Electron and photon stimulated desorption of alkali atoms from mineral surfaces

B. Yakshinskiy

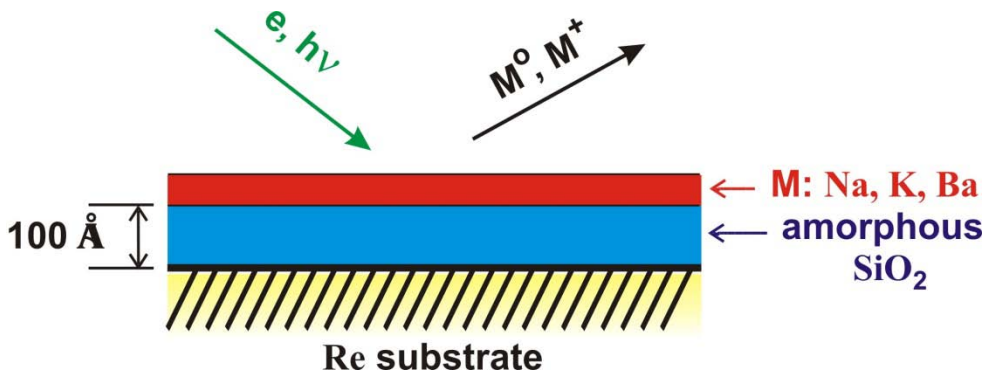
Rutgers, The State University of New Jersey
Dept. of Physics and Astronomy and
Laboratory for Surface Modification,
Piscataway NJ 08854-8019 USA

**** supported by NASA***

http://www.physics.rutgers.edu/lsm/

Outline

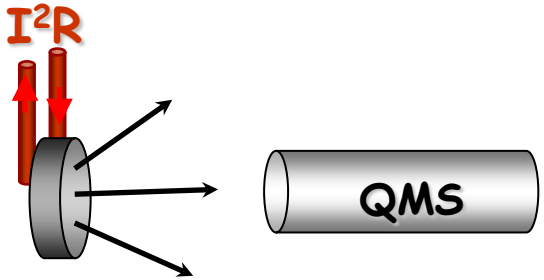
- Characterize T-induced interaction Na, K / SiO_2
- Characterize ESD, PSD of Na, K / SiO_2 , ice
- Mechanism of PSD, ESD from SiO_2
- Compare SiO_2 and Lunar sample
- Attempts to characterize ESD, PSD of Ba, Ca / SiO_2



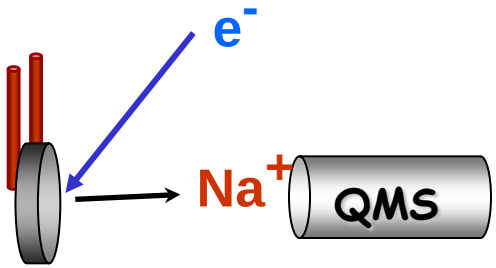
Sample

Methods

TPD: Temperature Programmed Desorption (BE, sticking)



