Laboratory Analysis of Solar Wind Neutral and Ion Sputtering on Lunar Soils

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Introduction

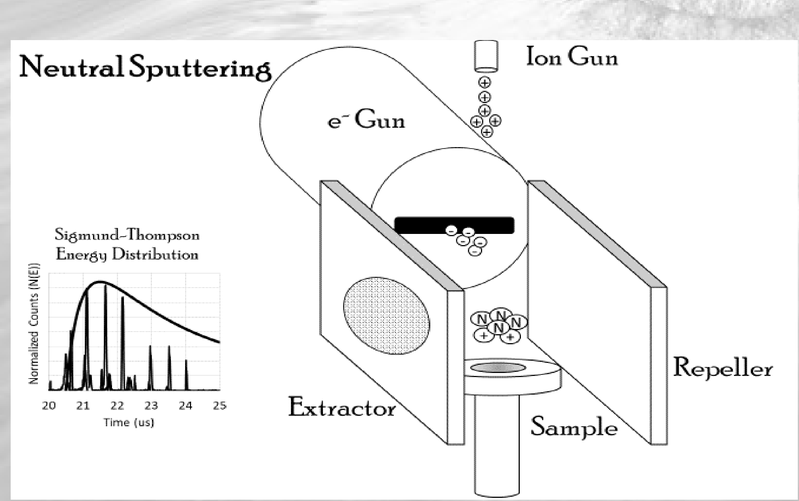
An array of state-of-the-art experimental techniques are being brought to bear on lunar samples and planetary simulants to answer the question: How does the kinetic energy distribution of sputtered and reflected neutrals and ions affect the number density of exospheric species as a function of altitude?

Goals

- Determine the relative and absolute solar wind sputtering "heavy" ion yields on a suite of lunar soils
- Characterize the composition and kinetic energy (velocity) distribution of sputtered and low energy reflected neutrals from lunar soils
- These data are needed to understand the fate of these particles and to compare to remote sensing data (Sarantos, Killen et al. 2012) etc…

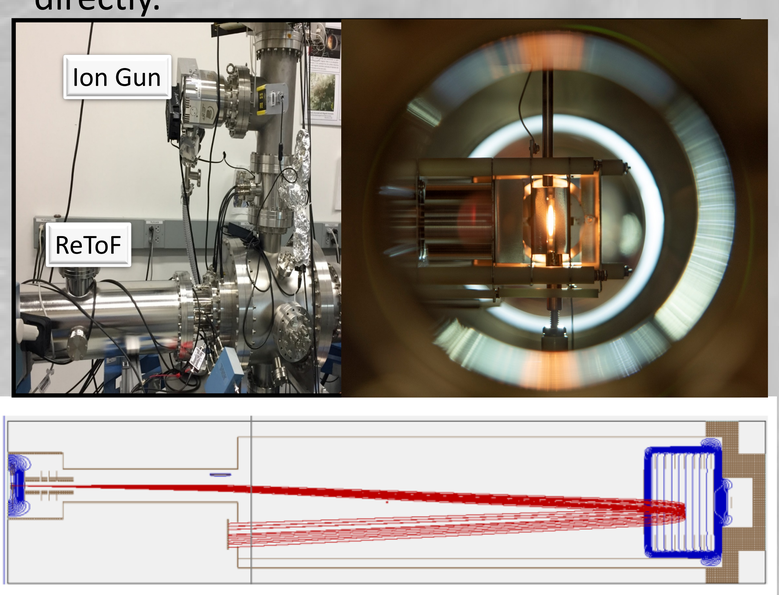
Methods

- A secondary ion/neutral sputtering apparatus using ions and energies found in the solar wind (SW) was constructed
- SW ions are pulsed allowing measurements on the evolving plume of sputtered ions and neutrals



Schematic illustrating experimental concept

- Neutrals are ionized through electron impact and extracted into a reflectron time-of-flight apparatus; secondary ions are extracted directly.



Apparatus and modeled TOF optics

- By varying the phasing of ion and extraction pulses, the energy distribution of sputtered ions and neutrals can be determined
- Ion and neutral velocity distributions should not vary significantly from each other for the same species, but the flux of secondary ions are strongly dependent on the ionization potential.

