The use of swept-charge devices in planetary analogue X-ray fluorescence studies

T. E. Walker, D. R. Smith

Centre for Sensors and Instrumentation
School of Engineering and Design, Brunel University, UK

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Talk Overview

- Context and history
- Purpose and goals
- Spacecraft
- C1XS
- Brunel involvement
  - Environment modelling
  - Radiation damage
  - Device screening
- Brunel C1XS test facility
- Moon Regolith
- The 'RAL' abundance algorithm
- Sample preparation
- Results and Conclusions

Chandrayaan-1 History

- ‘Moon Vehicle’
- Announced on Indian Independence Day, August 15th 2003 by Prime Minister Atal Bihari Vajpayeeon
- Indian government approved the *Indian Space Research Organisation* (ISRO) proposal for Chandrayaan-1 in November 2003
- Launched in October 2008 from India’s space port at Sriharikota on an Indian *Polar Satellite Launch Vehicle* (PSLV-XL):
  - developed in the early 1990s
  - 8 consecutive successful launches from 1994-2005

Mission Purpose

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Physical Properties

Topography

Gravity

Magnetic Field

Radiation Environment

Understanding the origin and Evolution of the Moon

Bulk Chemistry

Nature of the Lunar Crust

The Lunar Far-side:

Rock types, Chemistry

Special Regions of Interest

Polar Regions

South Pole Aitken Region (the oldest discernible impact feature)

Selected Basins and Craters with central uplift

Nature of Volatile Transport on Moon (Water on Moon?)

Mission Aims

- Create a 3D atlas of the Moon with a resolution of 5 – 10 m
- Conduct chemical and mineralogical mapping of the entire lunar surface for distribution of elements such as Magnesium, Aluminum, Silicon, Calcium, Iron and Titanium with a spatial resolution of about 25 km

Spacecraft Overview

- **Launch:** October 2008
- **Mass:** 1300 kg at launch, 590 kg at lunar orbit (55 kg payload)
- **Shape:** Cuboid in shape, ~1.5 m^3
- **Stabilisation:** 3-axis stabilised spacecraft using two star sensors, gyros and four reaction wheels
- **Power:** 700 W from single solar array with lithium ion batteries during eclipse
- **Lifetime:** ~11 day cruise phase with 2 years at lunar orbit (actual time on orbit was 9 months!)

Chandrayaan-1 X-ray Spectrometer (C1XS)

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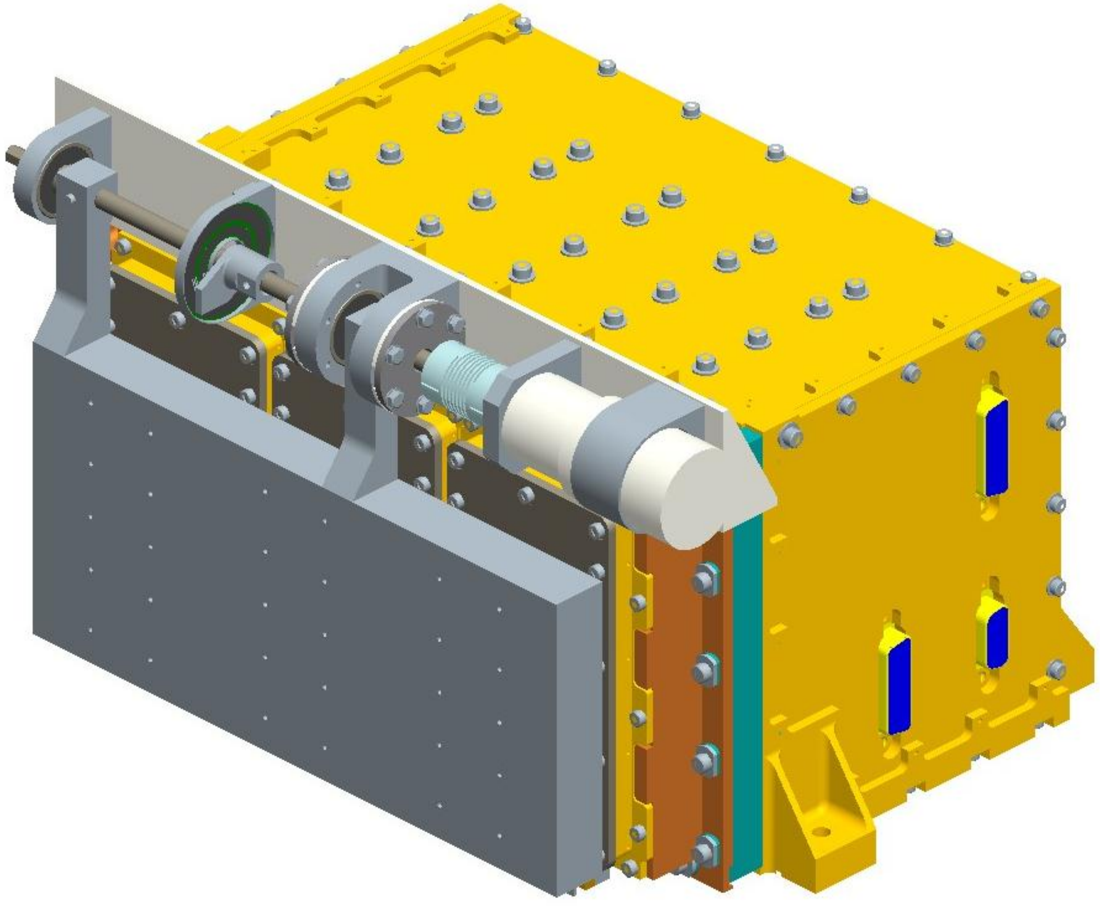