ESD: Electron stimulated desorption of positive ions

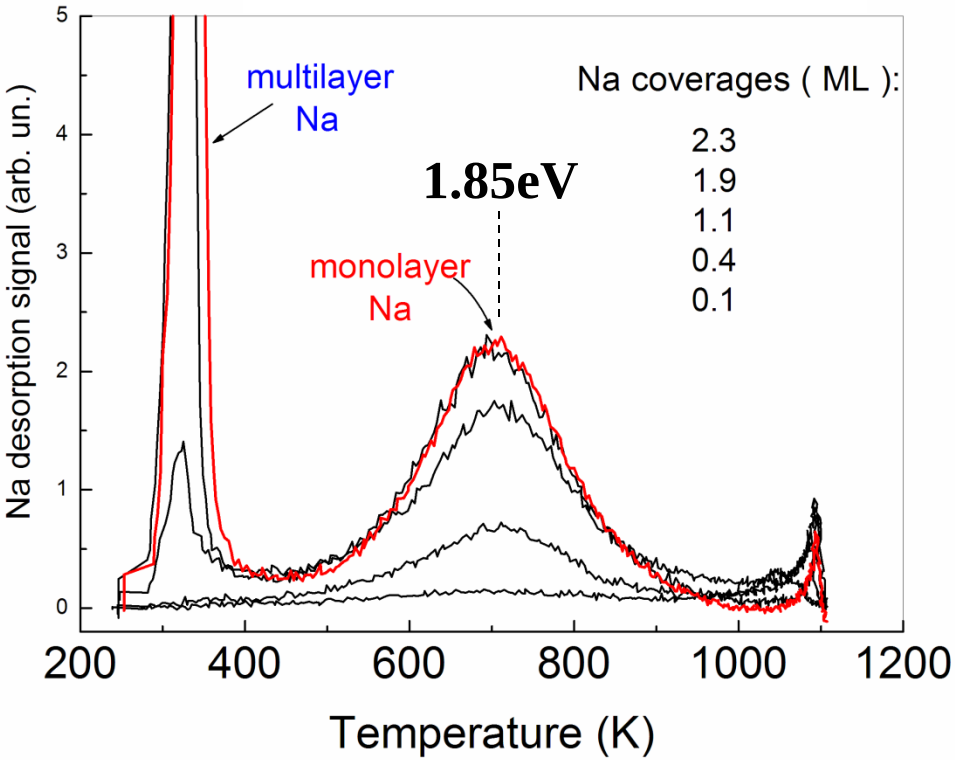


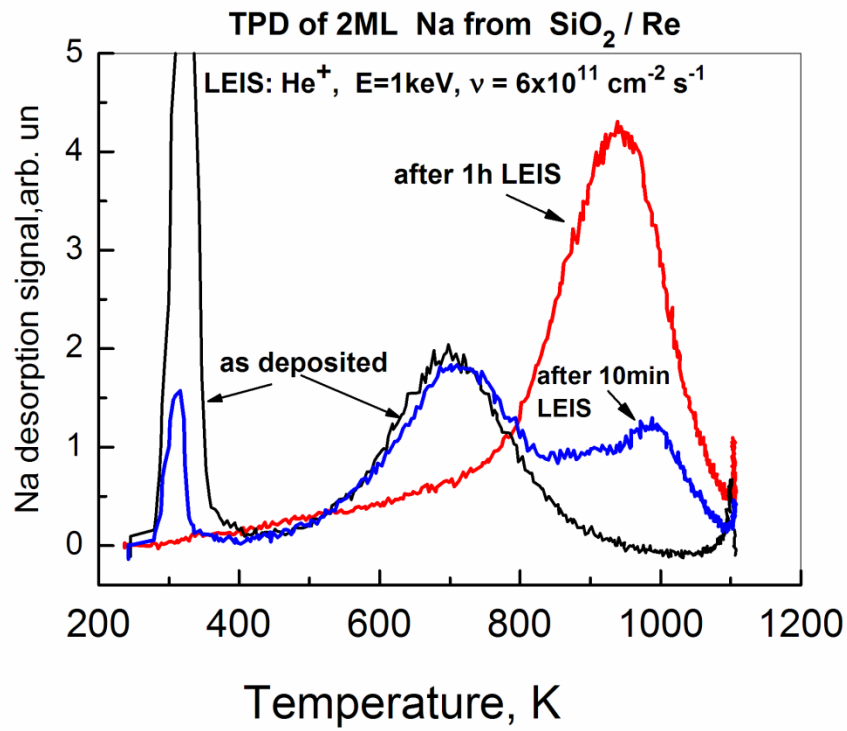
XPS: X-ray photoelectron spectroscopy

LEIS: Low energy ion scattering

Home-made detector: ESD and PSD of neutral alkalis

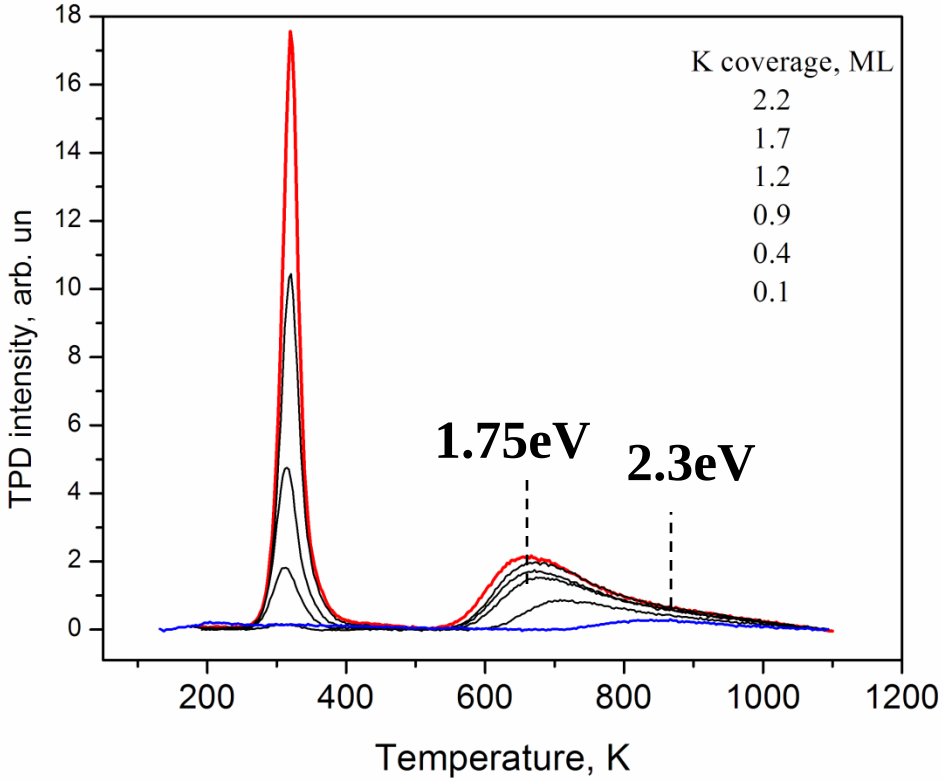
Thermal Desorption Spectra of Na / SiO_2

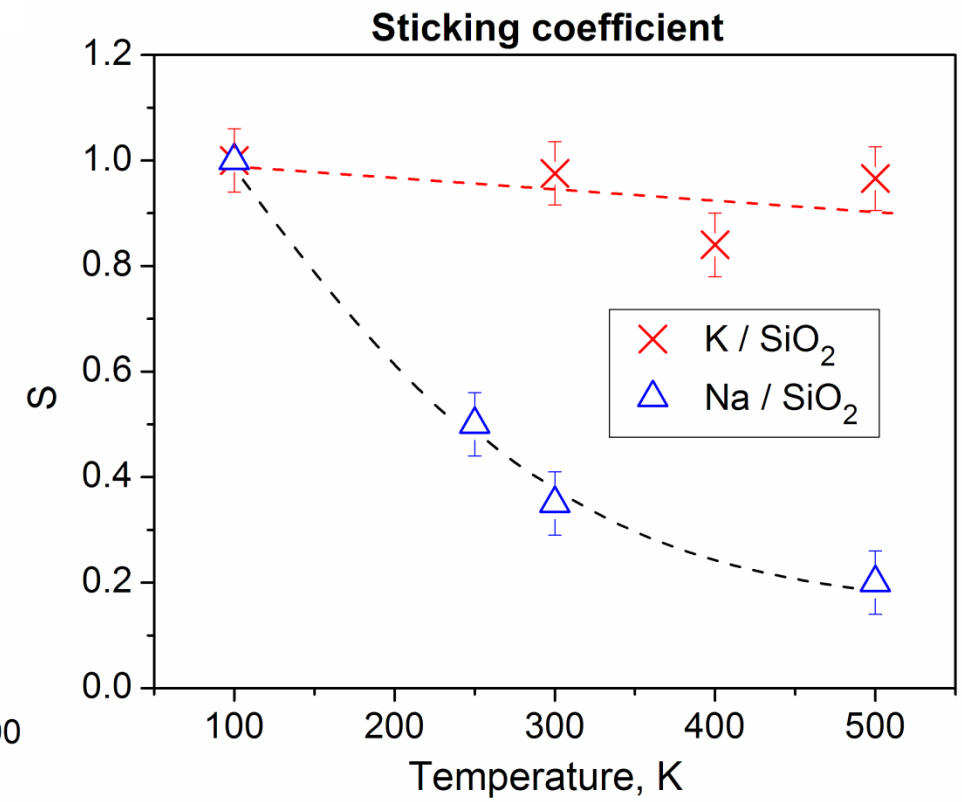




1. **Simultaneous population of binding sites with ~1.4 - 2.7 eV energy**
2. **Diffusion-limited desorption**
3. **Ion bombardment results in diffusion to bulk or chemical reaction**
4. **Relevance to Mercury surface**

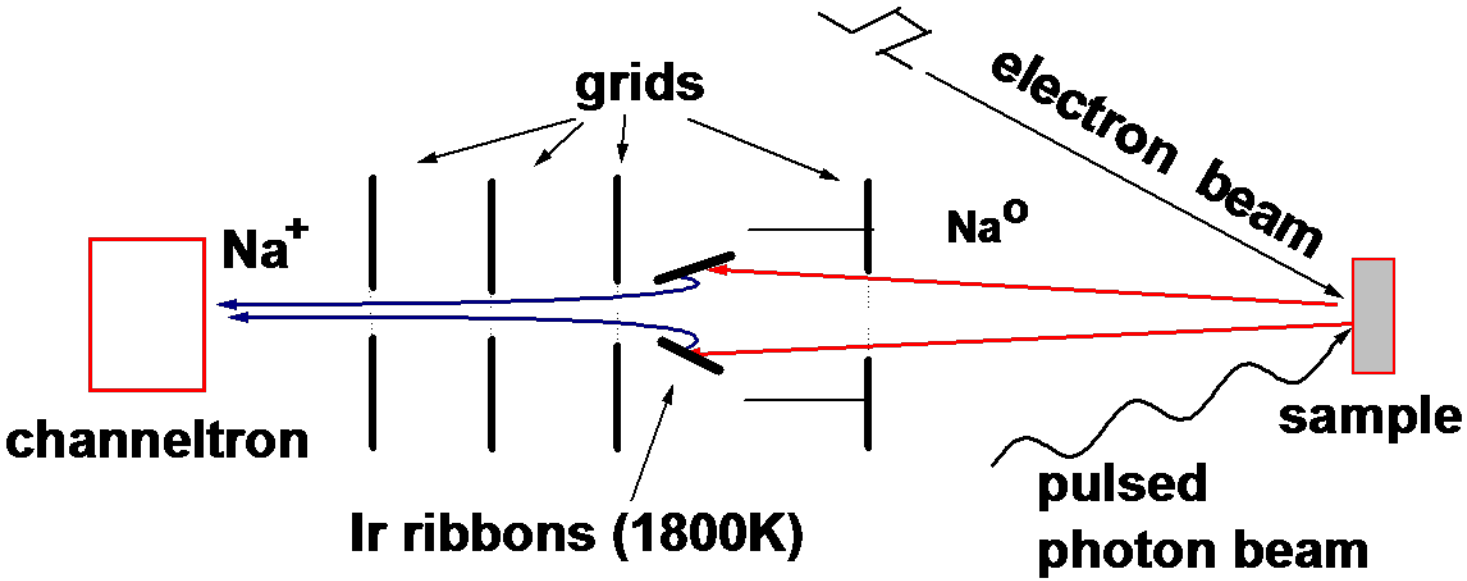
Thermal Desorption Spectra of K / SiO_2





1. **The states with higher BE are populated initially**
2. **For Na: the existence of weakly bound precursor state**
3. **For K: very efficient energy transfer to the substrate**
4. **K may possess a higher ionicity on SiO_2**

