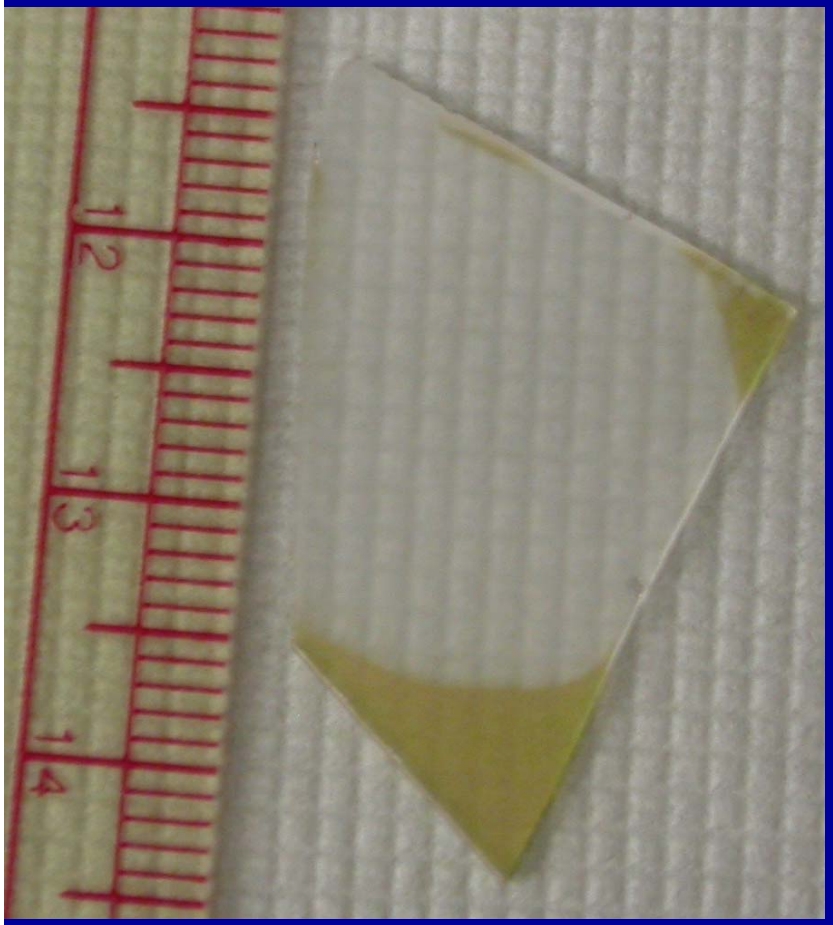
Elemental analysis of *Genesis* Silicon wafers

Munir Humayun

Florida State University

GENESIS: March 22, 2009

Flight SoS wafer fragment 50030 Results



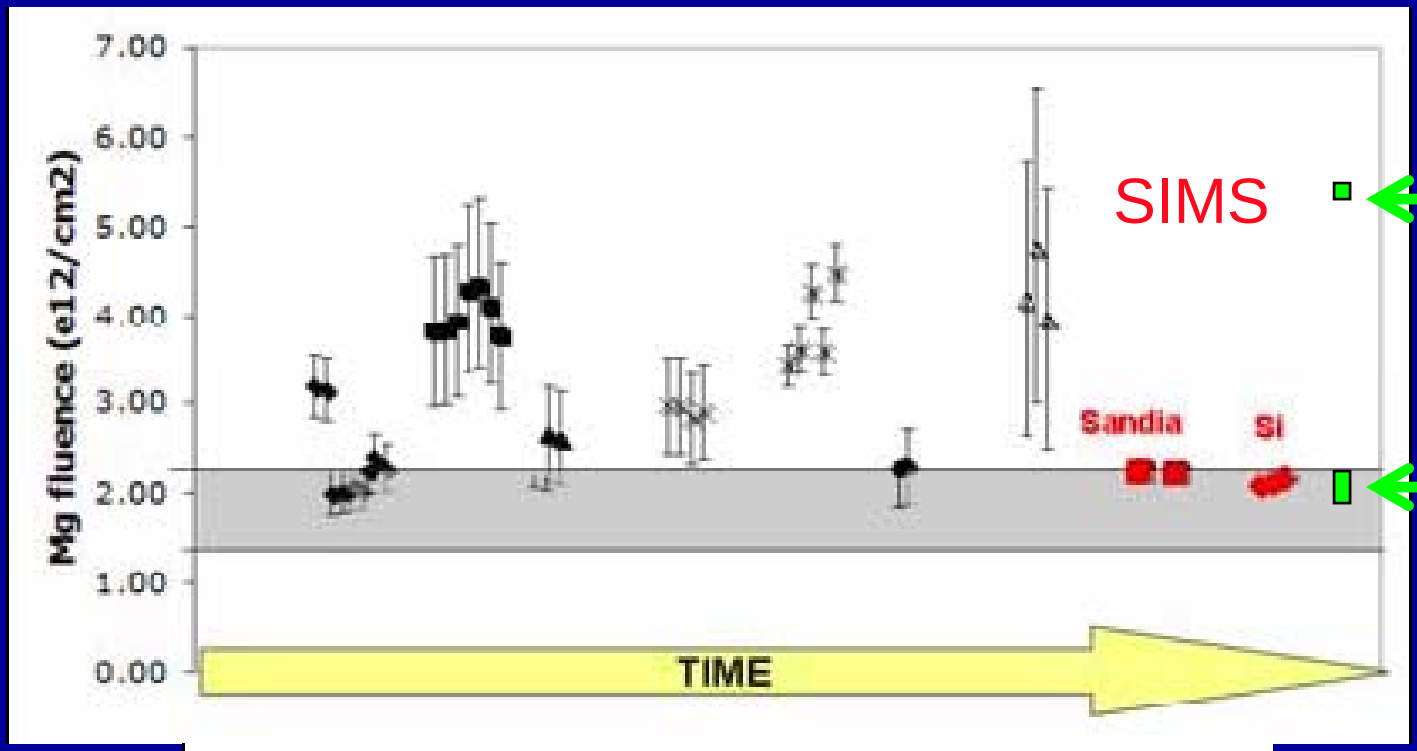
- Mg and Fe determined by isotope dilution;
- Si determined by external standardization.

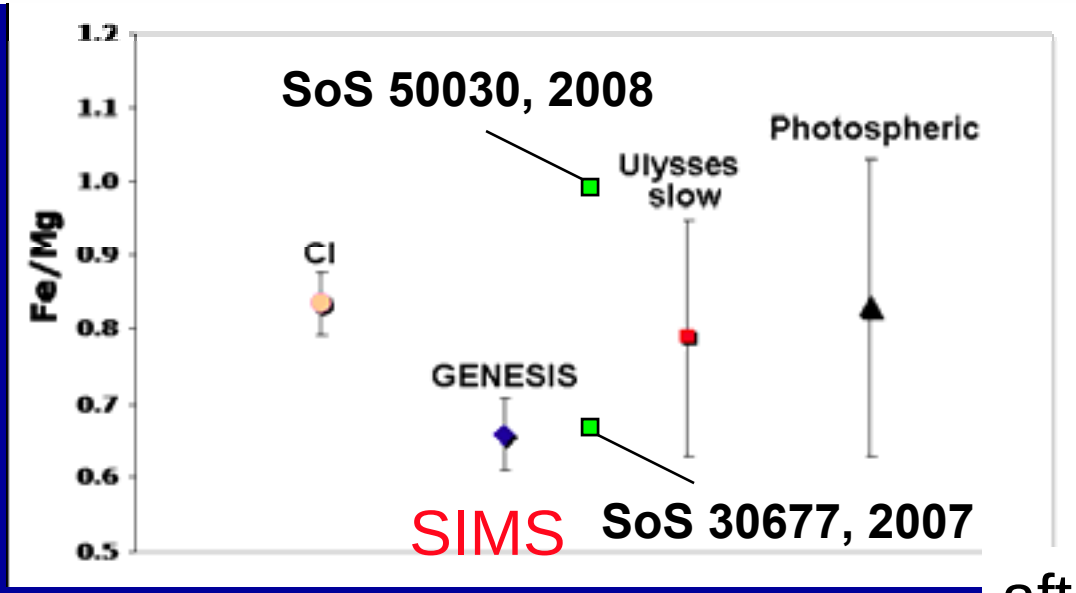
- Mg: 5.21 x 10^{12} ±1.2% (2σ) atoms
- Fe: 5.26 x 10^{12} ±1.0% (2σ) atoms
- Fe/Mg_{atomic} = 1.01 ±1.6% (2σ)
- Si: 2.08 x 10^{18} ±5% (2σ) atoms
- Area removed=2.47-2.76 cm^2, assuming a thickness of the Si layer of 170-190 nm, vs. geometrically measured area =2.76 cm^2.