Absolute elemental mapping in X-rays

X-ray solar monitor to measure solar spectrum

Detectors:
24 swept charge devices of 1 cm^2 each

E-range:	1 – 10 keV
E-resolution:	180 eV @ 1.45 keV

XSM Detector:	Si-PIN
Energy range:	1 – 20 keV
FOV:	14°
Ground Pixel:	25 km × 25 km FWHM

C1XS Overview

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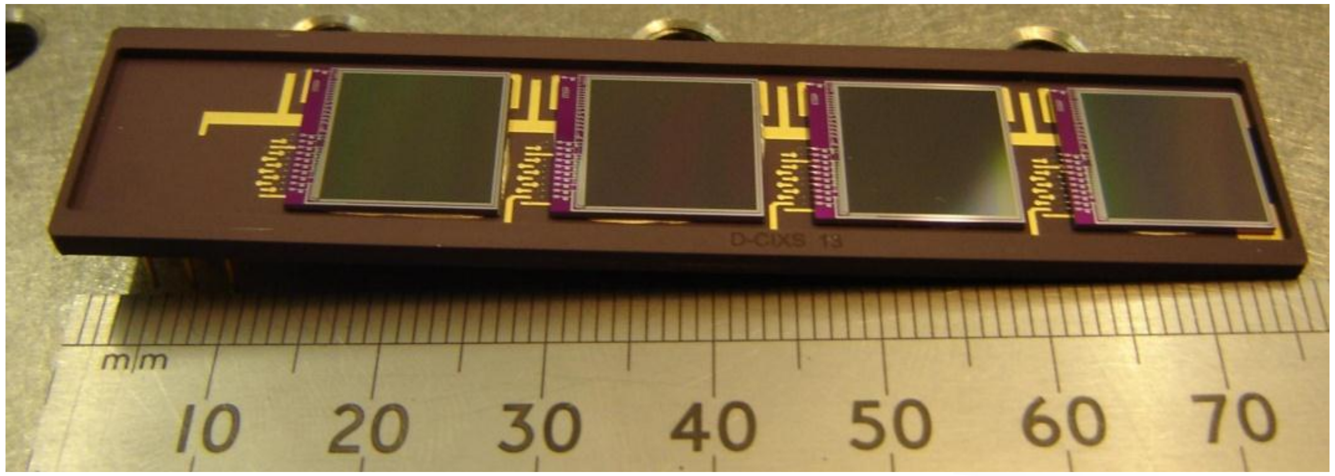
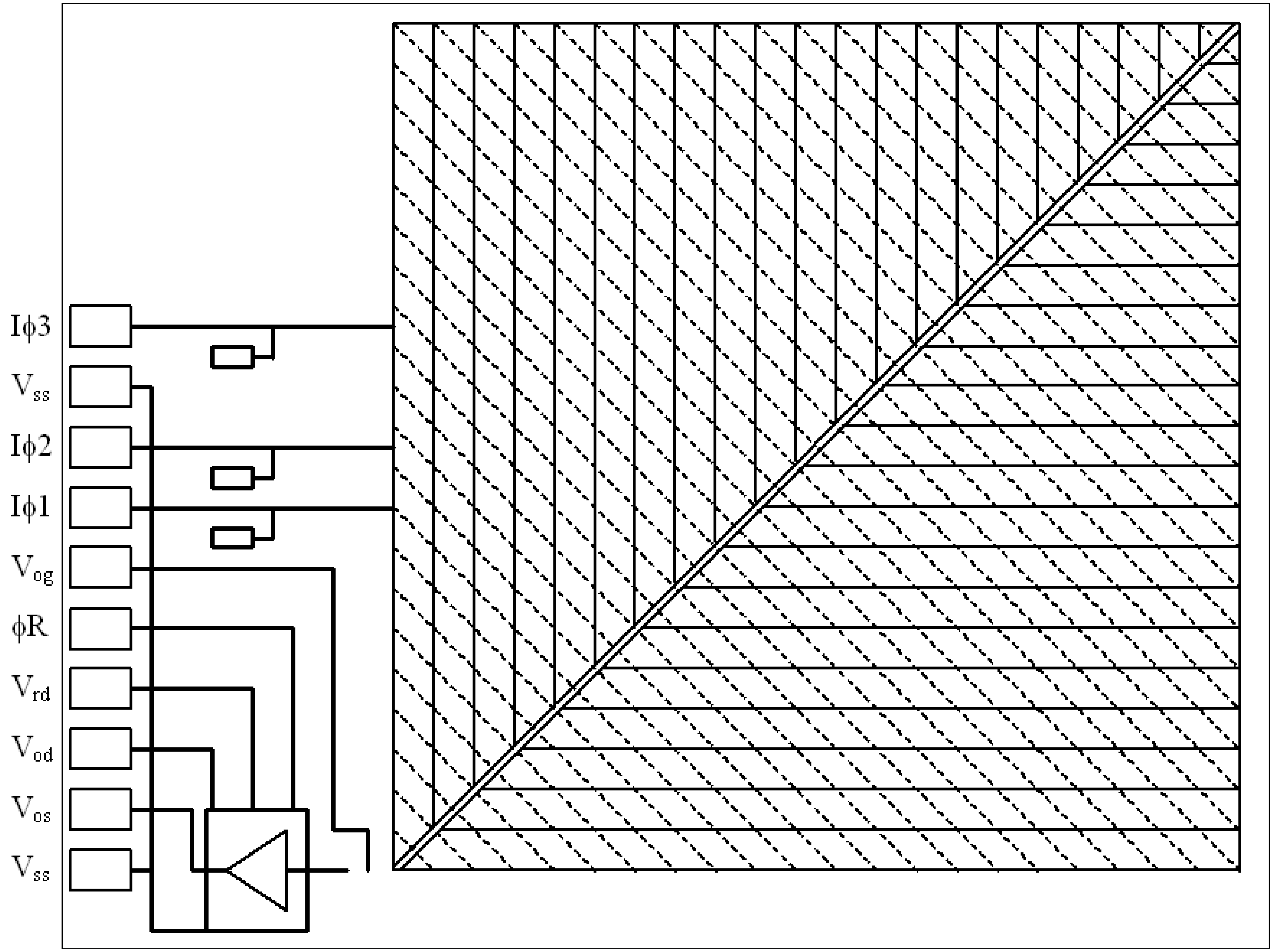
- **Sophisticated miniaturised X-ray spectrometer that employs radical new technology to greatly reduce the mass and volume of the instrument**
- **Based around e2v technologies CCD54 Swept Charge Devices (SCDs):**
  - a development on normal X-ray CCD sensors which require much less cooling