Schematic of neutral alkali detector



Surface ionization detector:

$$n^+/n^0 \sim \exp\{e(\Phi - I) / kT\}$$

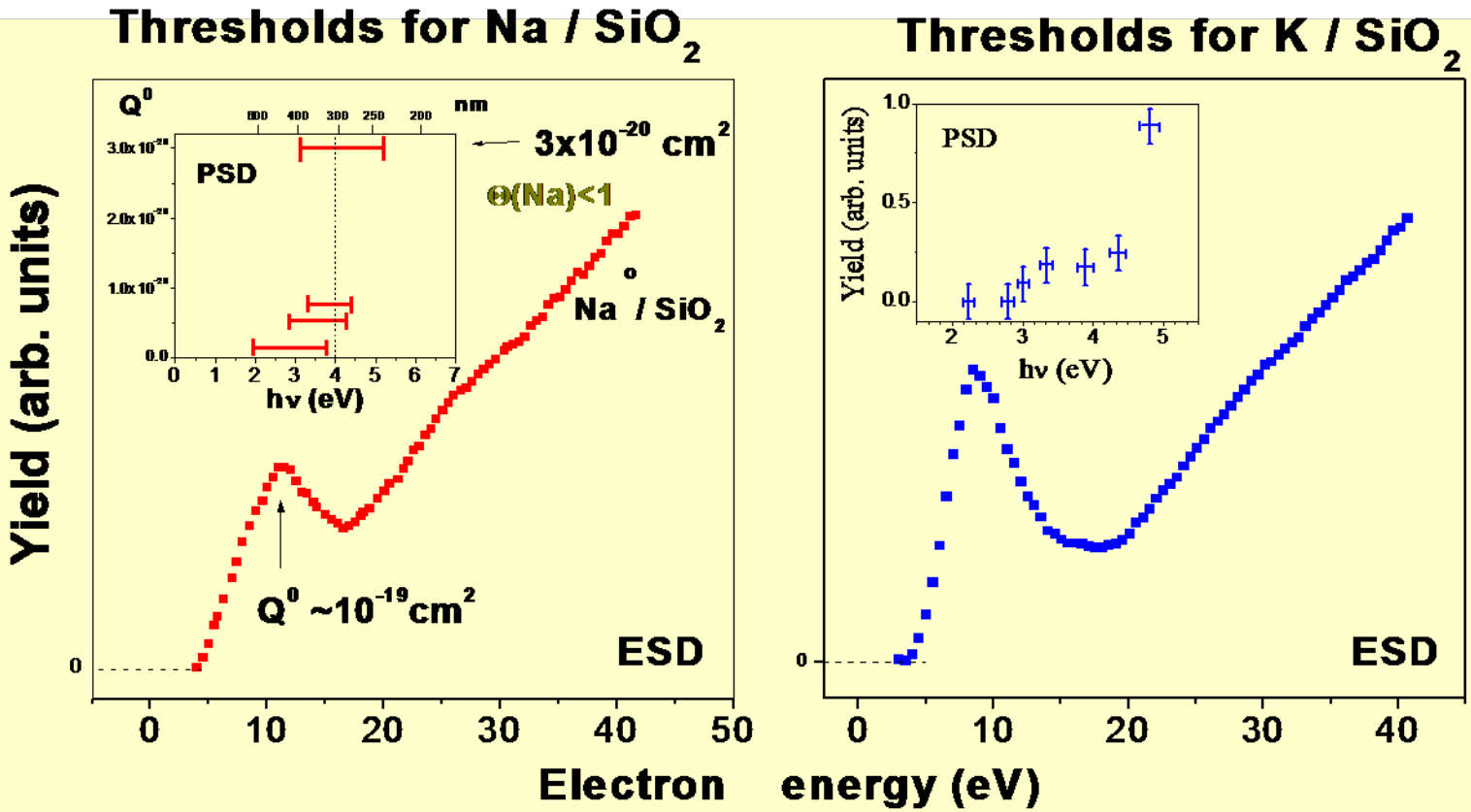
Detector efficiency

(% ionic desorption)

For Ir ($\Phi \sim 5.3$ eV) at 1800K:

Na, K	~100%	ionic
Ba	~ 60%	ionic
Ca	~ 1%	ionic

ESD of Na and K from SiO_2

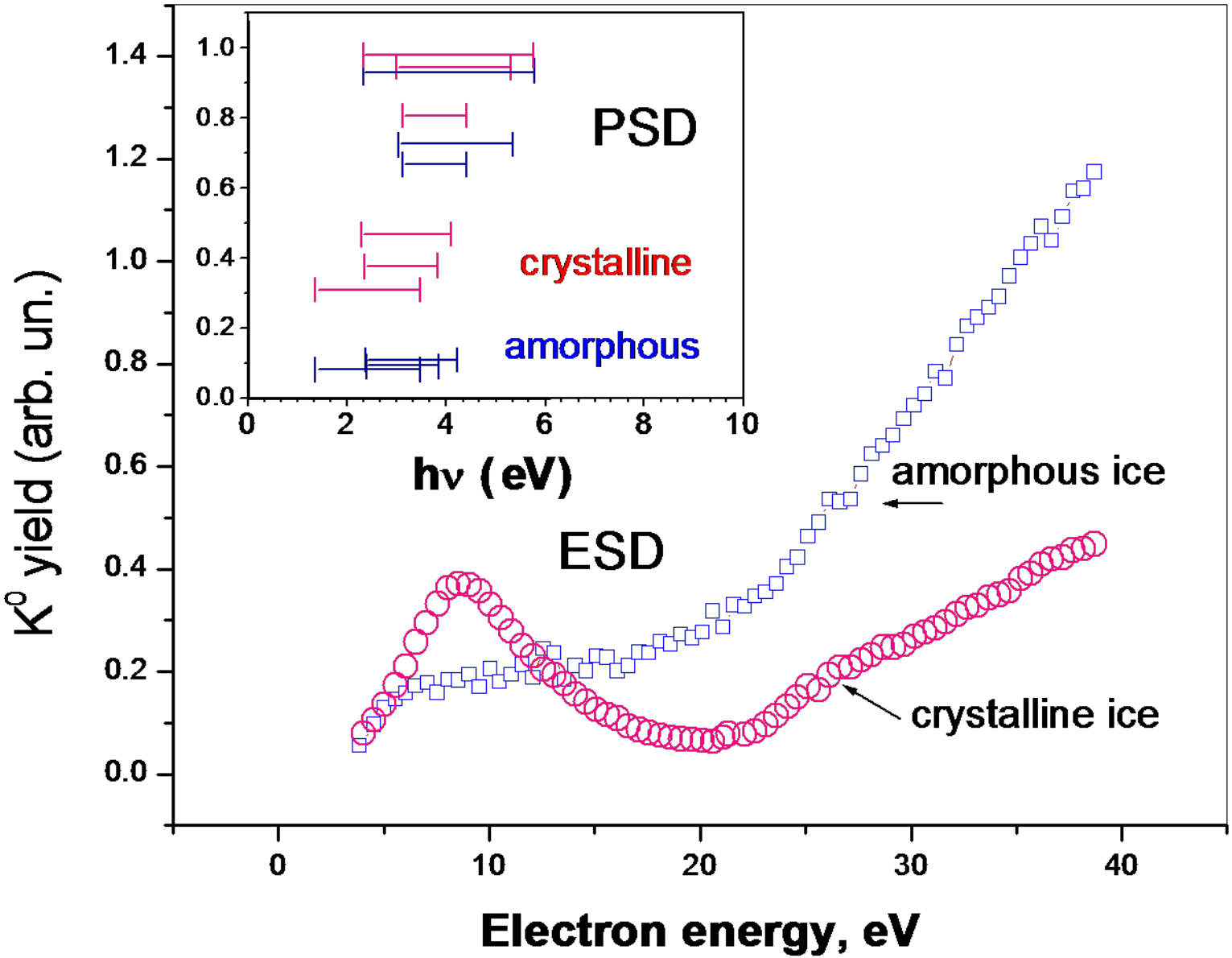


Prediction for lunar surface:

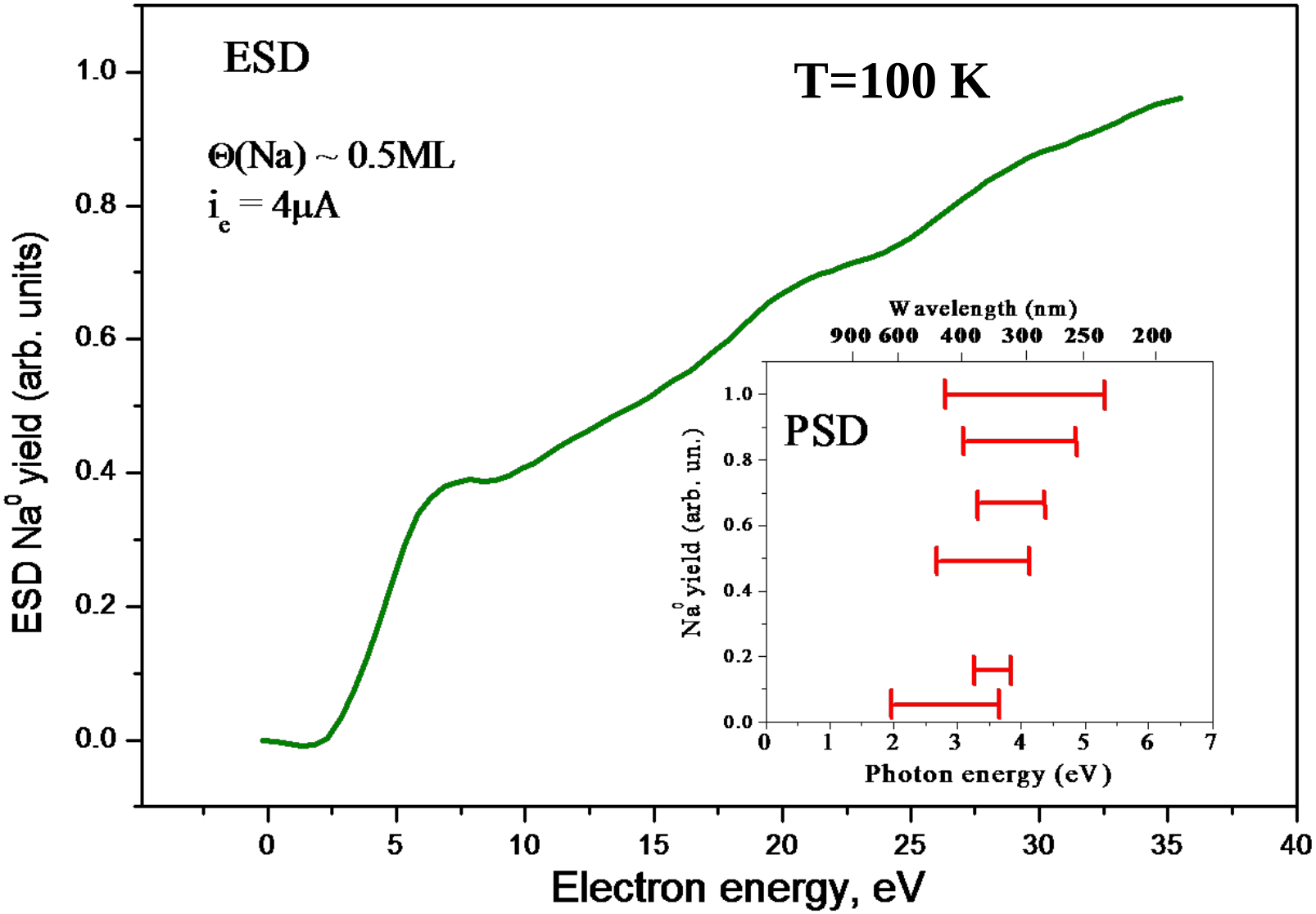
ESD: ~100 at/cm²s **PSD: ~10⁶ at/cm²s**

PSD is an efficient process!