Fluence:

Mg: 1.99 x 10^{12} ±5% (2σ) atoms/cm^2

Fe: 2.01 x 10^{12} ±5% (2σ)



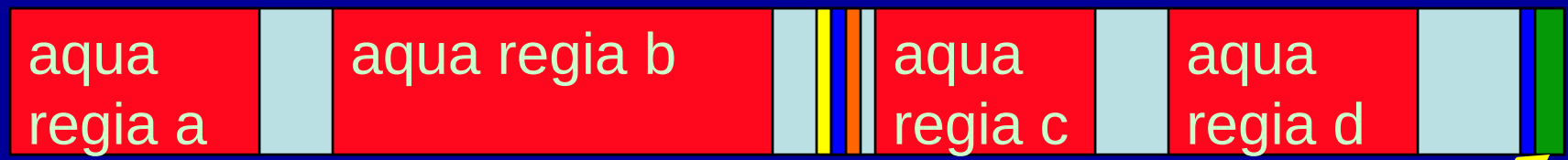


after Jurewicz et al. (2008

Cleaning sequence for Si wafers

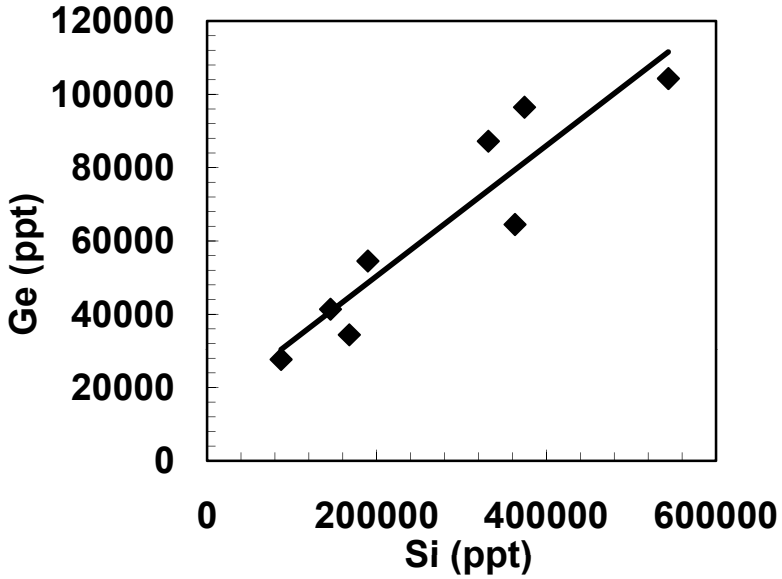
- Four steps of hot aqua regia attack (~88 hours), with 1 hour ultrasonic cleaning between steps, produced a successively diminishing blank with Mg, Fe < SW values.
- RCA cleaning step reduced many contaminants.

Time (hours)

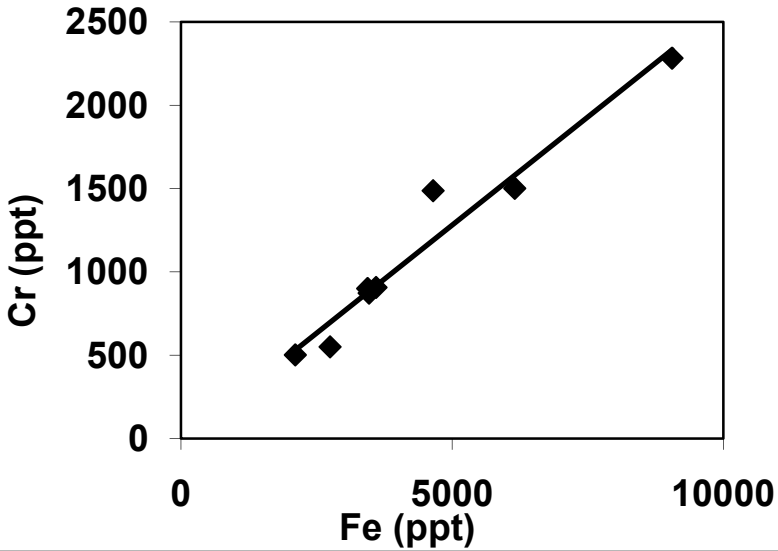


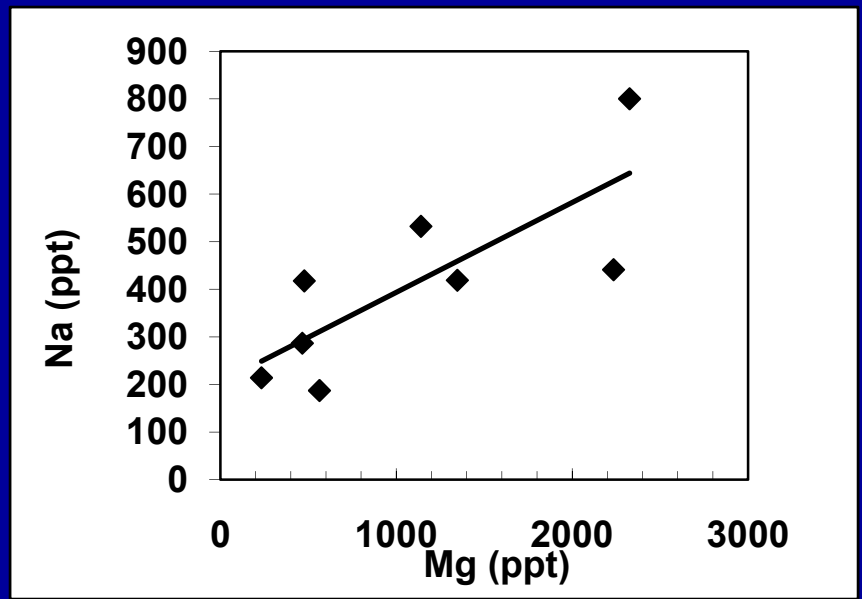
- SC-1: $NH_4OH:H_2O_2:H_2O$, 1:1:5, 10 mins. Hot
- HF:H2O, 1:50, 10 secs
- SC-2: $HCl:H_2O_2:H_2O$, 1:1:6, 10 mins. Hot
- HF:H2O, 1:50, 10 secs
- 4 steps: 10-15 secs of $HF:HNO_3:H_2O$ @ room T released 4, 5, 7, 8 µm-equivalents of Si