Modular package design with 4 devices on one ceramic carrier

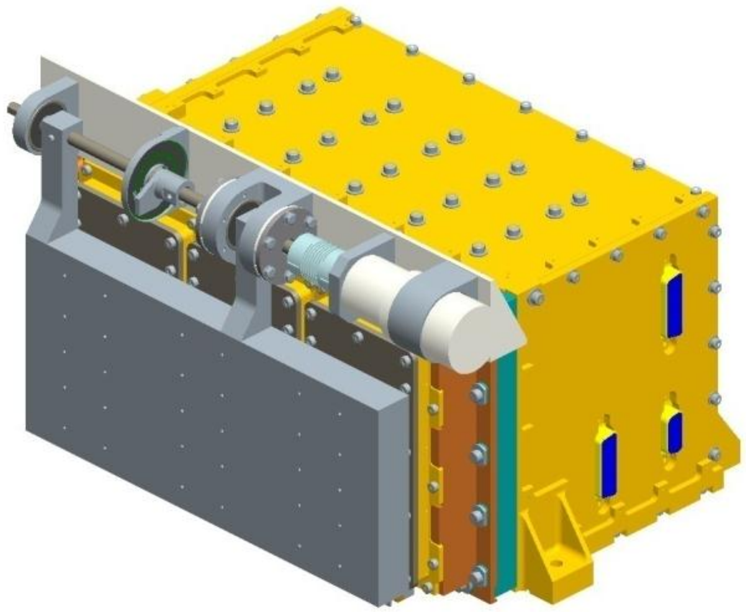


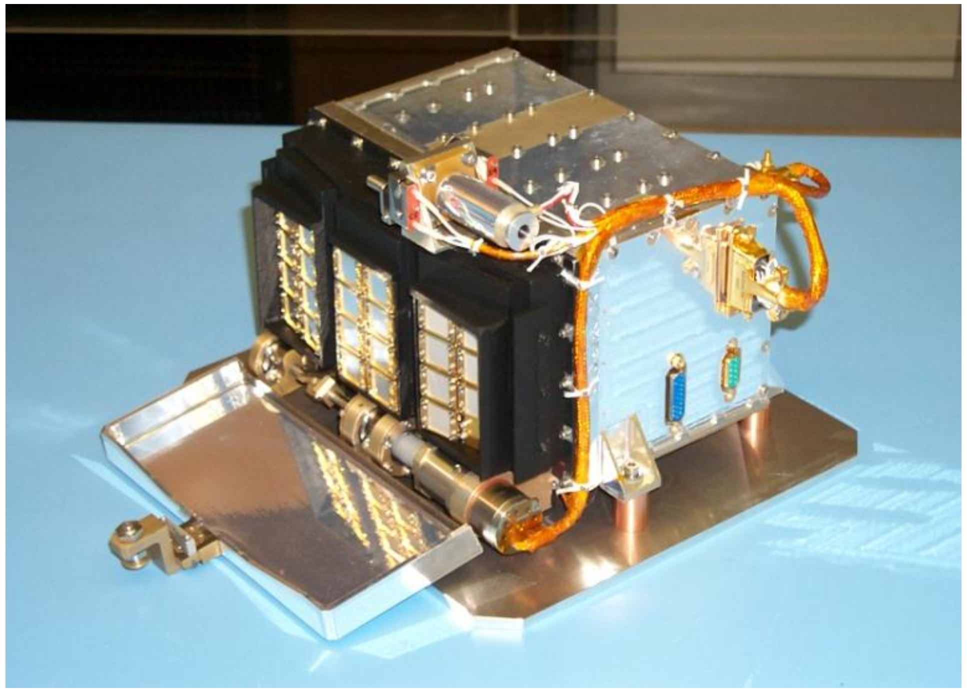
The Swept Charge Device



C1XS Heritage

- C1XS is based on the proven heritage of D-CIXS which successfully demonstrated the technological capabilities of this technique when it flew around the Moon on the ESA SMART-1 spacecraft