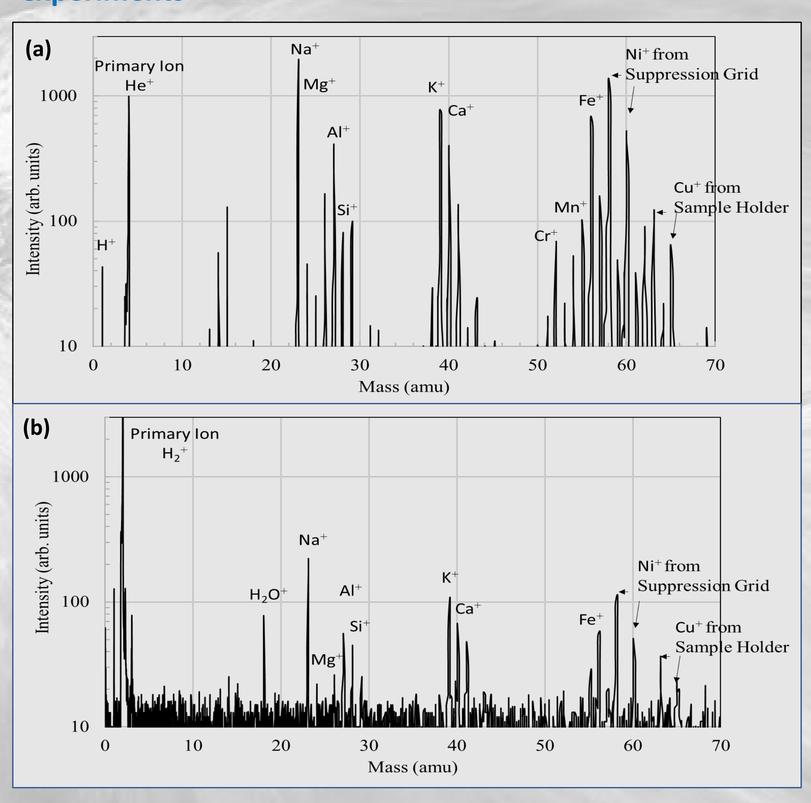
Progress

- Initial testing has been performed verifying the performance of the apparatus using an argon ion beam to effect sputtering.
- Testing on Apollo sample was performed. This sample has been altered through prior experimental use but serves to characterize, generally, sputtering from lunar material.

Apollo 17 Sample 76055 Vesicular breccias-phase abundances, averaged phase composition and bulk chemical composition (Albee et al, 1973).

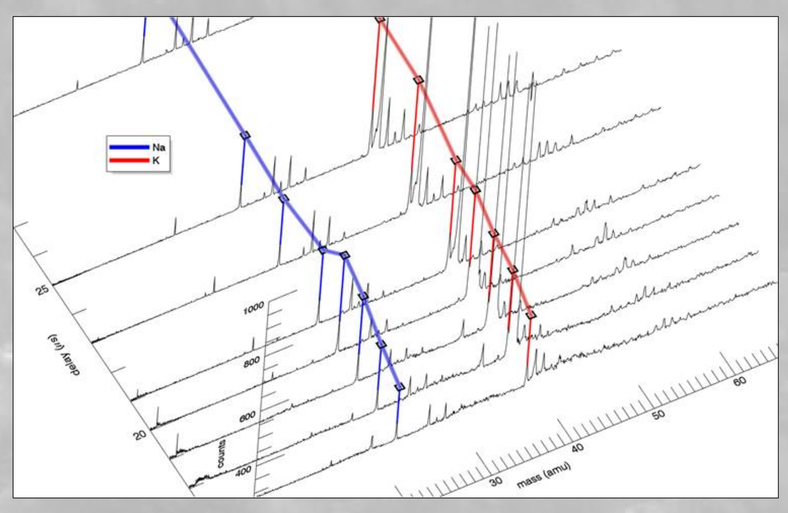
	Plagioclase	Lo-Ca Pyroxene	Olivine	Hi-Ca Pyroxene	Spherulite	Armalcolite	Fe-metal	Apatite	Whitlockite	Bulk
vol%	48.5	24	18.1	5.8	2	0.8	0.3	0.1	0.1	
wt%	41.6	25.8	22	6.1	1.8	1.2	0.8	0.1	0.1	
SiO_2	44.77	53.43	38.69	50.69	46.03	0.3	0.08	0.46	0.35	45
Al_2O_3	35.22	1.55	1.04	2.57	33.16	1.33		1.56	0.05	16.1
Cr_2O_3		0.53	0.19	0.6	0.17	1.9	0.01			0.2
TiO_2	0.14	1.23	0.2	2.2	0.37	70.45	0.02			1.4
MgO	0.1	28.25	39.14	16.85	0.16	8.39	0.04	0.24	3.37	17.1
FeO	0.15	12.48	20.2	6.34	0.33	14.41	86.37	0.22	0.64	9.2
MnO		0.29	0.19	0.14		0.1				0.1
CaO	19	2.36	0.4	20.06	16.85			53.12	42.39	10.3
Na_2O	0.83	0.04		0.13	1.07			0.04	0.61	0.3
P_2O_5					0.06		0.06	40.15	42.66	0.1
Ni			0.02				11.97			0.1
Co							0.76			0.1