Chemical systematics in first aqua regia leach step of Si wafers

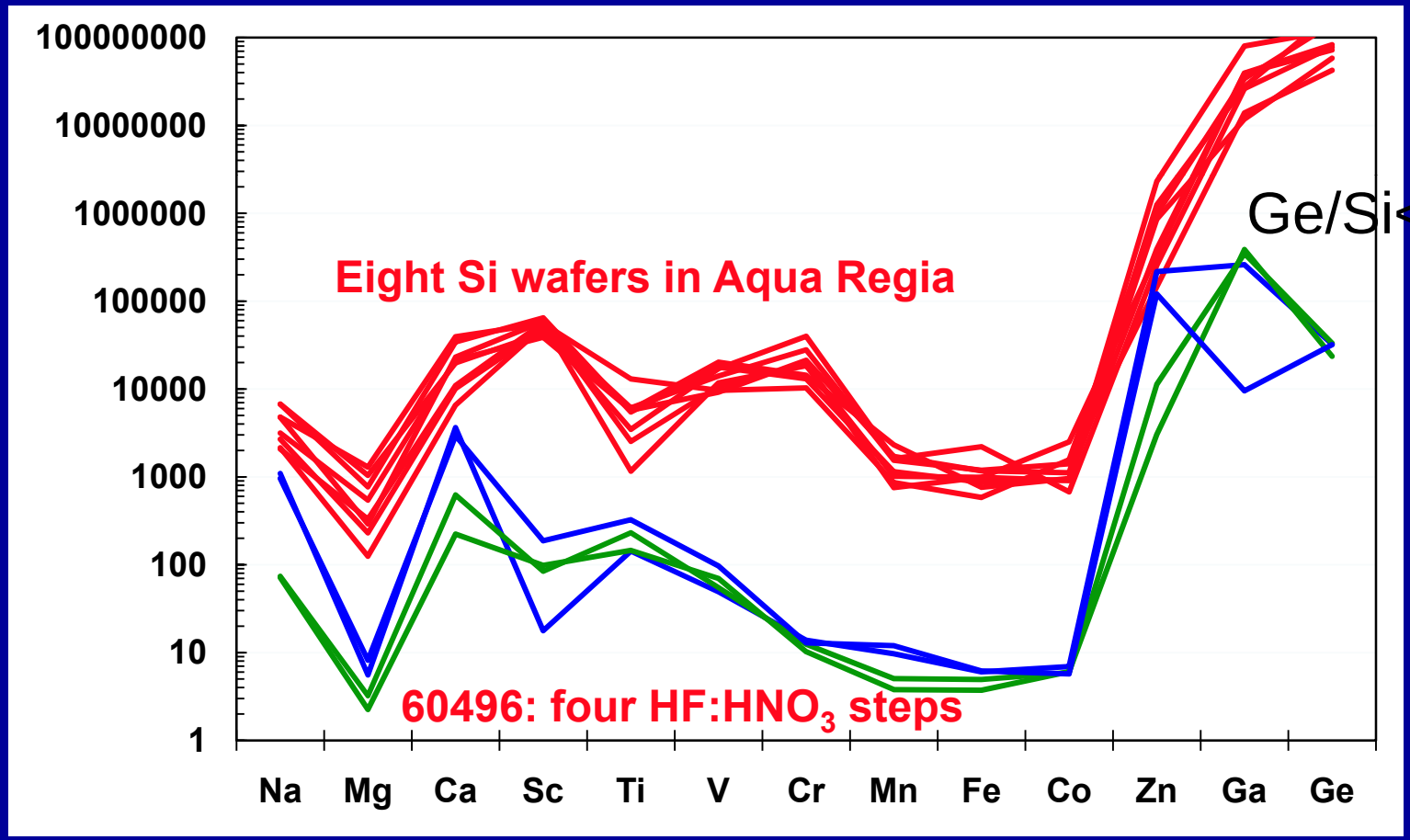


- **Ge/Si**~ 0.2
- **Fe/Cr**~ 4 (stainless steel)
- Mg correlates with Na, Ca, and less with Ti, Si, and not with Fe.

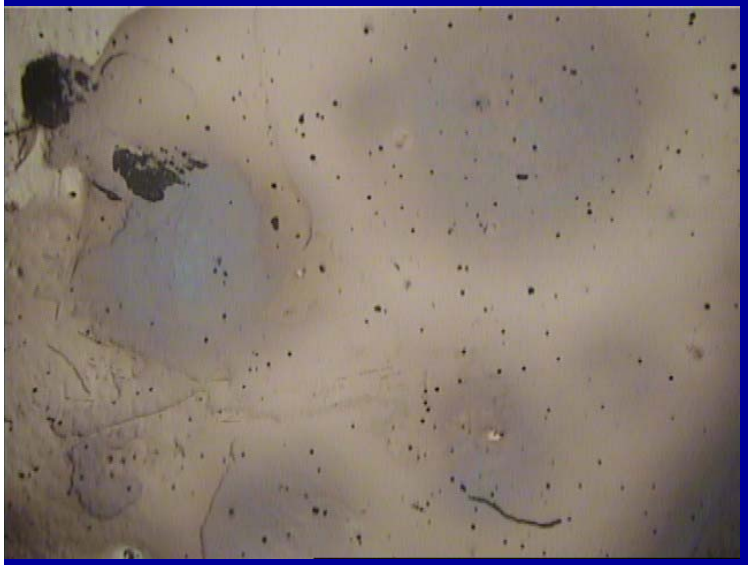


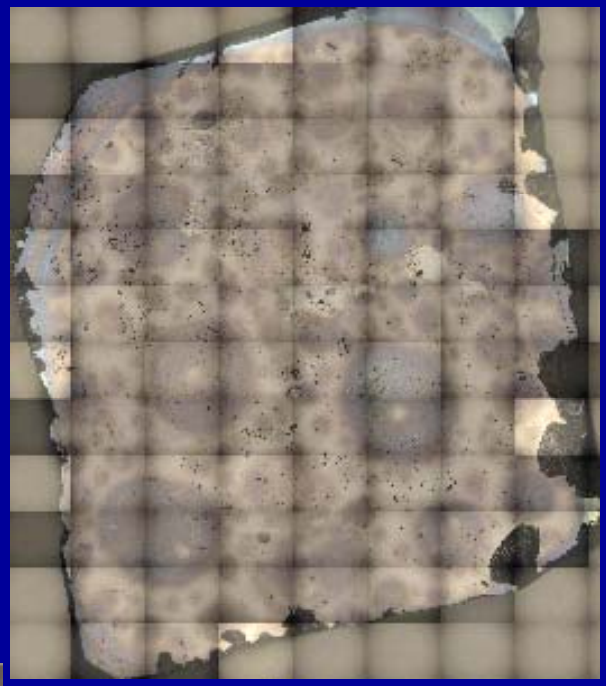


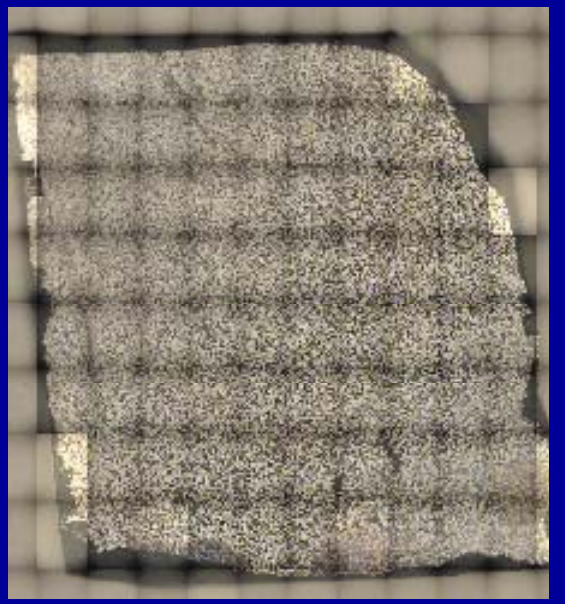
Comparison of chemical abundances in first AR step with final $HF:HNO_3$ digestions.

