GENESIS SOLAR WIND DEPTH PROFILING: ENHANCING SIMS ION YIELDS USING NOVEL BEAMS.
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Introduction: The goal of the Genesis Discovery Mission is to determine the elemental and isotopic compositions of the Sun through measurement of collected solar wind (SW) and modelling of stellar ion acceleration and fractionation mechanisms. Of utmost importance is the ability to determine the Sun's composition with sufficient precision to inform our understanding of solar system (SS) formation and planetary science. Recent modelling efforts have focused on the difference in fractionation between the closed loop solar corona and the slow speed SW [1], and the effects of chromospheric flow velocities and torsional Alfvén waves on the fractionation [2]. Most transition metals are comprised of several isotopes, making them useful targets for measuring isotopic fractionation in the SW. Similarly, a comparison of elemental and isotopic fractionation between low first ionization potential (FIP) elements, e.g., Fe and Mg, would be useful in constraining non-FIP-related fractionation processes. The abundances of transition metals in Genesis collectors are low, however, expected to lie in the range of, e.g., 3 $\mu mol \cdot mol^{-1}$ for Fe, 200 $nmol \cdot mol^{-1}$ for Ni, and 35 $nmol \cdot mol^{-1}$ for Mn, in the top 100 nm of bulk SW collectors [3]. The low abundances of these elements, the need to measure minor isotopes, and the need to discriminate intrinsic and contaminant signals compels us to find ways to increase their yields during secondary ion mass spectrometry (SIMS) depth profiling analyses.

Using the NAval Ultra-Trace Isotope Laboratory's Universal Spectrometer (NAUTILUS) [3,4], a combination SIMS and single-stage accelerator mass spectrometer (SSAMS), we investigated the use of different primary ion beam species and sample flooding gases on the secondary ion yields of elements from a variety of sample matrices. Earlier work has shown that fluorinated primary ion beams may increase the yields of transition metals [5-10], though none of these are routinely used today due to several drawbacks, including lack of stability and lack of beam intensity. The goal of this work was to create stable and useful primary ion species to enhance Genesis-relevant element sensitivity and be used for depth-resolved ion implant measurements.

Methods: We built a "testbench" mass spectrometer with a duoplasmatron ion source and a gas mixing manifold to investigate fluorinated and polyatomic ion beam production. We modified the anodes of the testbench and NAUTILUS sources to be semi-magnetic, which aided in extracting negative ion species [11]. We designed and built custom arc supply electronics to power

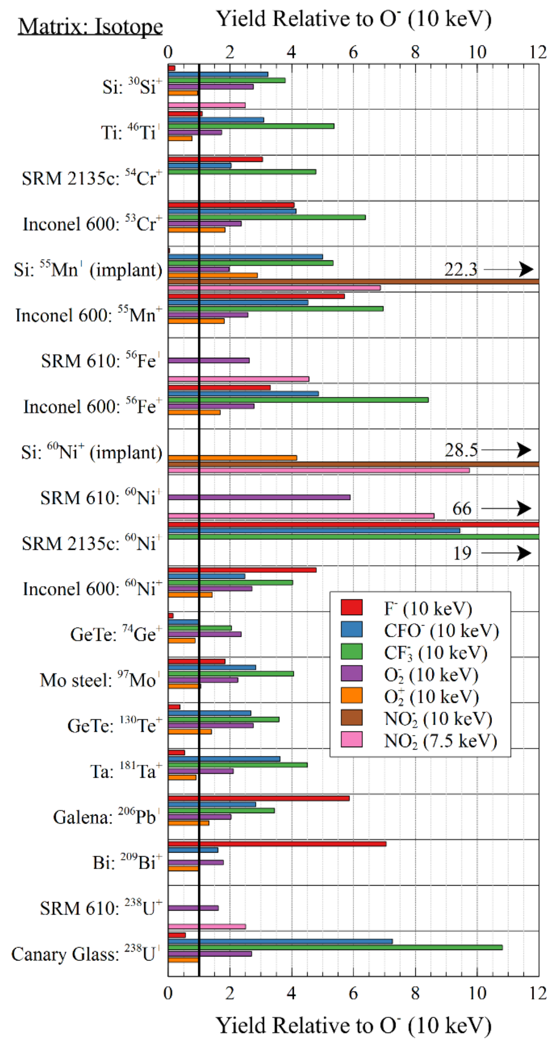

Figure 1: Comparison of instantaneous ion yields for several primary ion species relative to O$^-$.

the sources, which provided more stability than the original equipment manufacturer supplies. Using a variety of primary ion beams and sample flooding species on the NAUTILUS, we measured major and trace element components from several matrices, including oxidized (e.g., NIST 610 glass) and reduced (e.g., Inconel 600, Si wafer) materials. We also measured the depth profiles of ion implanted ^{55}Mn (3×10^{13} $ions \cdot cm^{-2}$, 55 keV) and ^{60}Ni (4×10^{13} $ions \cdot cm^{-2}$, 60 keV) in Si, and ^{54}Fe (2×10^{13} $ions \cdot cm^{-2}$, 168 keV) and ^{56}Fe (4×10^{13} $ions \cdot cm^{-2}$, 168 keV) in sapphire. We also experimented with fluorinated sample flooding gases (e.g., NF_3 and CF_4) under different primary ion bombardment conditions.