C1XS Science

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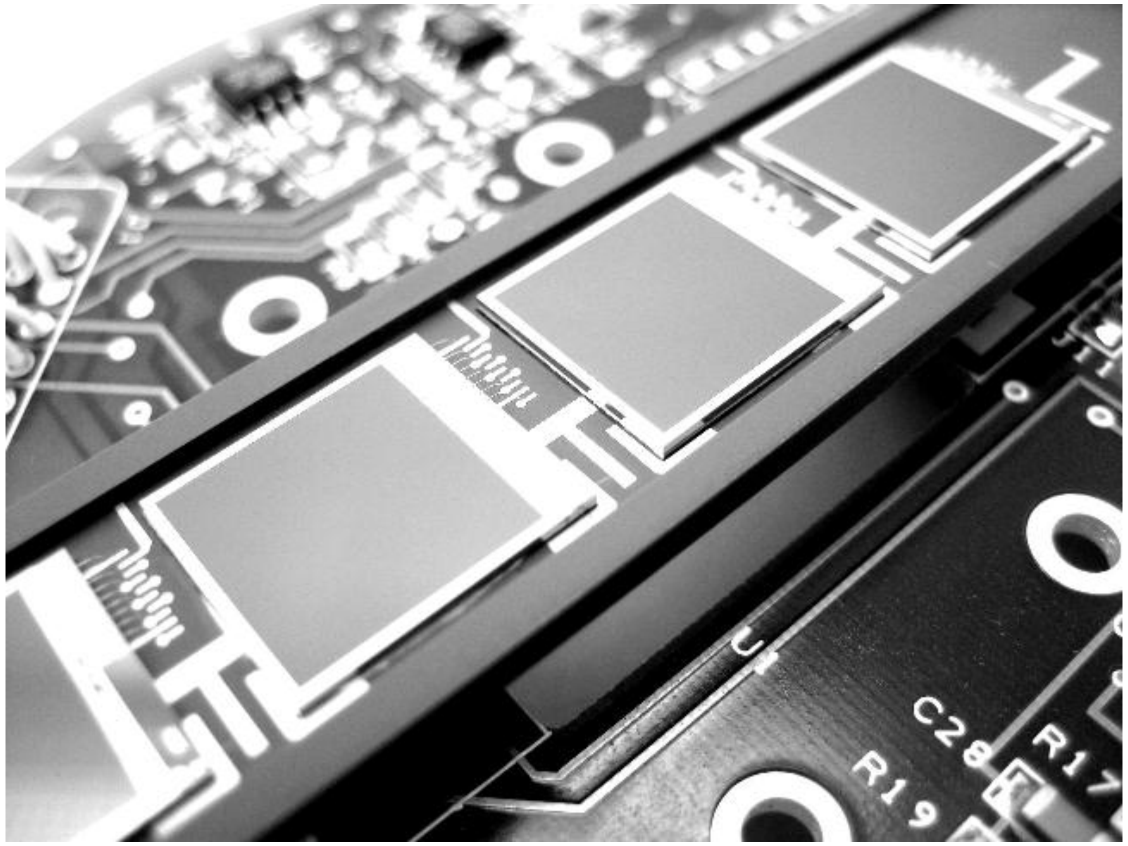
- **X-rays from the Sun strike the Moon and are absorbed into the upper few microns of the surface layer**
- **Occasionally an X-ray is then emitted from the surface layer by the process of X-ray fluorescence:**
  - these X-rays are uniquely characteristic of the atom that emitted them
- **C1XS will detect these emitted atomic signatures and provide information about the chemistry of the lunar surface:**
  - during normal solar conditions, C1XS will be able to detect elements like Mg, Al and Si
  - during stronger solar X-ray periods it is possible to detect other elements too, such as Ca, Fe and Ti

Brunel Involvement

- **The Centre for Sensors and Instrumentation at Brunel has been involved with the C1XS instrument onboard Chandrayaan-1 in the following ways:**
  - Radiation environment analysis for the duration the mission
  - Characterisation of SCD and assessment radiation tolerance
  - Screening of flight devices for SCD flight instrument



Brunel C1XS Test Facility

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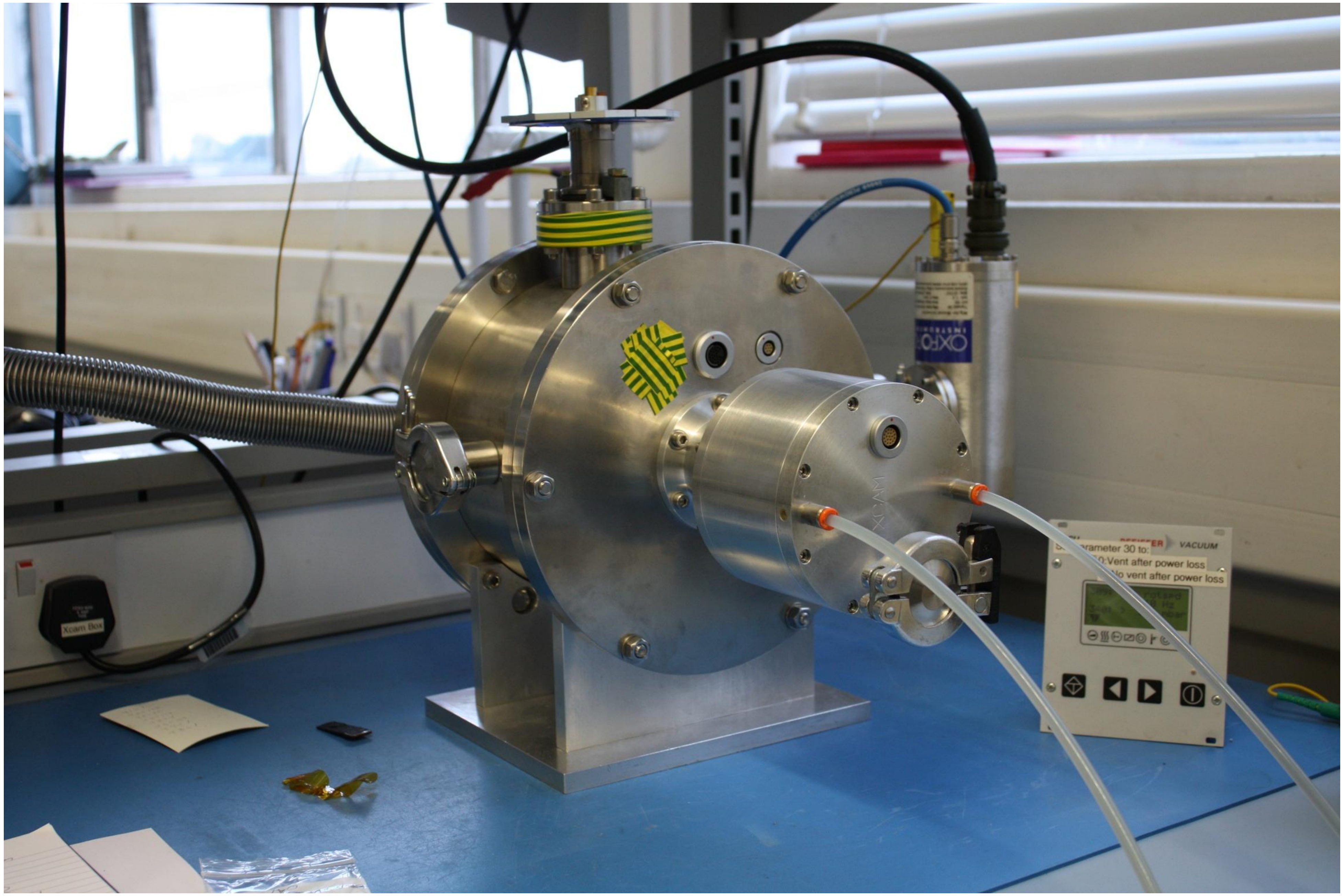