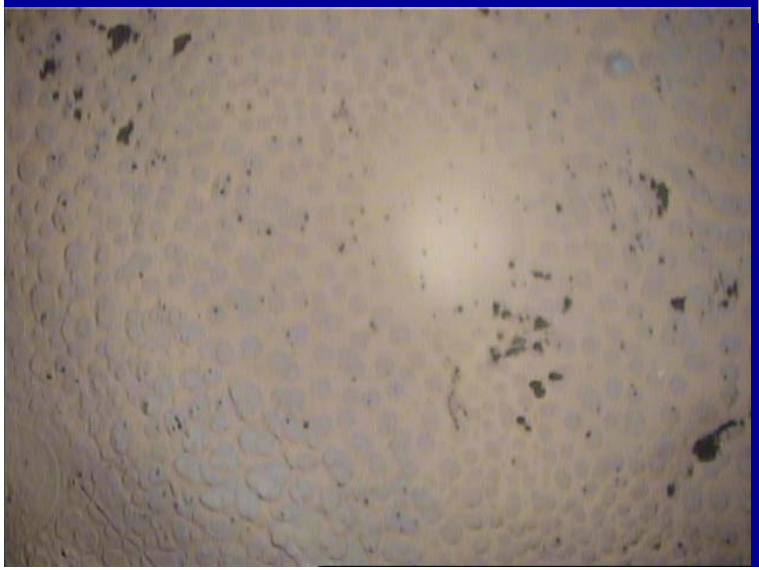


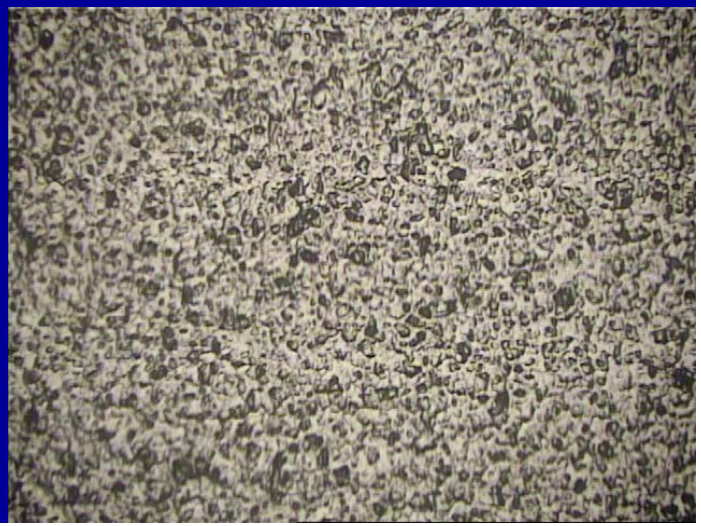
Post HF attack, reflected light images of Si 60496











Summary

1. Si wafers proved more intractable to our cleaning procedures than SOS wafers.
2. Large amounts of post-crash contaminants are leached in hot aqua regia steps, but some contaminants appear to be “sheltered” from acid attack.
3. HF-HNO_3 releases further contaminants, which indicates possibly located in melted Si.
4. Mg recovered was 2xSW, Fe ~ 4xSW in 60496-2.

Isotope fractionation of Solar Wind elements as a tracer of SW abundances

Bochsler (2000) predicts a light isotope enrichment of ~12‰/m.u. for Mg which could be a powerful tracer of SW Mg. Even a 100% contamination of SW Mg would retain an isotope enrichment of ~6‰/m.u. This is best done in unspiked runs.

