Characterizing Silicon Nitride and Aluminum Window SDD for XRFApplications

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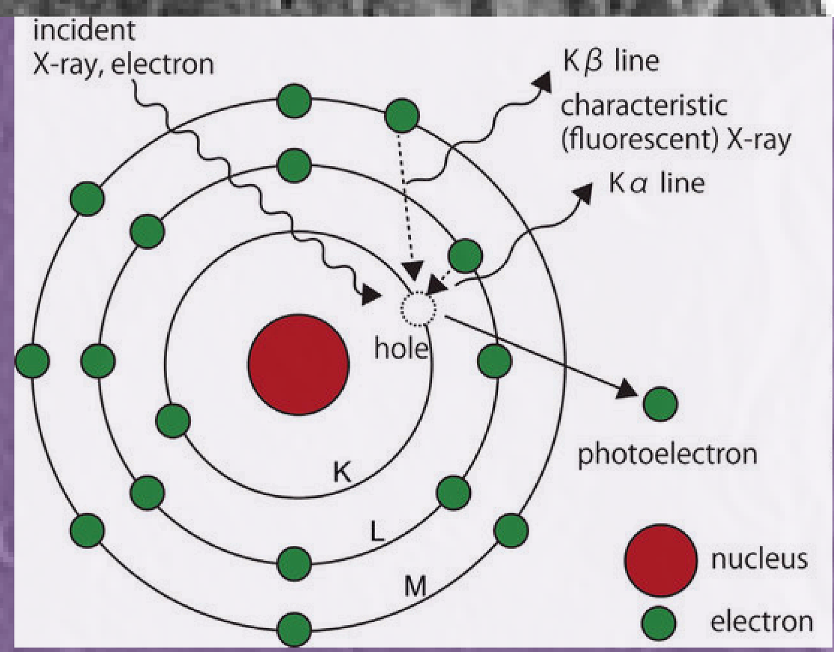
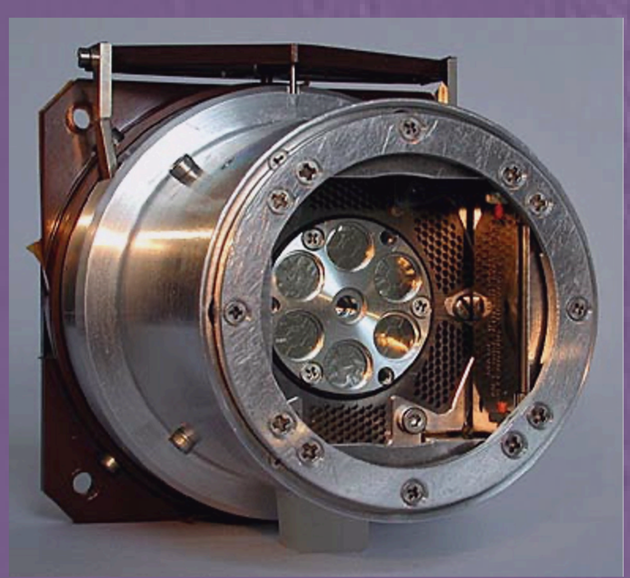
Understanding XRF

X-ray Fluorescence (XRF) is a non-destructive analytical method used to determine the elemental composition of materials.

- Materials are bombarded with high-energy particles (X-rays), exciting electrons, creating electron holes within the atoms.
- Higher energy electrons fall to fill these holes, they emit photons.
- The energy of emitted photons, indicative of the difference between high and low energy levels, is characteristic of specific elements.