Brunel C1XS Test Facility

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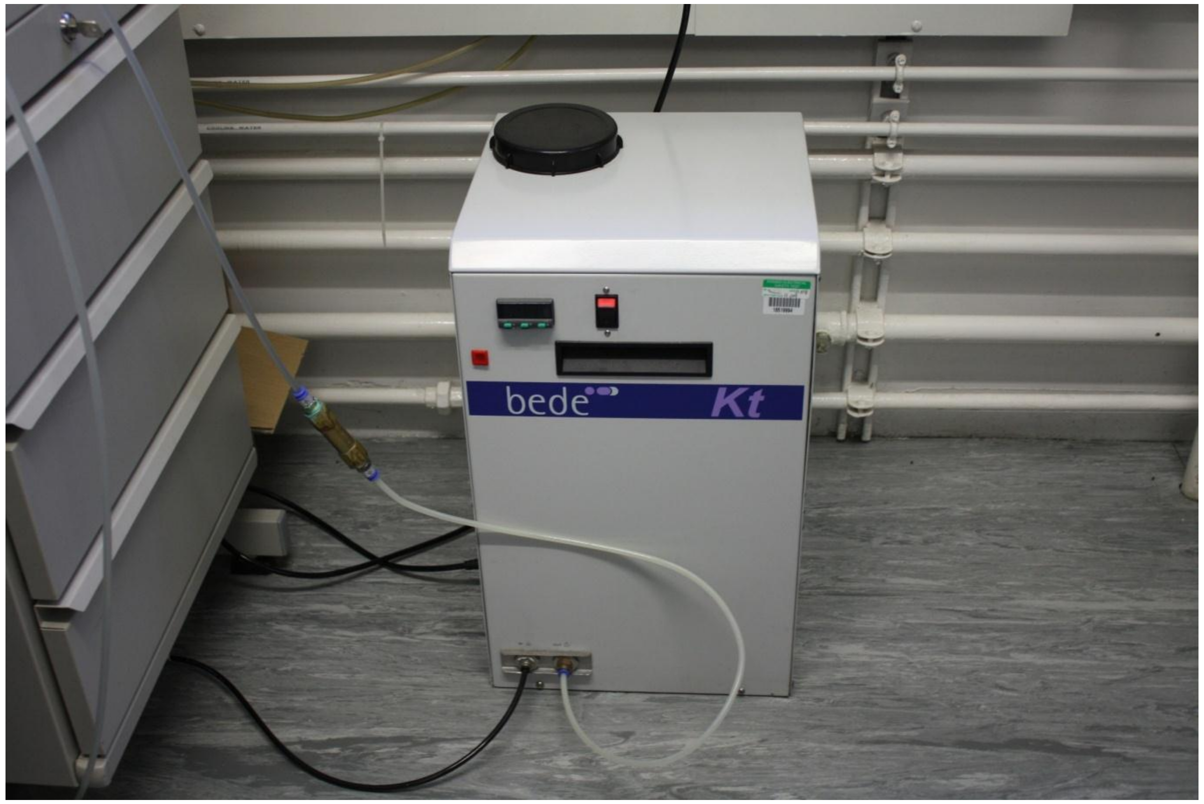