K° / ice DIET thresholds

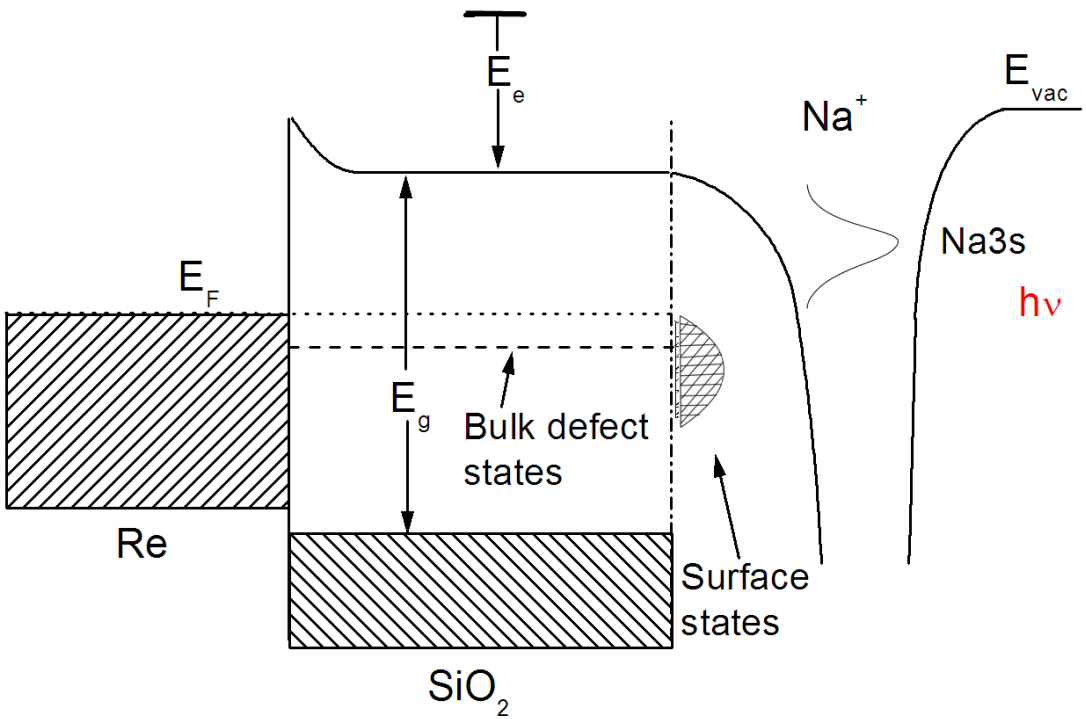


DIET of Na from Lunar sample

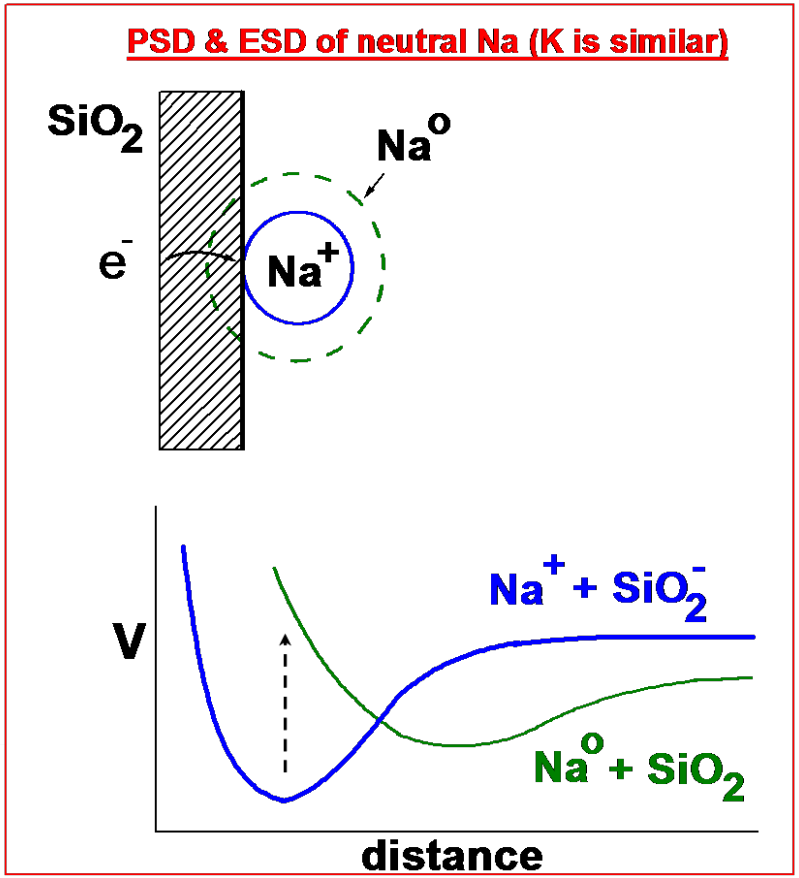


No sharp resonance, mixture of oxides

Model for ESD and PSD of Na from SiO_2

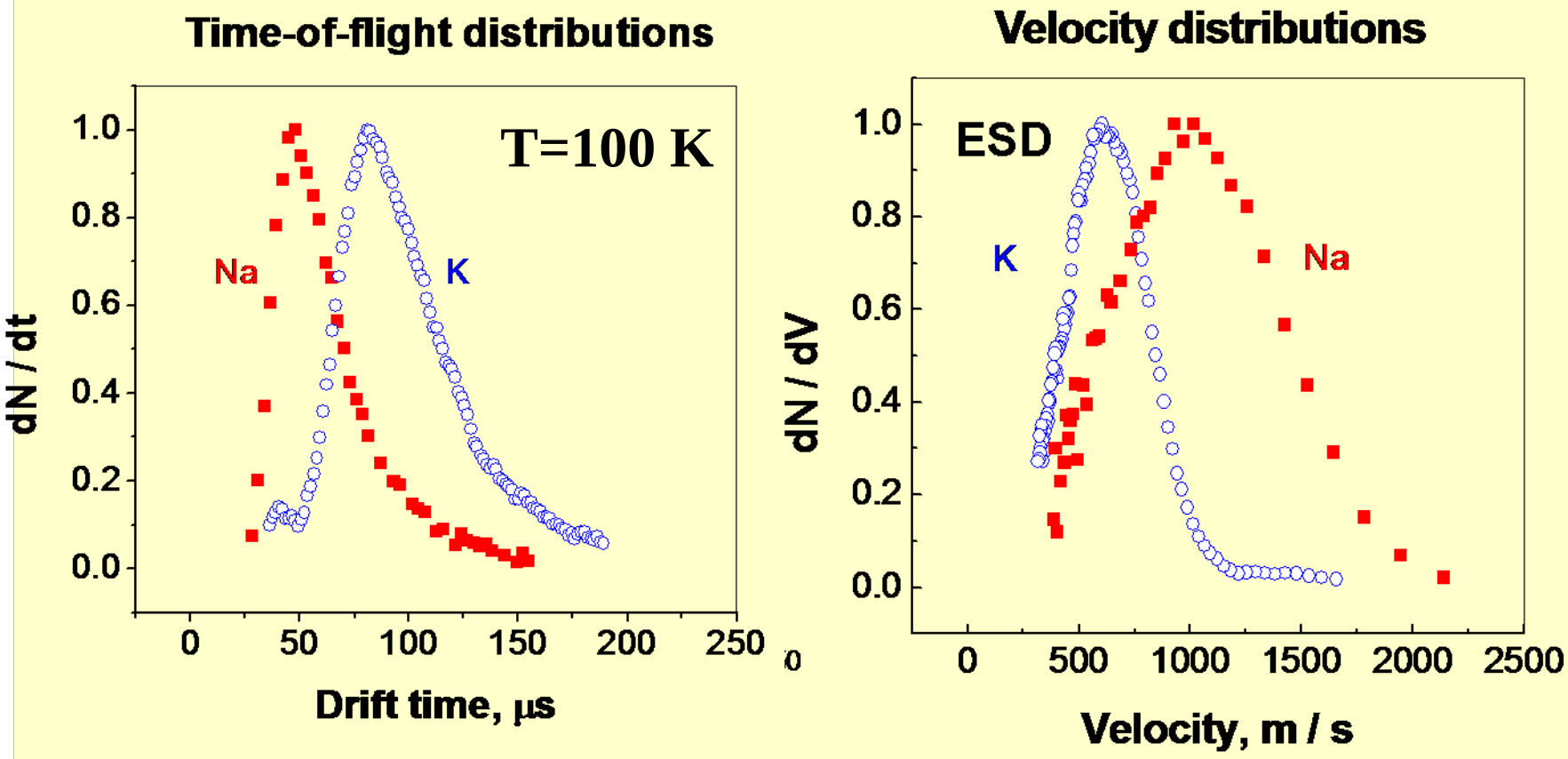


$Na^+ + e^- \rightarrow Na^o$ in repulsive configuration