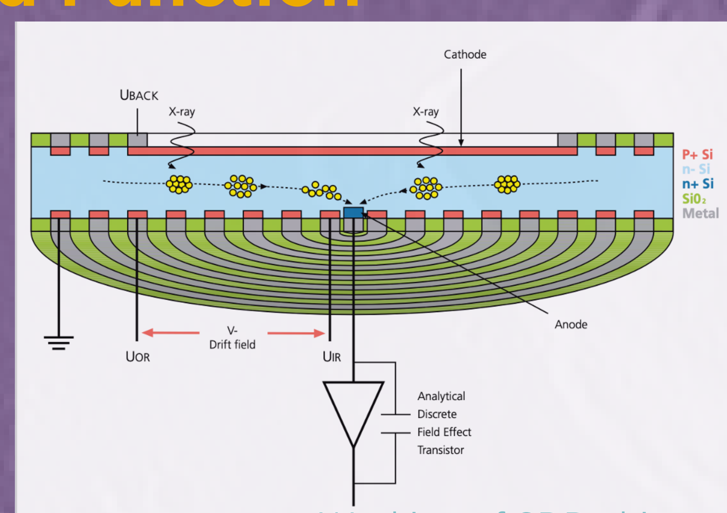
Examples of use of the XRF Technique


APXS from NASA's Curiosity Rover

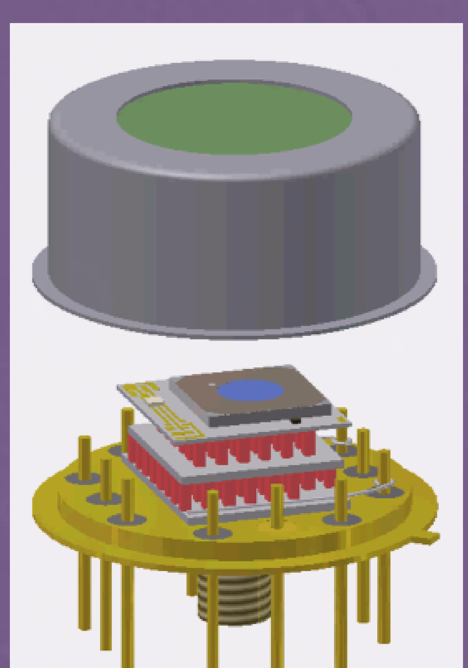
Using a Silicon Drift Detector (SDD) we can measure and analyze characteristic X-ray emissions, providing insights into the elemental composition of a material. Alpha Particle X-ray Spectrometers (APXS) use alpha particles along with X-rays to analyze elemental composition, notably in space exploration missions like the Mars Curiosity rover. APXS uses radioactive source Curium-244 to induce emissions from a sample. Along with charecteristic X-rays, alpha particle back-scattering is used to obtain data that can help reconstruct information about elements that are too light to be detected by only XRF.

Silicon Drift Detector (SDD) Design and Function

- The SDD has p-n junctions created by the concentric circles of p-doped silicon on the n-doped silicon.
- A reverse bias voltage creates a depletion region to drive the photogenerated charge carriers.
- Photogenerated electrons are directed by a radial electric field
- These electrons are collected at a central anode