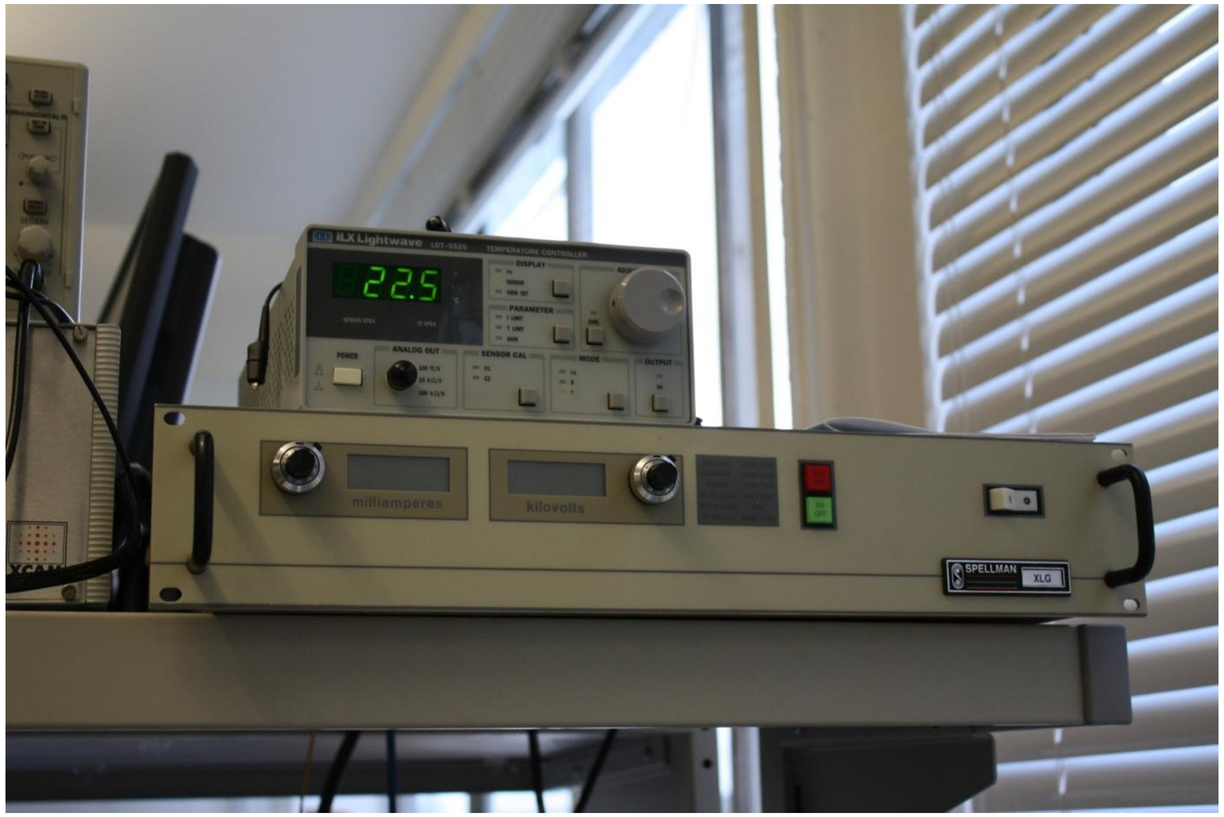
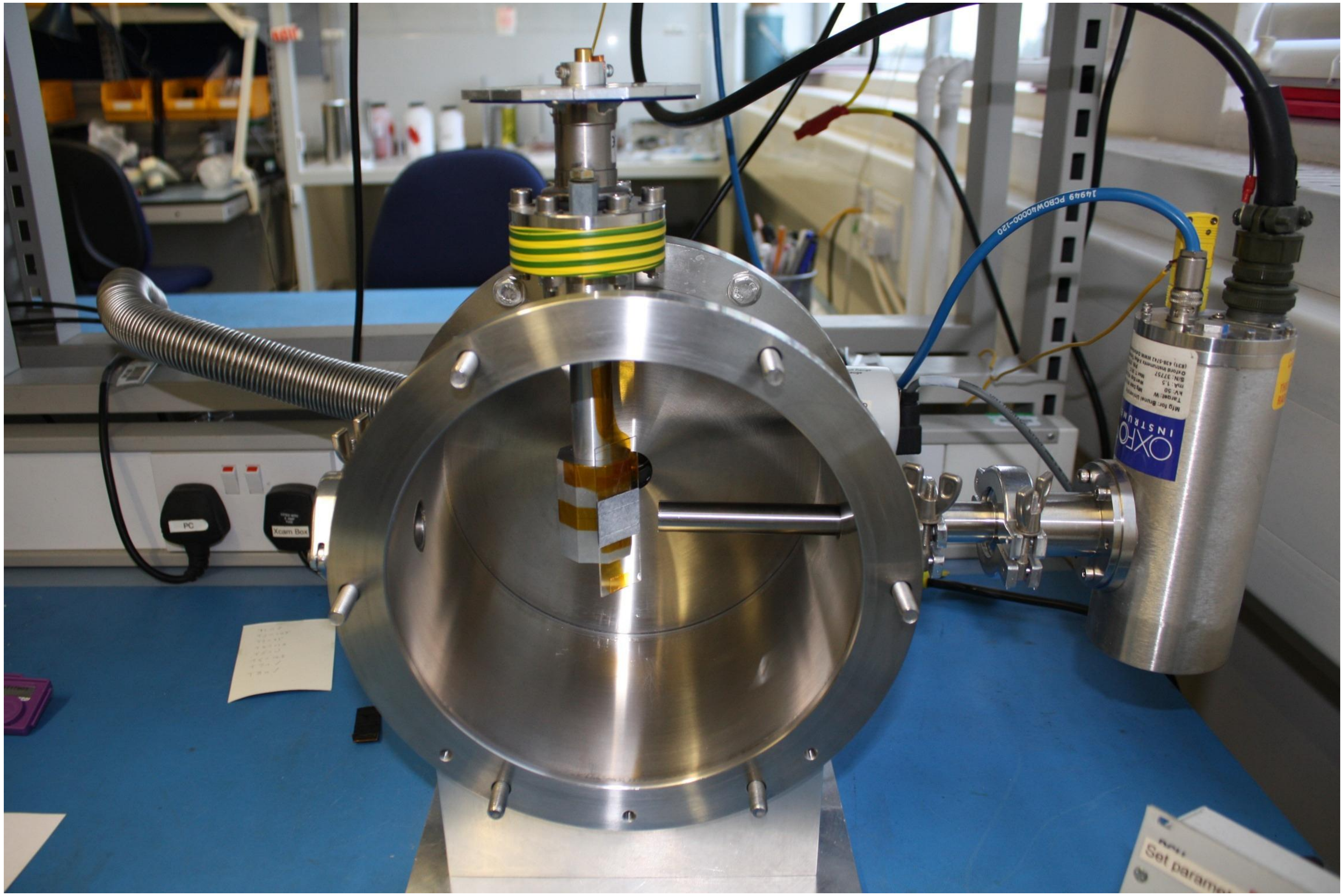