1-e charge transfer mechanism – for monovalent Na, K

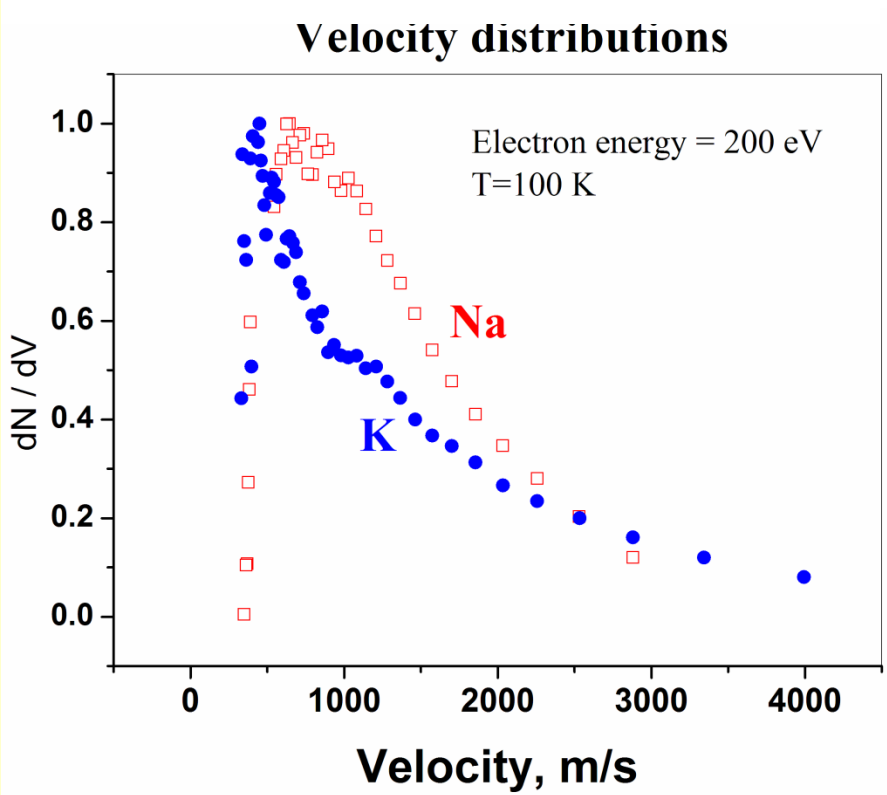
DIET of Na and K from SiO_2

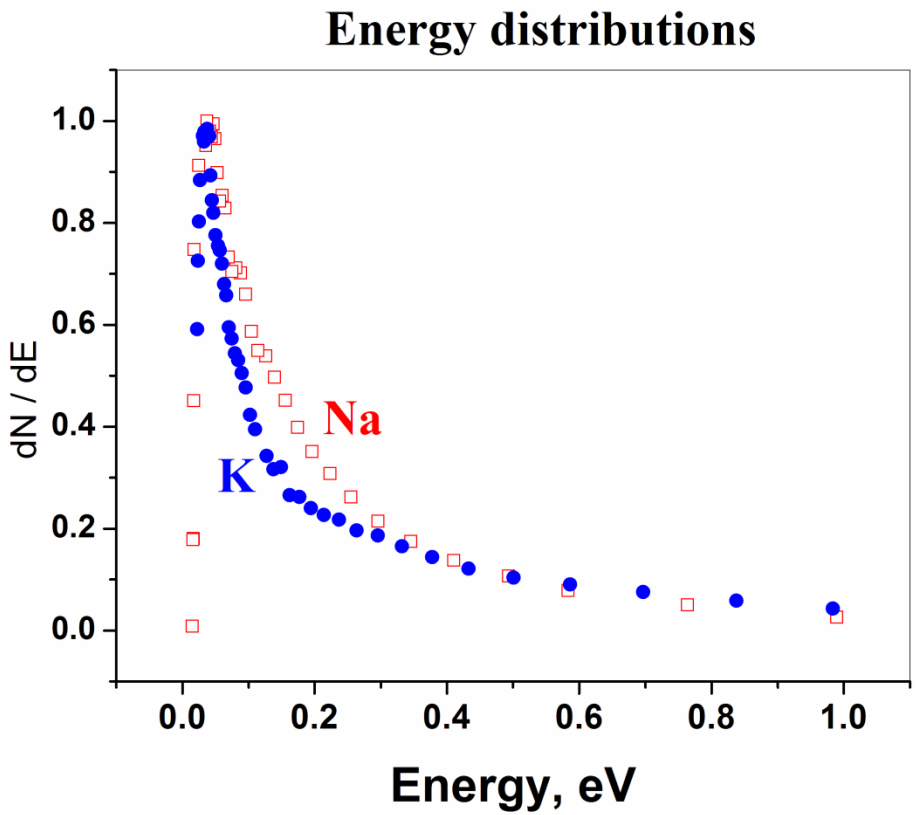


$E_{kin} \sim 0.1eV$

K ~650 m/s ; Na ~1000 m/s – velocities are clearly non-thermal

DIET of Na and K from H_2O ice