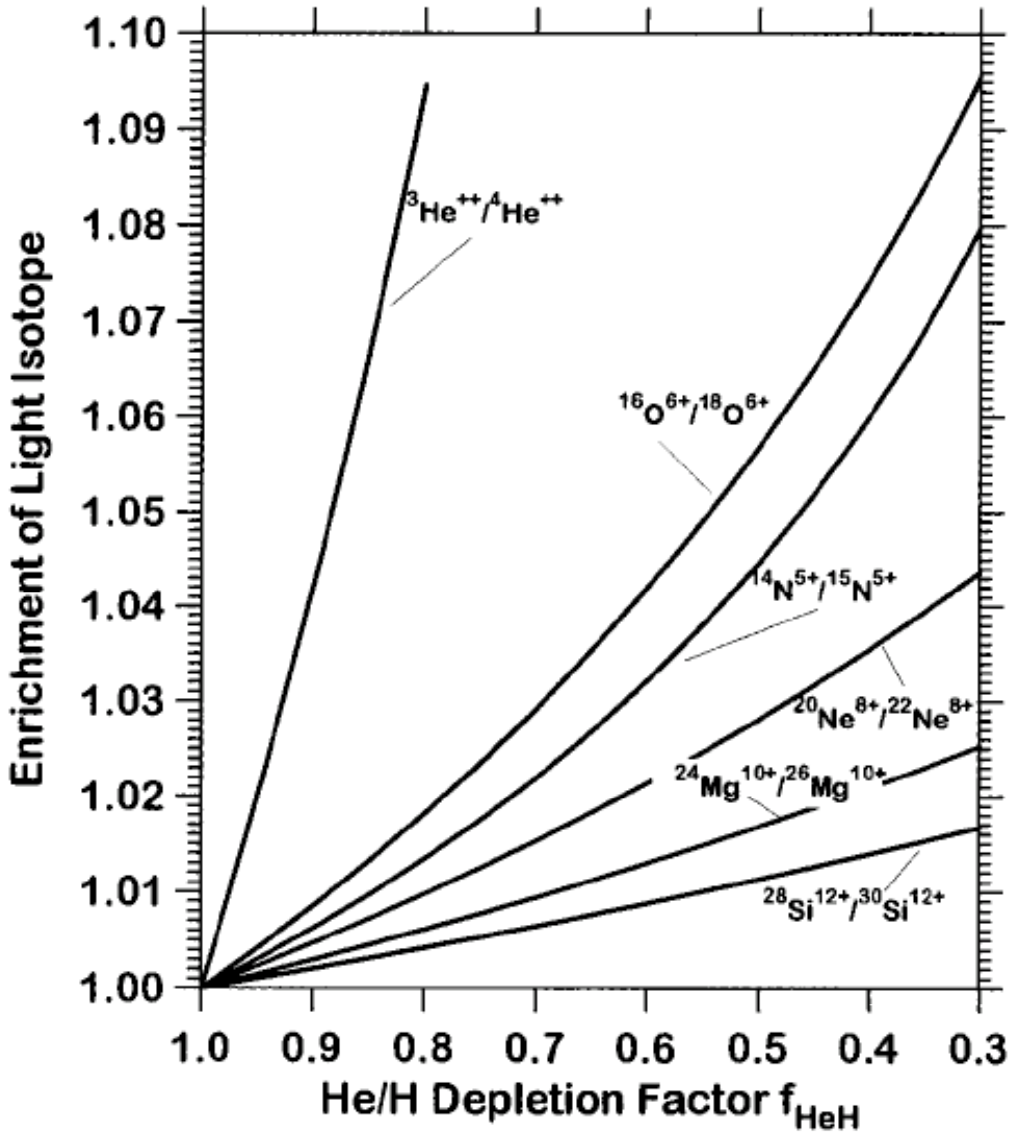
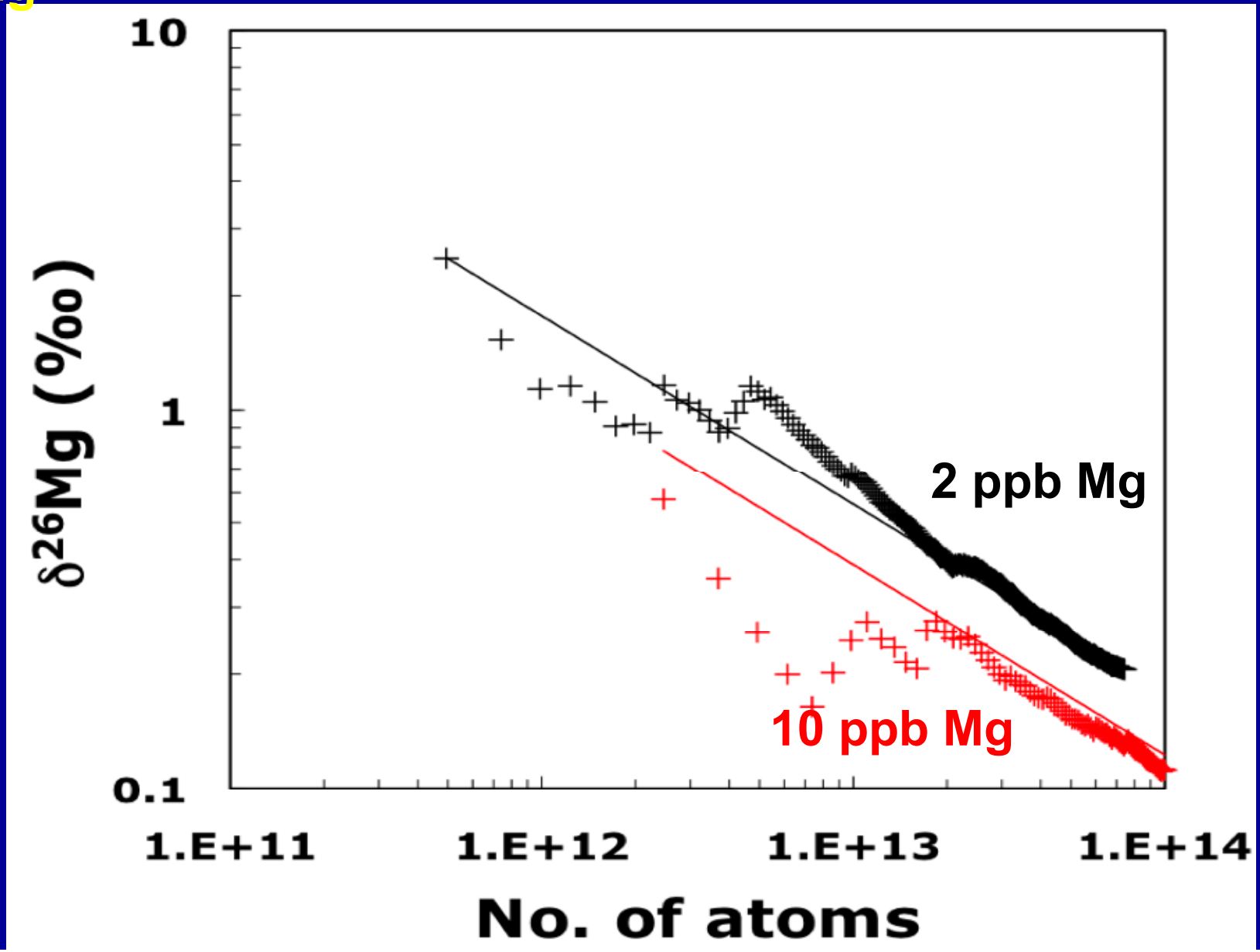
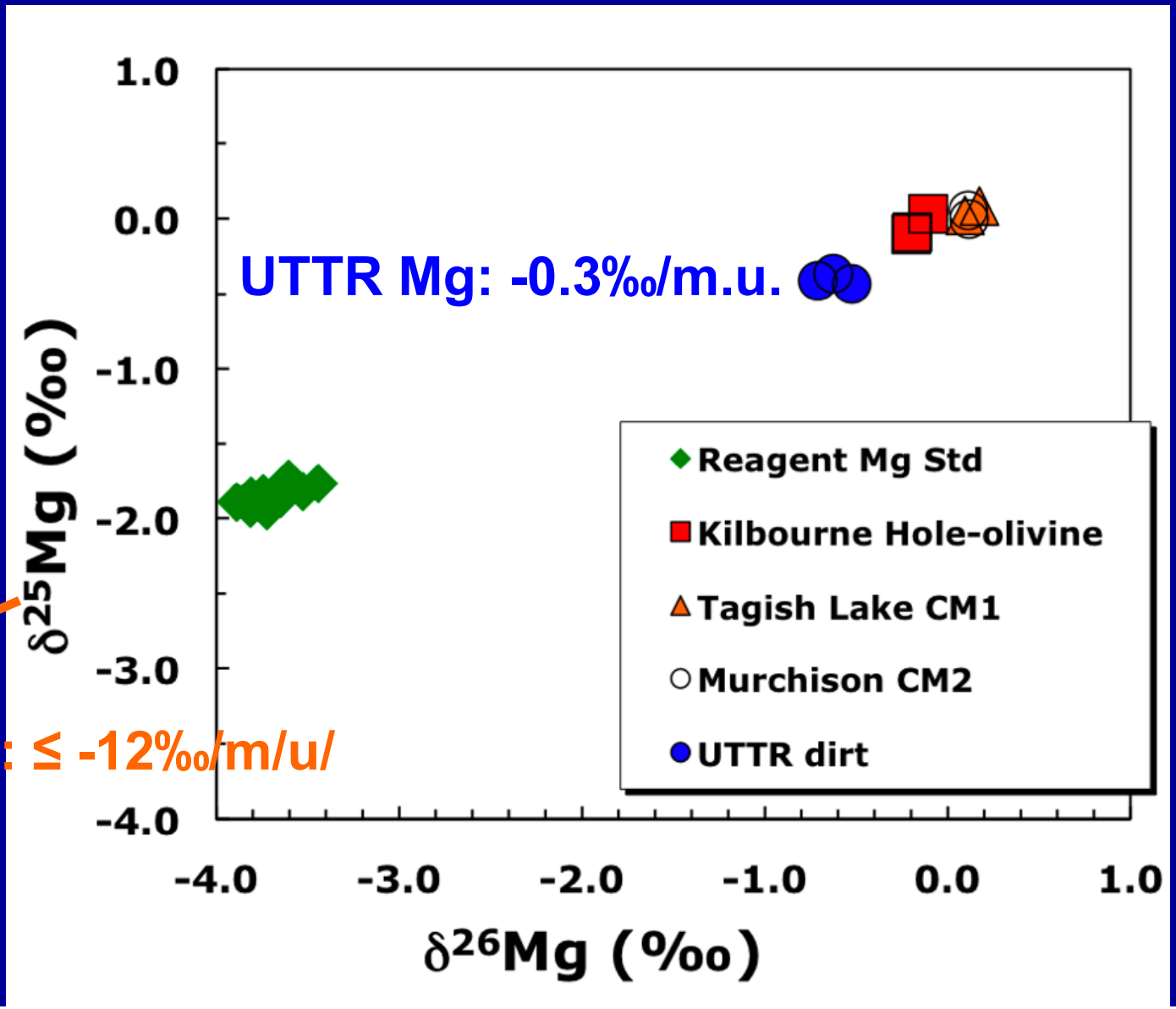


Figure 5. Expected isotope fractionation factors associated with He/H depletion factors. For instance, a depletion of He/H to 30% of its normal value in the equatorial streamer belt implies an enhancement of the $^{28}Si^{12+}/^{30}Si^{12+}$ ratio up to 1.7% over its normal coronal value.