Composition of Apollo sample used in these preliminary experiments

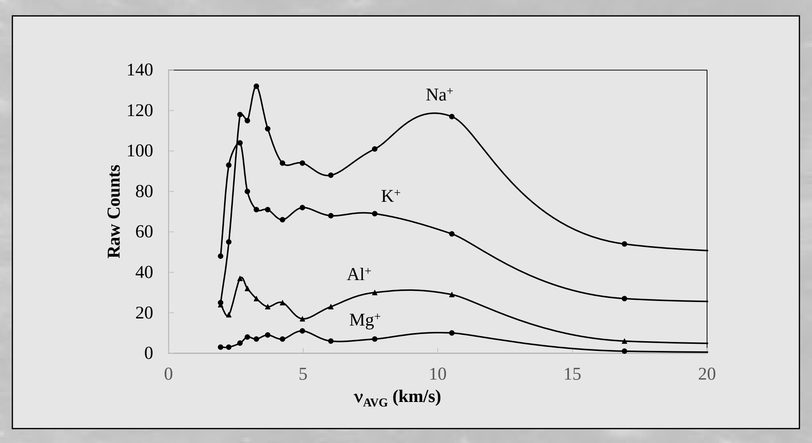


Ion Sputtering from sample using (a) 4keV He^+ and (b) 2 KeV H_2^+. Water peak in second chart due to adsorption of background, note the absence of oxygen ions. Unidentified peaks are comprised of organic contamination and sputtered oxides.

- Sputtering fluences from the Apollo sample, above, are a factor of 10 down from metal blanks, probably due to random surface orientations of the fine-grained material.
- The RTOF allows for simultaneous measurement of sputtered species energy distribution as in the example below.



TOF spectra evolution as ion extraction time is varied



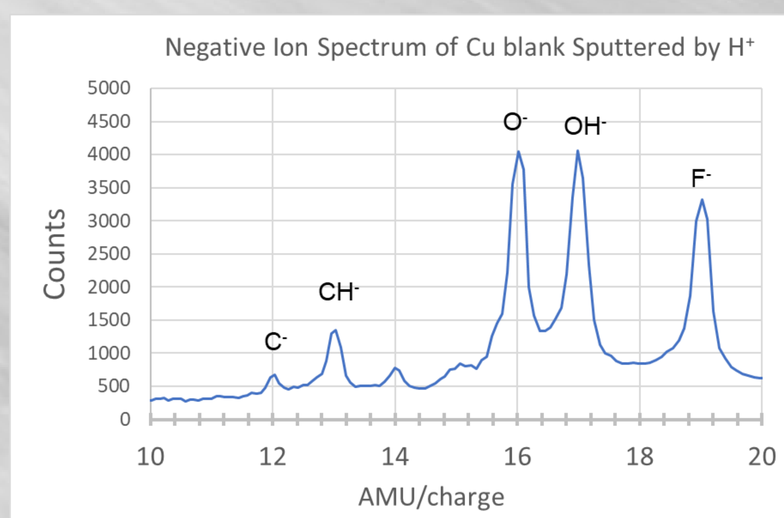
Vertical velocity distribution of sputtered ions from sample for selected ions. Much of the distribution is above the lunar escape velocity of 2.3 km/s but we observe a significant low energy component that will be gravitationally bound.

Neutral Sputtering

- Preliminary efforts have focused ion sputtering but exospheres are fed by neutrals, since neutral yields are considerably larger that ion yields for SW energies. We have not yet observed reproducible measurements of neutral sputtering above background using EII of the neutrals, but we are introducing laser multiphoton ionization where we anticipate favorable signal to noise conditions.

Negative ion Sputtering

We planned to present initial measurements of the negative ion spectra from the samples, but we were unable to conduct the experiments. Below is the results from a run on the copper sample holder which yielded significant O^- and OH^- signal, presumably from copper oxide on the surface.



Conclusions and Next Steps

- We have successfully demonstrated the validity of the method for sputtered ions.
- Ionization of neutrals is the next challenge which will require increased pulsed ion fluxes and, possibly, the introduction of ionizing laser to replace electron impact source.