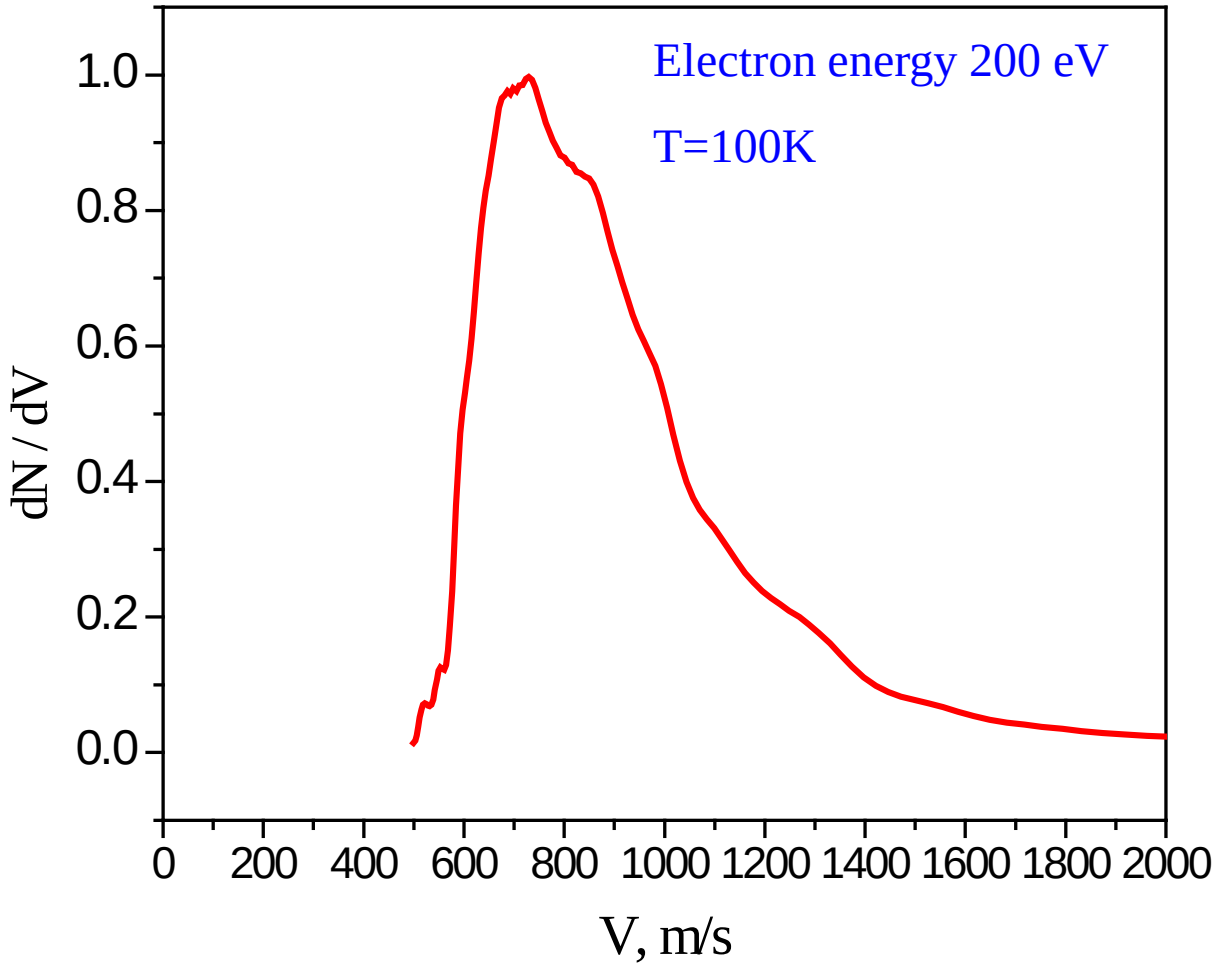


E_{kin} ~ 0.04 eV

K ~500 m/s ; Na ~800 m/s- consistent with Europa observation

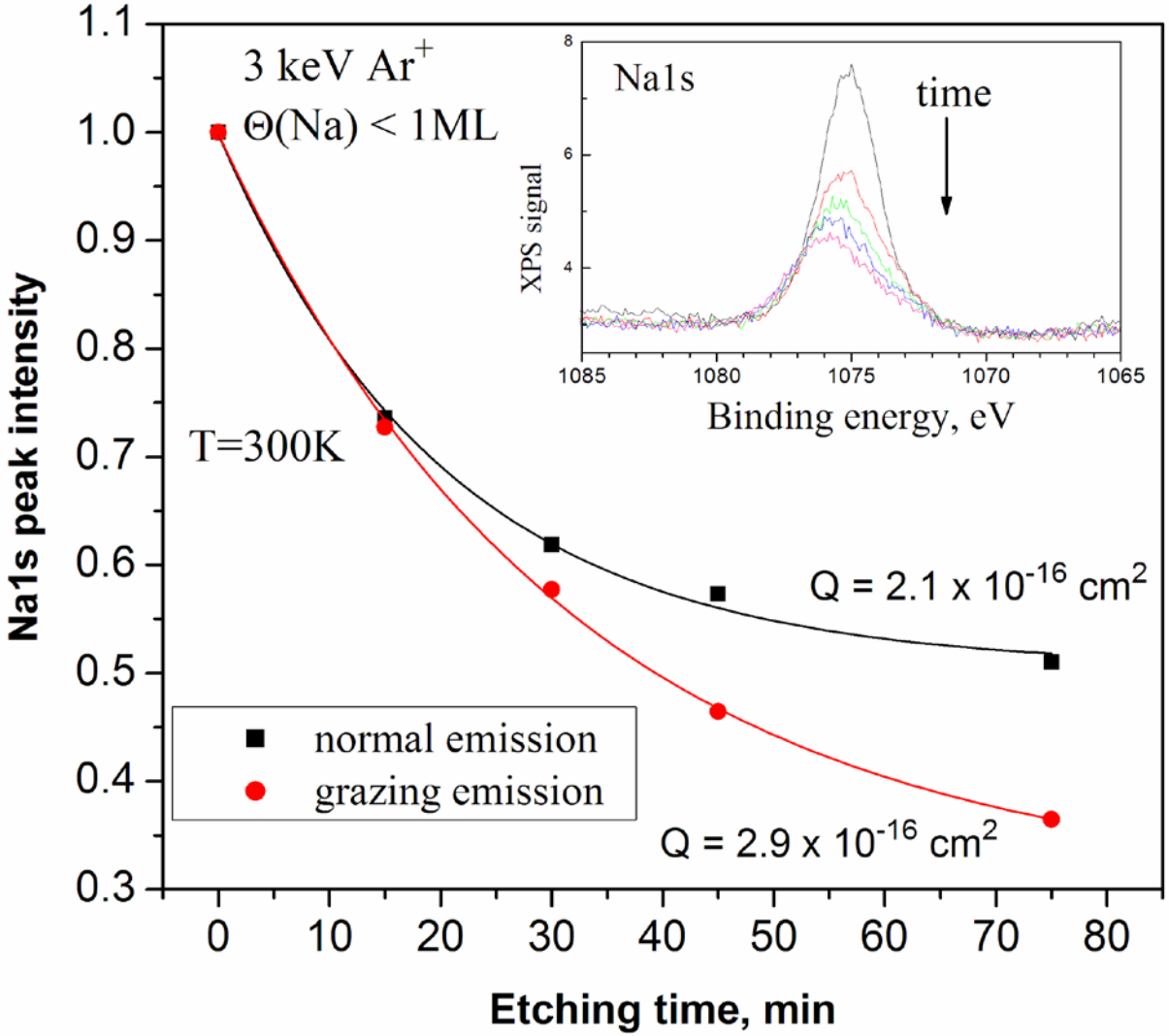
ESD of Na from Lunar sample

Velocity distribution



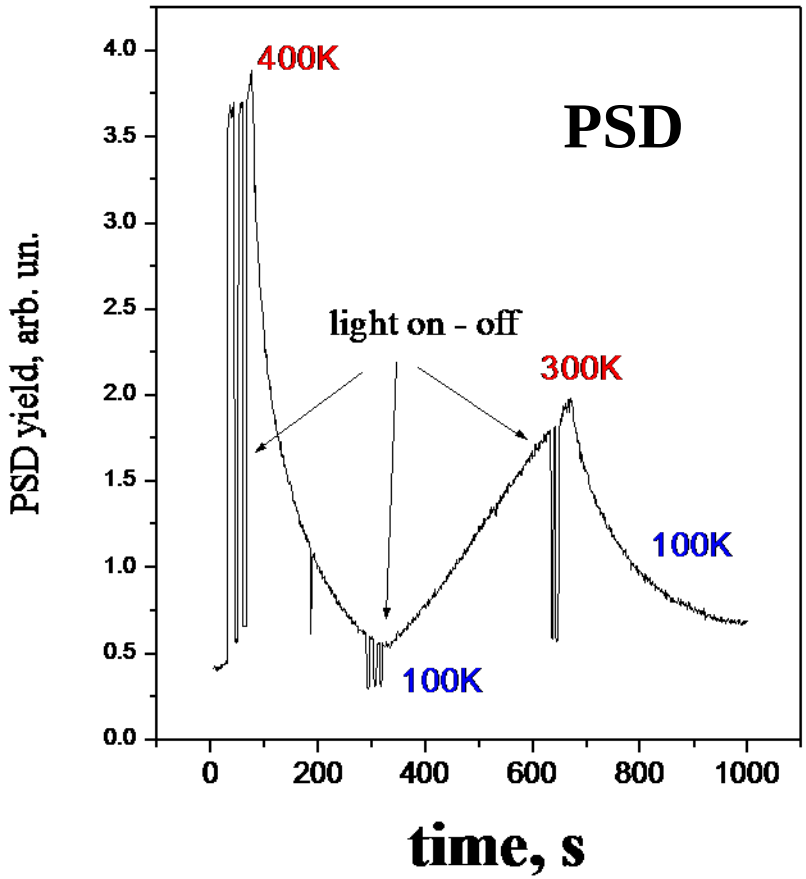
Shift to lower velocity compare to SiO_2