Isotope ratio precision with MC-ICP-MS using ~80 pg Mg



Mg isotopic compositions of UTTR Mg, chondrites, terrestrial rocks

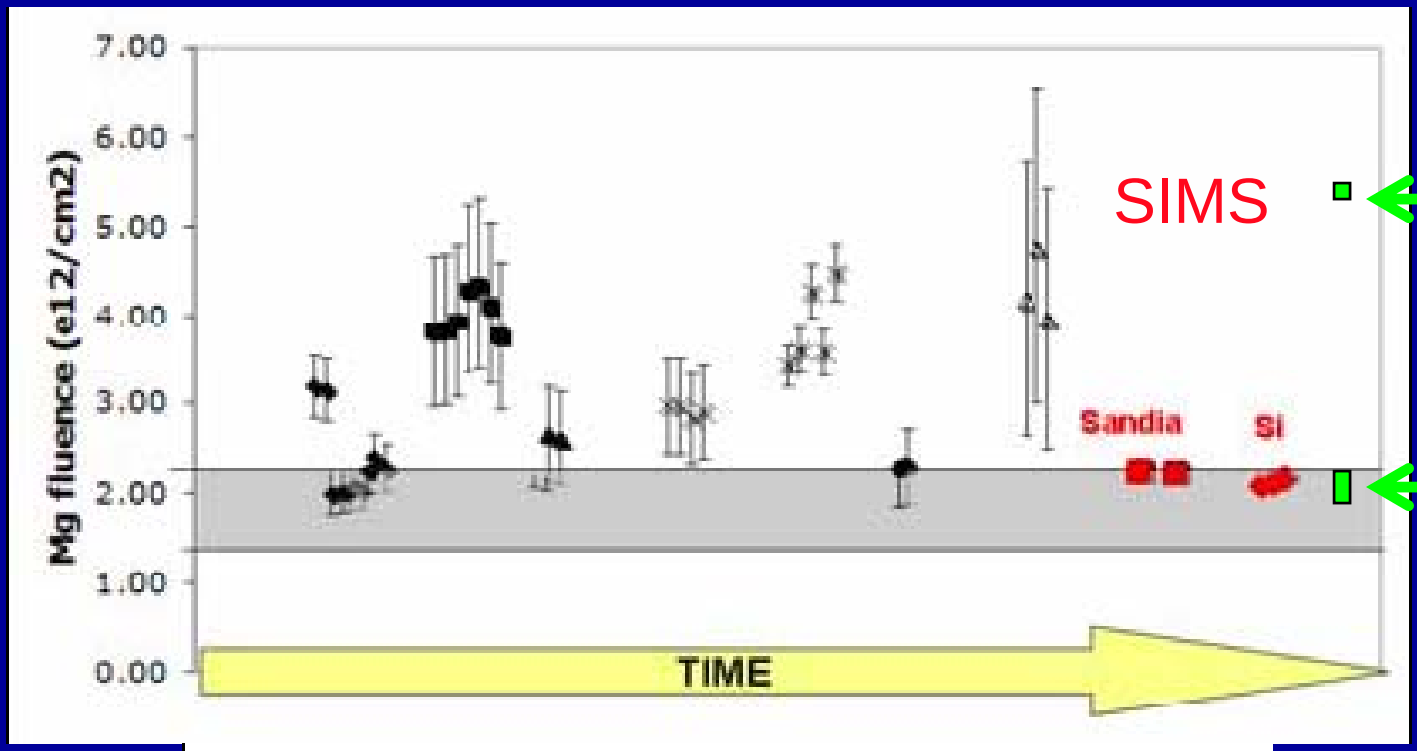


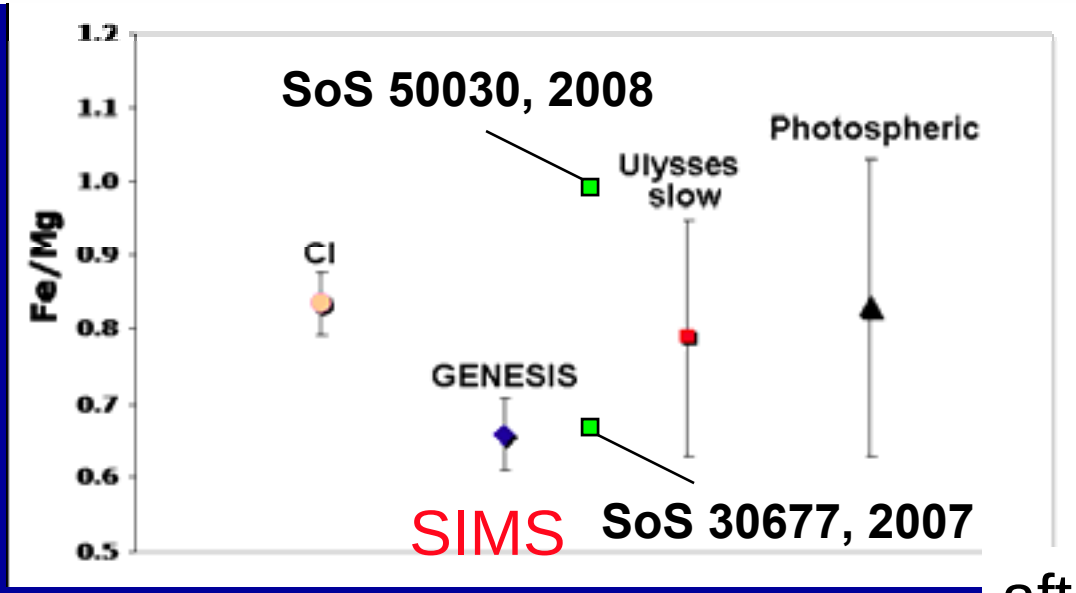
1. Consortium studies of Genesis flight wafer 60472: a proposal

Si wafer 60472 is a 0.3 cm2 wafer that has been cleaned by our acid procedure, with analyzed elemental abundances.

1. SEM examination of residual contaminants.
2. TR-SXRF or TOF-SIMS study of surface layer.
3. Focused cleaning effort at FSU.
4. Mg isotopic analysis of extracted Mg (MC-ICP-MS) and elemental composition by isotope dilution (Element XR) on separate aliquots.

2. Return to SoS wafers for combined elemental and isotopic analyses of Mg (Fe, etc.)





after Jurewicz et al. (2008

Checking ^{26}Mg-^{57}Fe Spike

	BHVO-1	BHVO-2	BCR-1	BIR-1	NIST SRM 612	Tagish Lake
Mg(%) literature	4.36	4.36	2.15	5.85		
Mg(%) measured	4.58	4.51	2.14	5.88		
relative difference	5.0%	3.4%	-0.3%	0.5%		
Fe(%) literature	8.55	8.60	9.38	7.09		
Fe(%) measured	8.71	8.86	9.36	8.06		
relative difference	1.8%	3.0%	-0.2%	1.9%		
Fe/Mg literature	1.96	1.97	4.37	1.35	0.727	2.02
Fe/Mg measured (2σ)	1.90 ±0.7%	1.97 ±0.7%	4.37 ±0.8%	1.37 ±0.7%	0.727 ±0.7%	2.11 ±0.9%
relative difference	-3%	0%	0%	1%	0%	4%

Step-Cleaning Procedure:

1. Two sequential 15-46 hour steps with hot aqua regia ($HCl:HNO_3:H_2O$ 3:1:1) attack.

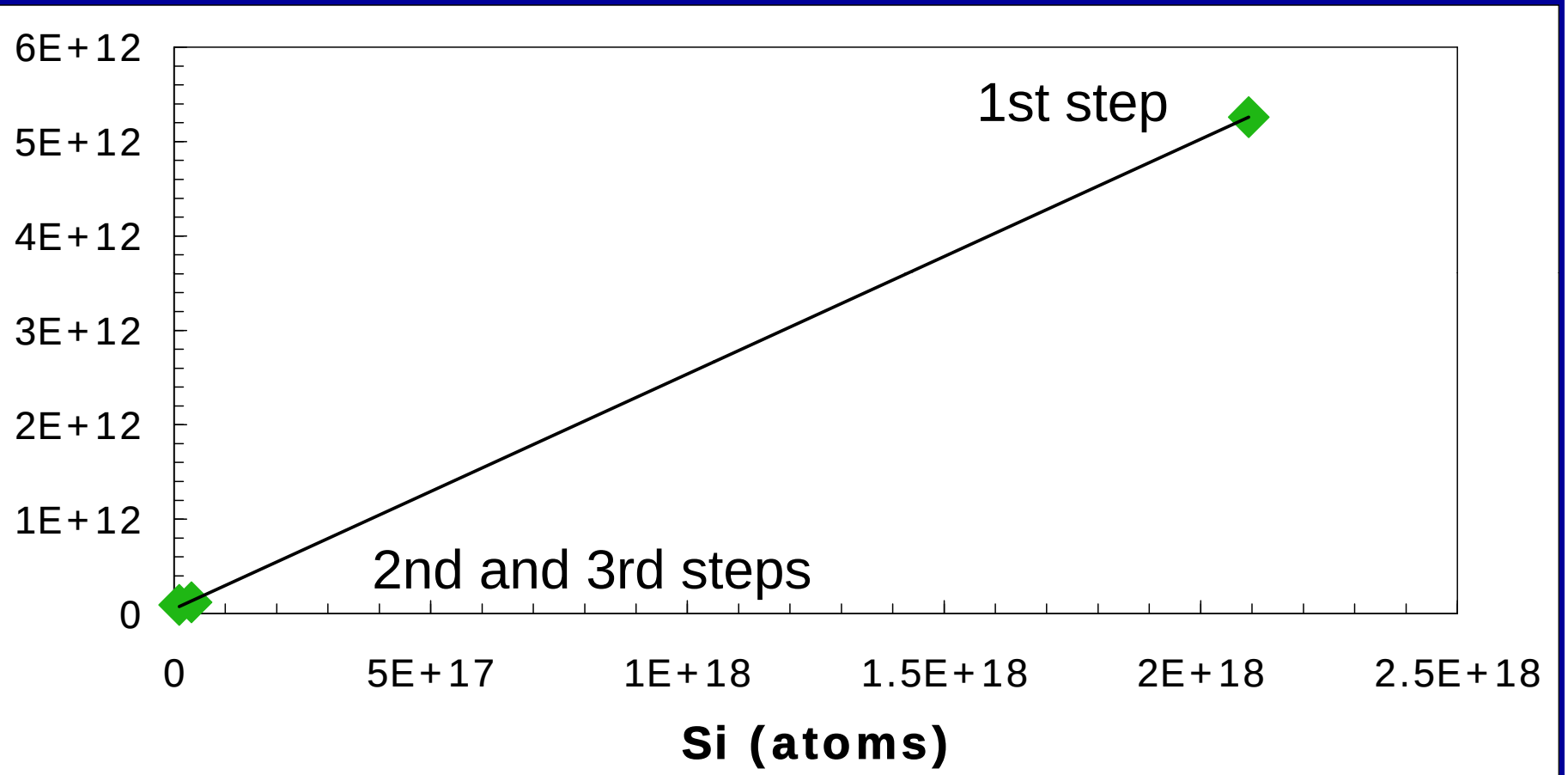
2. RCA clean:
   - ultrasonication in 1 H_2O_2 : 0.5 NH_4OH: 10 H_2O;
   - ultrasonication in 0.7 HCl : 1 HF : 100 H_2O;