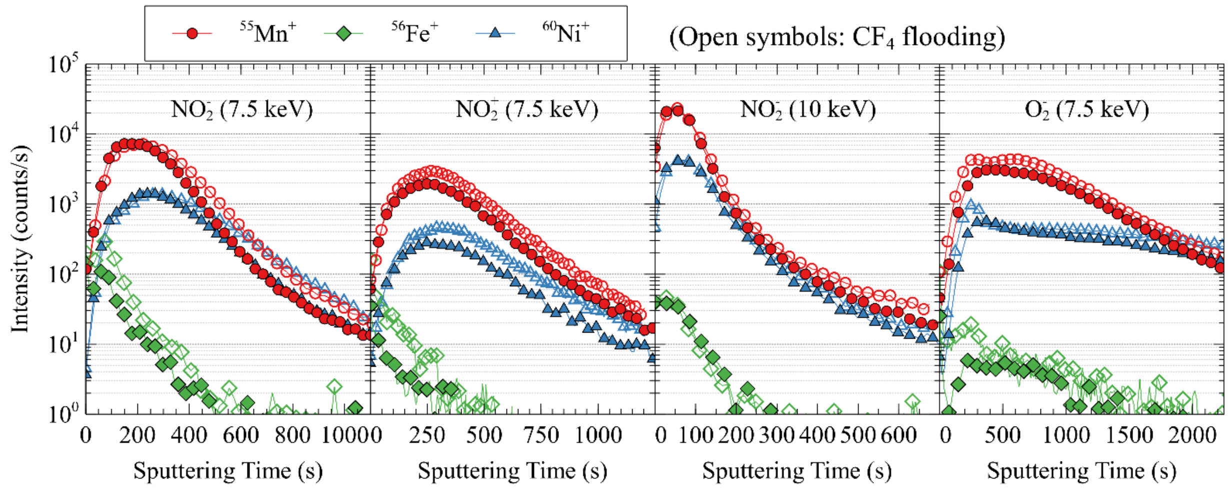

Figure 2: Depth profiles of Mn, Ni implants in Si using different primary beam species and energies. Sample voltage +4.5 kV, yielding impact energy of 12 keV for 7.5keV (-) ions (panels 1,4), and 3 keV for 7.5 keV (+) ions (panel 2). Symbols thinned.

Results: We successfully generated stable and usable (> 10-100 nA) ion beams of F^-, CFO^-, CF_3^-. $O_2^{\pm}$, and $NO_2^{\pm}$, using various mixtures of O_2, N_2, Ar, NF_3, CF_4, C_2F_6, C_3F_8, and C_4F_8 in the duoplasmatron. Several beam species resulted in large (2-66×) increases in instantaneous ion yields (Figure 1). Yields in SIMS are a function of the chemical enhancement of the matrix by the primary ions, impact energy and depth, sputter rate, the element of interest, and the composition of the matrix. Fluorinated beams show the largest yield increases for analytes in reduced matrices. Polyatomic beams, such as NO_2^-, show higher instantaneous yields and better depth profiling characteristics than O^- due to their higher sputter rate (Figure 2Figure 3). The cumulative yield of NO_2^- was similar to O^-, however, given a similar chemical enhancement of the matrix (Figure 3). Faster sputter rates and higher instantaneous yields improve Genesis analyses by decreasing analysis time and increasing count rates relative to instrument background.

Improved chemical matrix enhancement would increase the total yield of Genesis SW ions, increasing precision for measurements in regime and bulk collectors.

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References:

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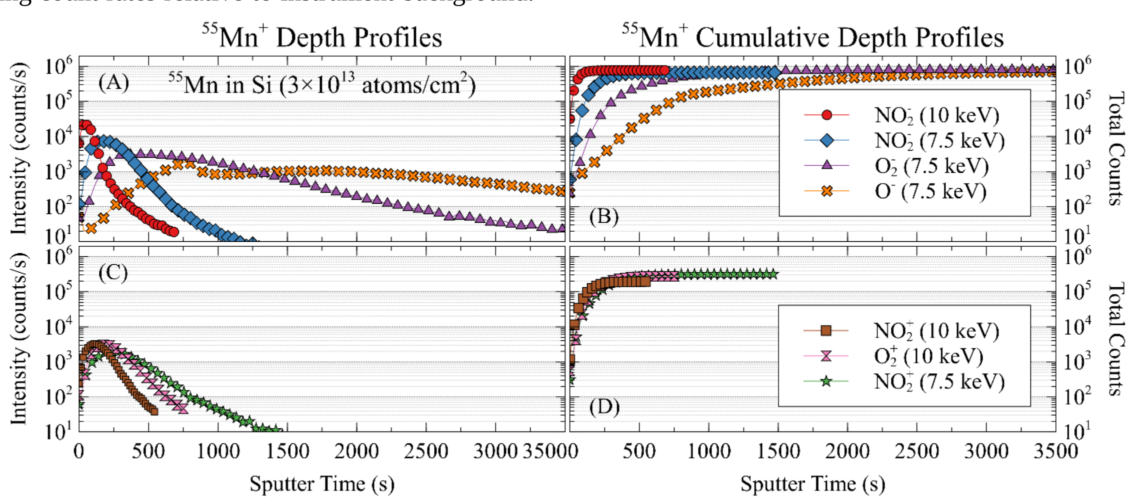

Figure 3: Cumulative depth profiles of Mn, Ni in Si using 1 nA primary beams. NO_2 has a larger instantaneous yield due to a higher sputter rate, but similar cumulative yield to O given similar chemical enhancement of the matrix. Symbols thinned.