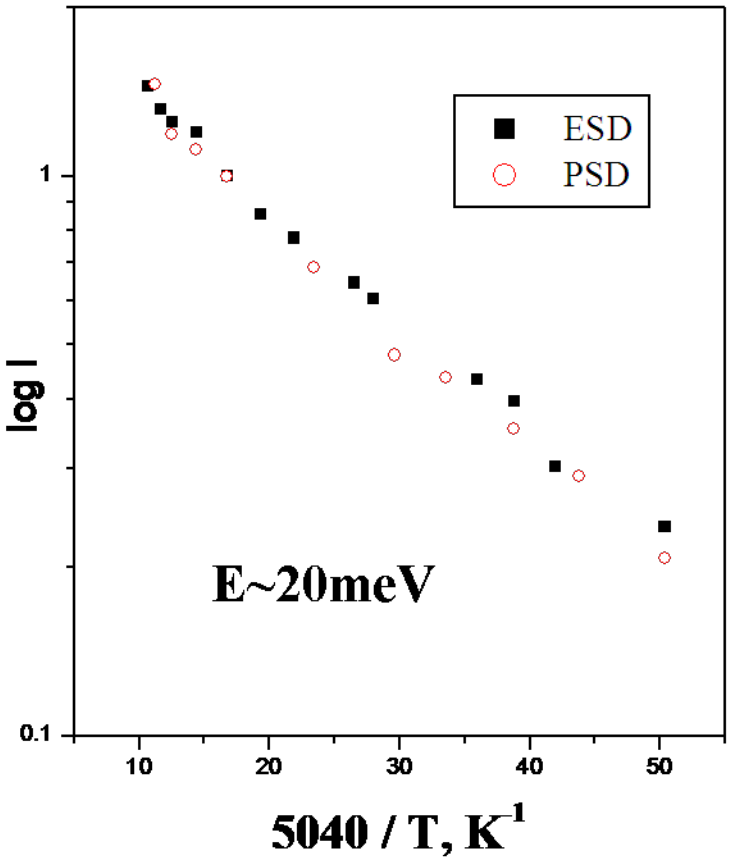
Ion sputtering of Na / lunar sample



Ar^+ bombardment removes Na from substrate: sputtering and implantation

Temperature dependence of Na yield



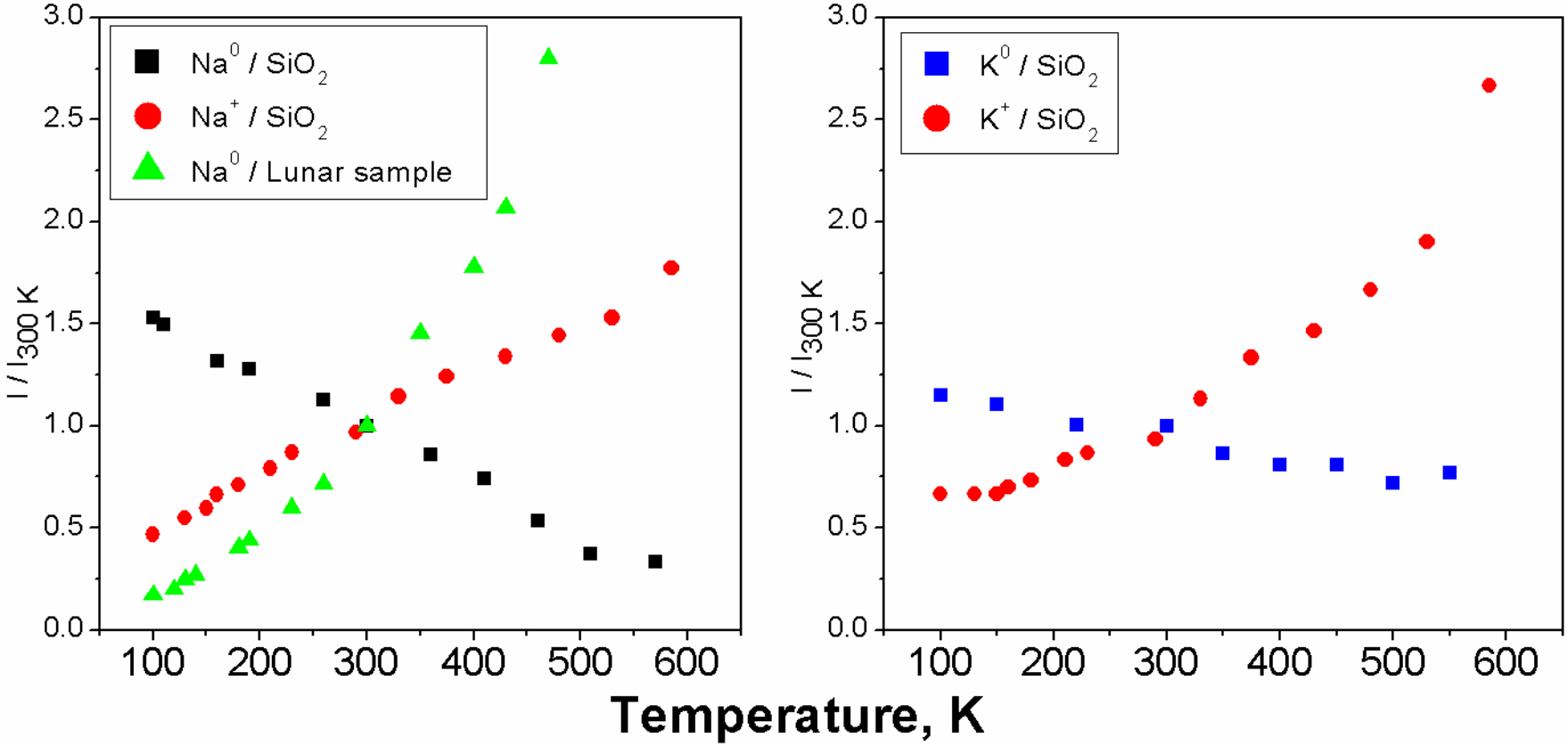


Lunar sample

- Na^0 signal varies reversibly with T
- T- dependent change in binding sites, local atomic coordination

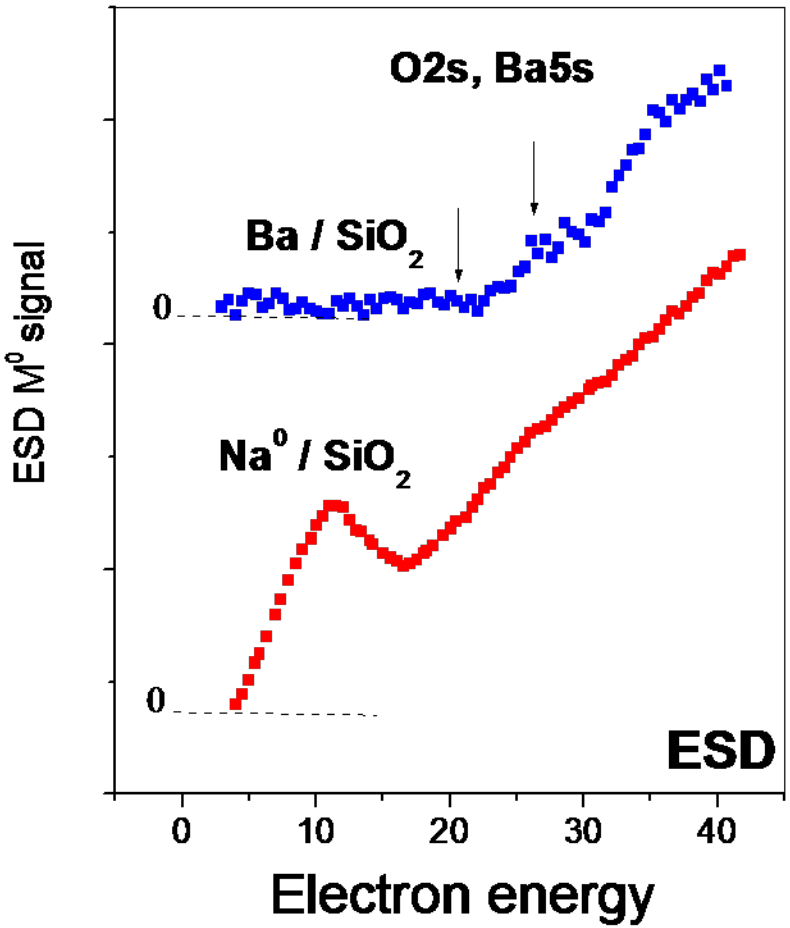
Temperature dependence

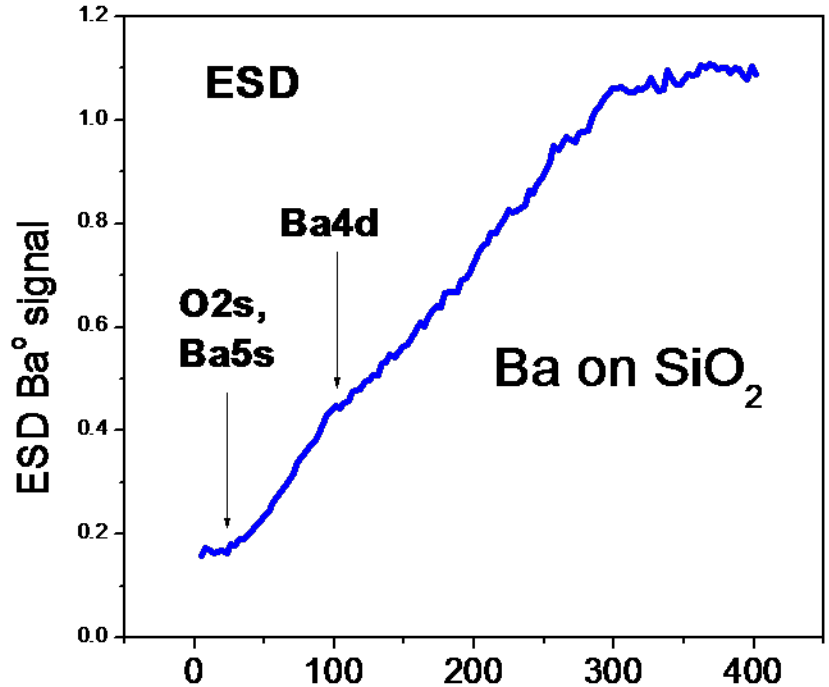
ESD of alkalis from SiO_2 film and lunar sample



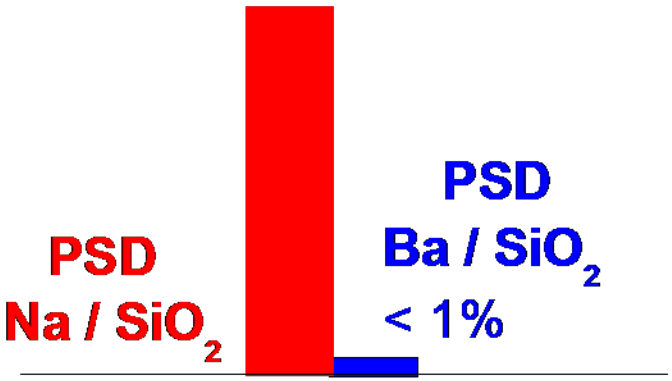
ESD of neutral and ionic Na(K) proceed via different mechanisms

ESD / PSD of Ba from SiO_2





2-electron charge-transfer is less likely process



Summary and Conclusions

- **DIET (mainly PSD) contributes as dominant source process for Na, K in tenuous atmospheres**

- **Ca more abundant than Na, K in soils; scarcity of Ca in atmospheres due to less efficient photon-stimulated two-electron charge transfer**

- **Na atom ESD and PSD yields demonstrate strong reversible temperature dependence on Lunar sample**

Future:

- **Temperature; ion-enhanced PSD; ion-induced diffusion**