Working of SDD chip

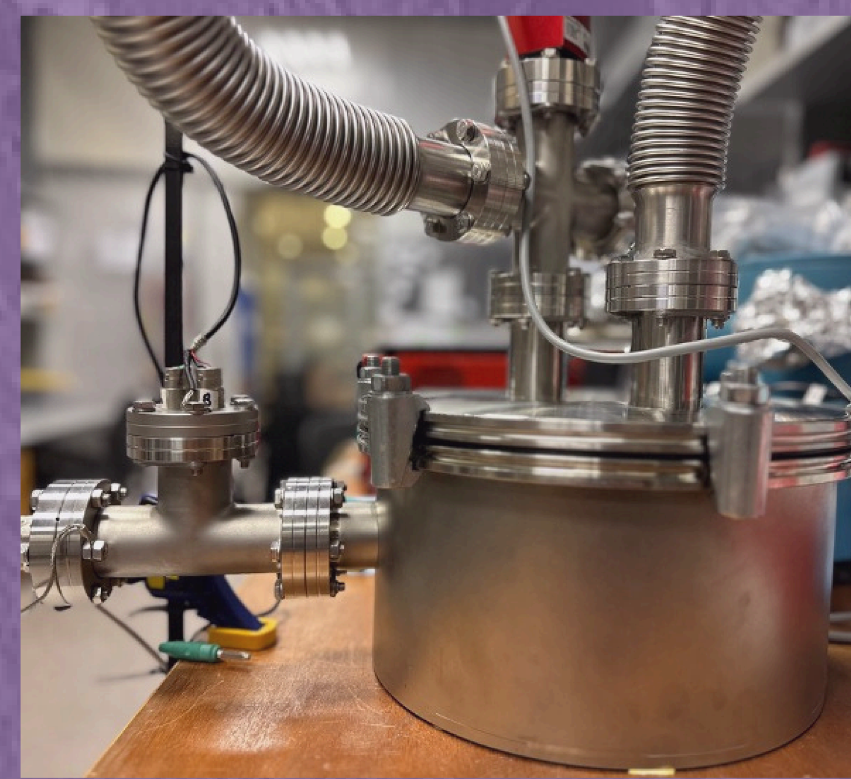

Schematic of the SDD

SDD Beryllium Window

- The SDD chip is protected from the environment within a vacuum enclosure
- Beryllium windows are chosen to maintain the vacuum seal while also letting in X-rays.
- Beryllium has opacity to X-rays below 1 keV, limiting the SDD's ability to detect lighter elements like oxygen.
- Recent developments have used a combination of Silicon nitride (SiN3) and Aluminum for the window

Experimental Design

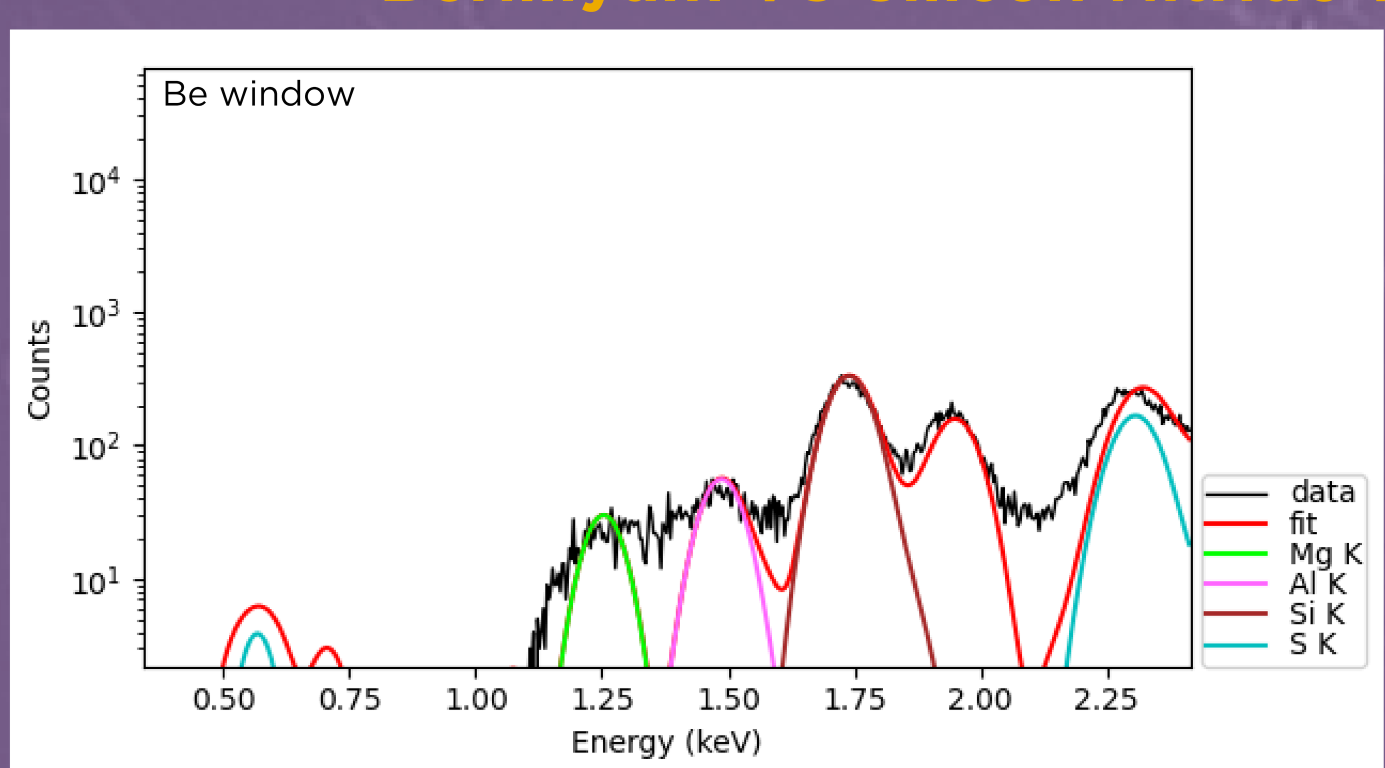
The objective of the experimental setup is to evaluate how replacing the beryllium window with silicon nitride (SiN3) and aluminum (Al) in the detector affects its ability to capture low-energy X-rays, especially those near the edge of the beryllium window detector's sensitivity.