3. Two further 15-hour steps of hot aqua regia ($HCl:HNO_3$ 3:1).

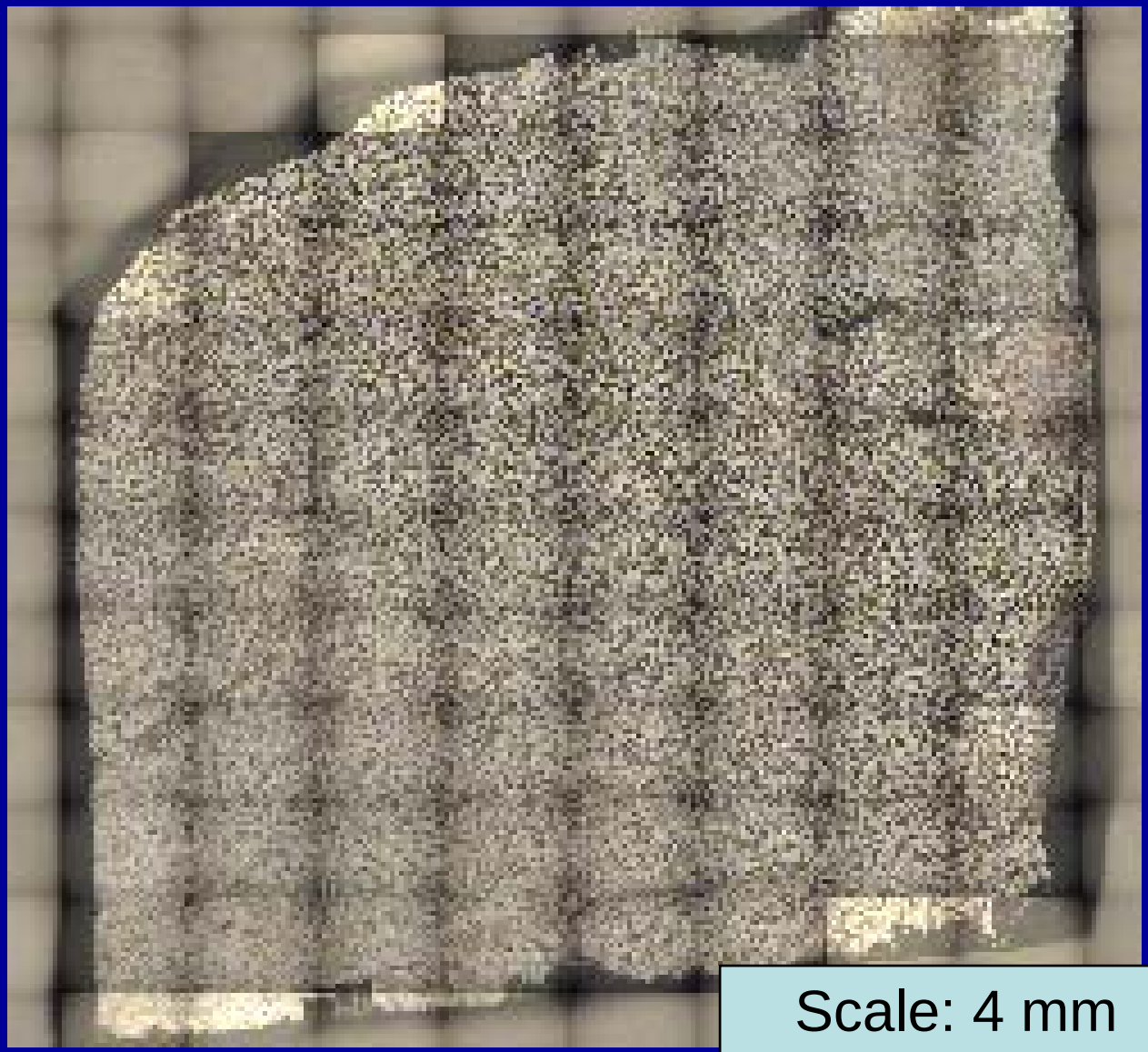
4. Quick rinse with 1:50 HF:MQ water

5. Four sequential steps of sono- $HF:HNO_3:H_2O$

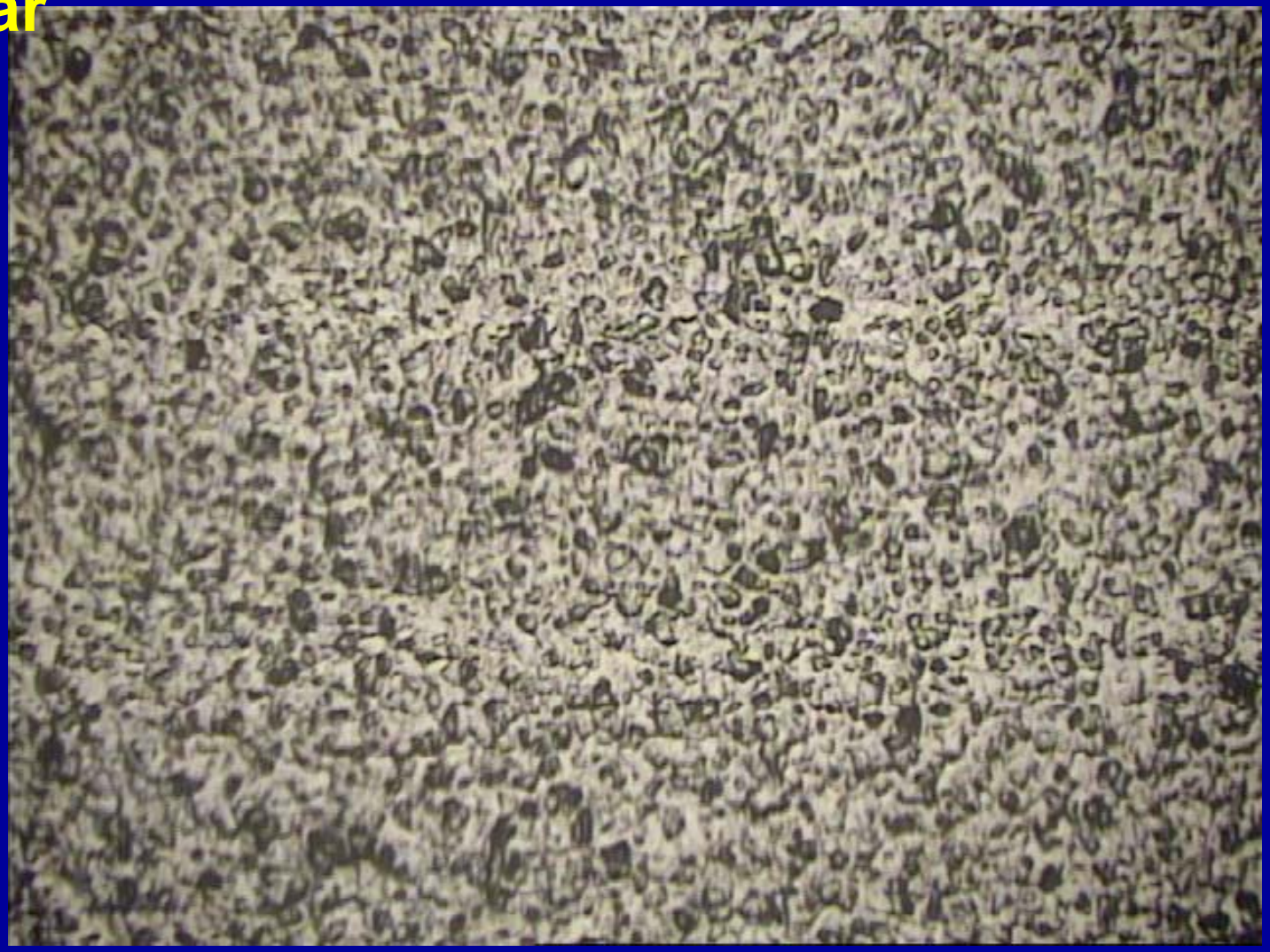
Flight SoS wafer fragment 50030 Results



Post HF attack, reflected light mosaic of 60496 rear

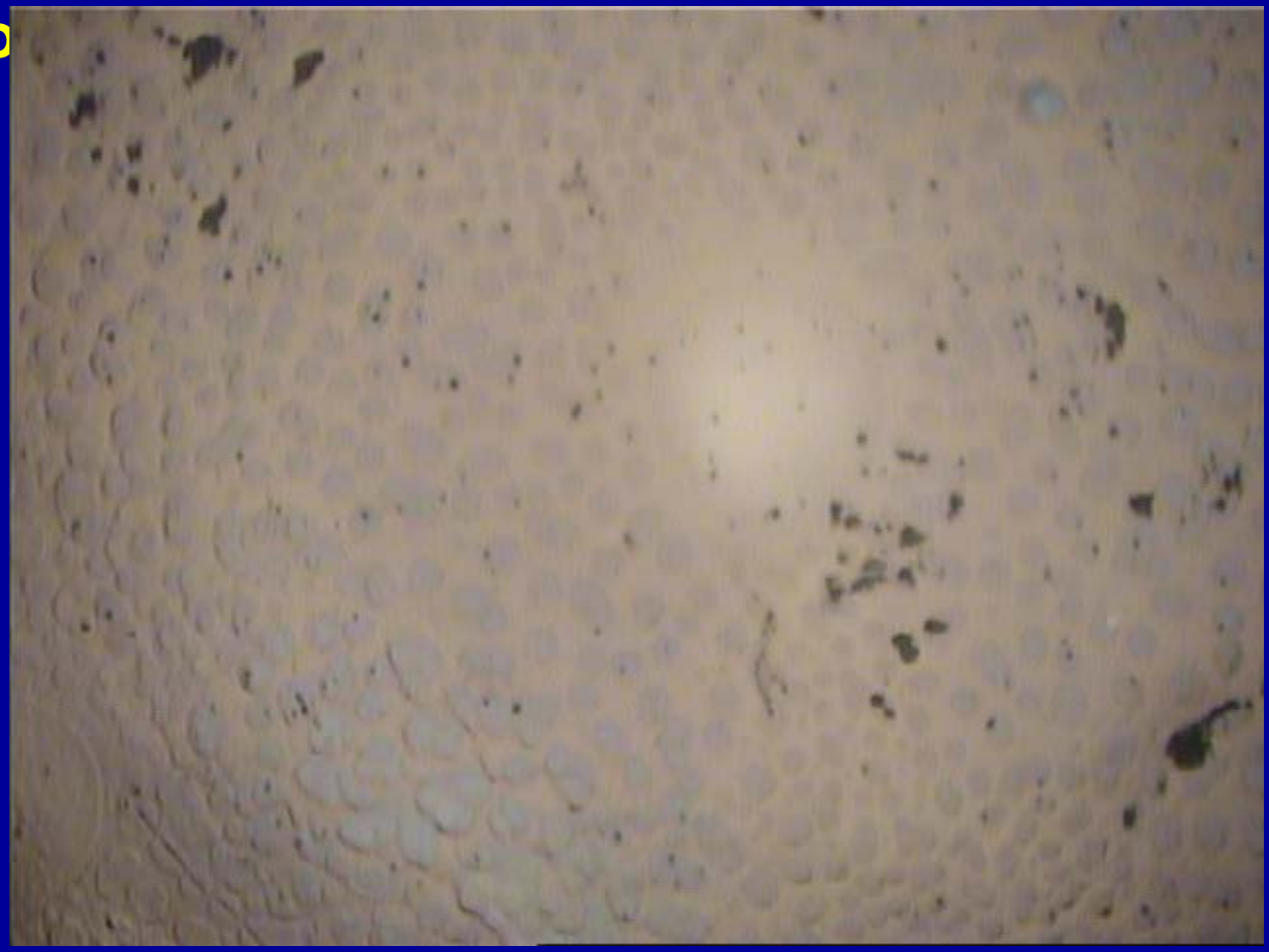


Post HF attack, reflected light image of 60496 rear



Scale: 800 µm

Post HF attack, reflected light image of 60496 fro



Scale: 800 µm

Post HF attack, reflected light image of 60496 front

Scale: 800 µm