Brunel C1XS Test Facility



Moon Regolith

- Formed by the breaking up of rock and minerals by meteorite and micrometeorite impacts
- Due to the formation of the regolith, the different elements may not be contained in the same matrix and the elements could be in varying ratios in the soil
- Current abundance algorithms do not take this effect into account

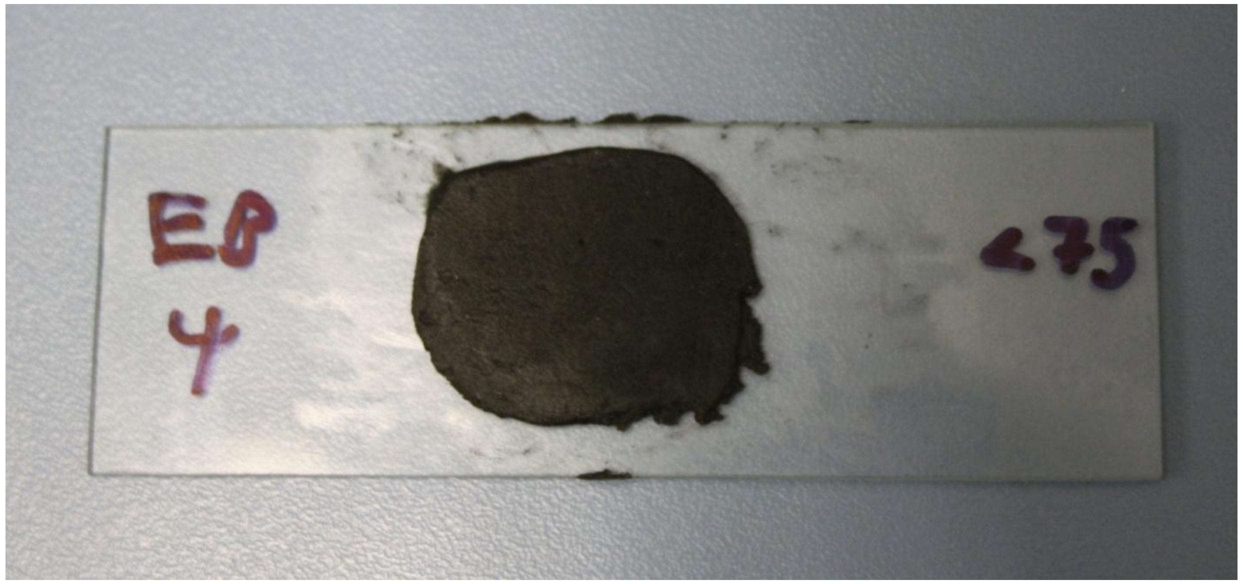
The 'RAL' Algorithm

- Software to make elemental abundance estimations from input spectrum and XRF data:

1. Model input spectrum is generated
2. A primary model spectrum is generated
3. Total number of counts in the Si peak is used to normalise the modeled spectrum to the XRF data
4. For most lunar soils the Si concentration lies within a small range
5. Si concentration can be fixed and all other elemental abundances are assessed against it