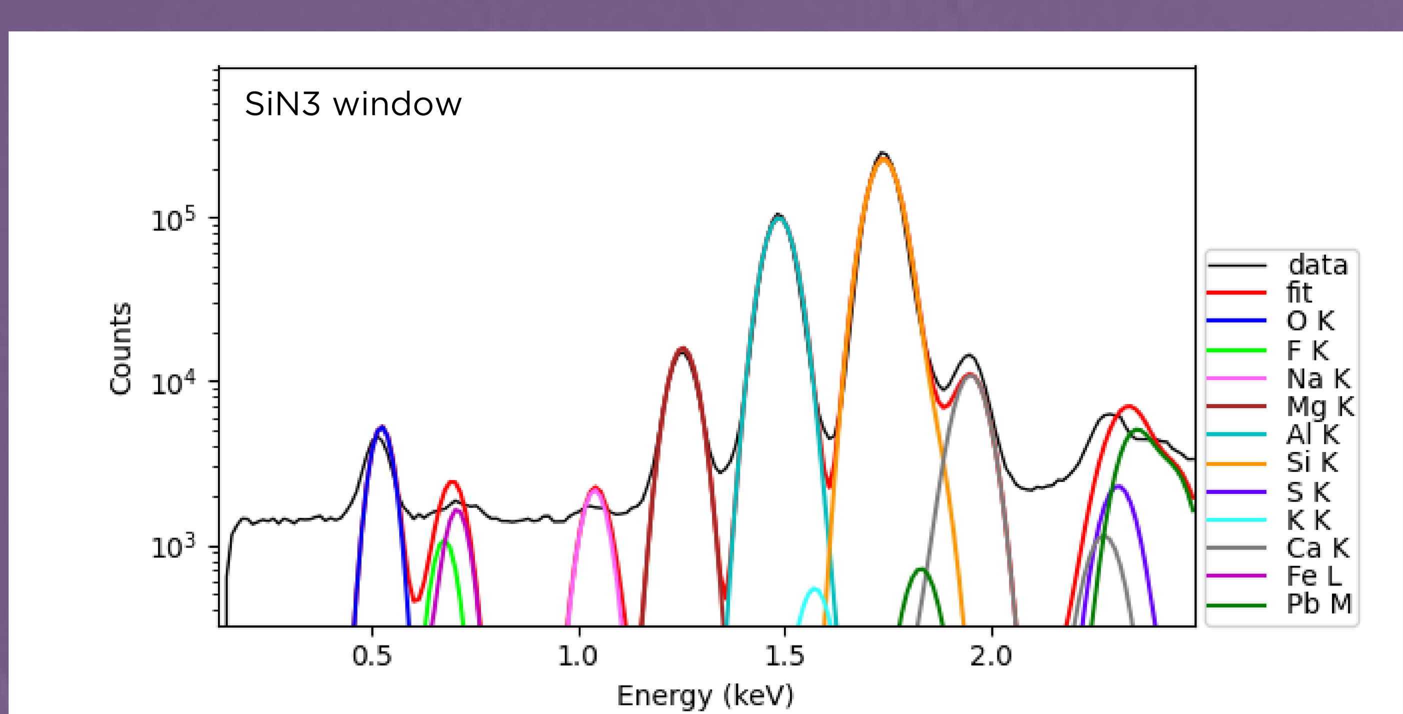


- **Use of Vacuum Chamber:** A vacuum chamber at 10e-5hPa was used in to eliminate air-induced X-ray attenuation.
- **Experimental Power Details:** A 70 kV, 12 W X-ray tube with a molybdenum target was used.
- **Testing Protocol:** Standardized conditions by operating the X-ray tube at 15 kV and 15 µA to produce reliable and comparable data.

- **Detector geometry:** Positioned the detector at a 45° angle to the X-ray source to optimize detection efficiency
- **Thermal Management:** The SDD was thermally coupled to an aluminum platform and the chamber casing to stabilize operating conditions and prevent overheating

Berilliyum VS Silicon Nitride window





With the Silicon Nitride window, we detected light elements like Oxygen, identifying its Kα lines at 0.5 keV which are energies typically absorbed by the Be window

SDD resolution at 230K