Nucl. Instr. Meth. B206, 820-829 [4] [2] Streli, C. et al., (2001) X-Ray Spectrometry, 24-29.

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