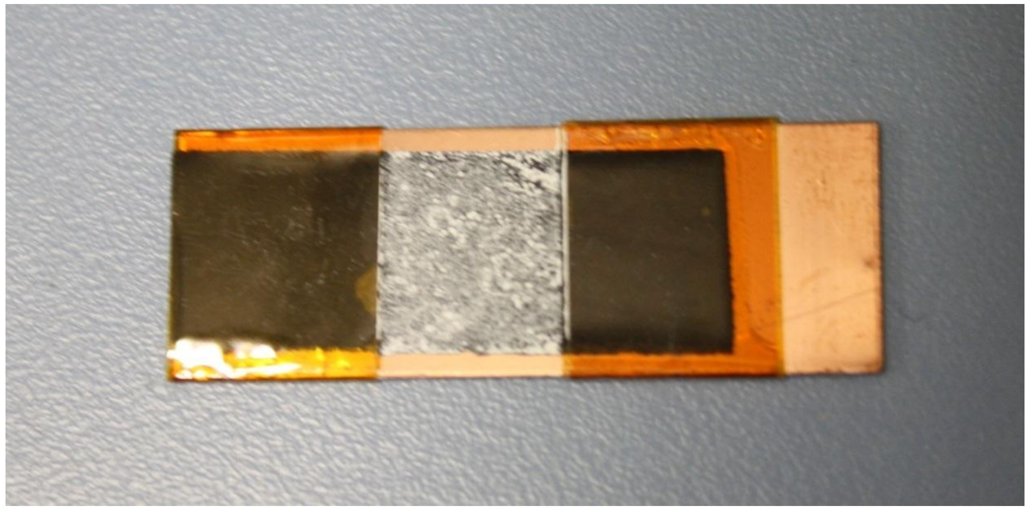
Previous Study Sample Preparation

Simple oxide mixture on copper plate with carbon tape

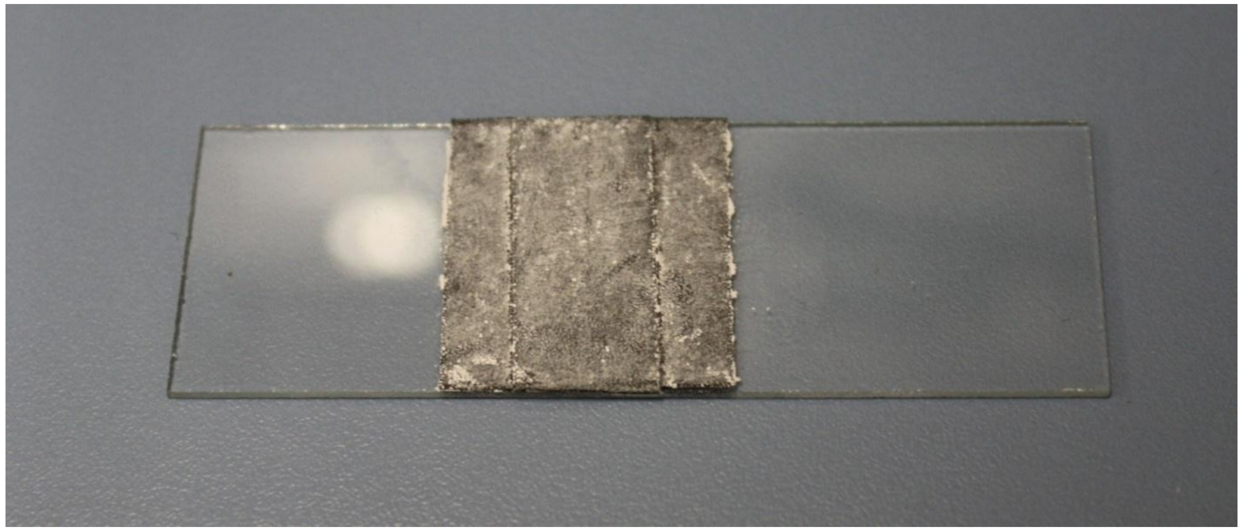


Glass slide and glue mixture

Current Study Sample Preparation



Copper plate with carbon tape



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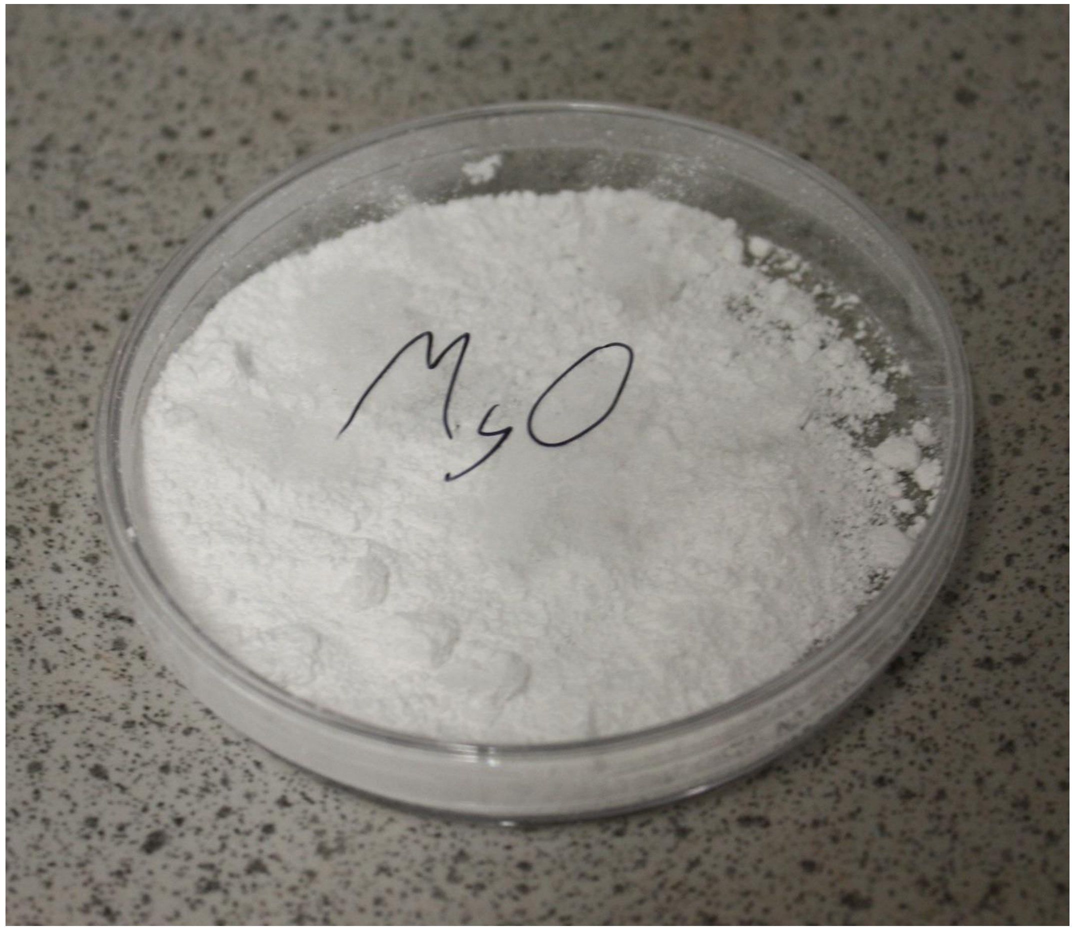
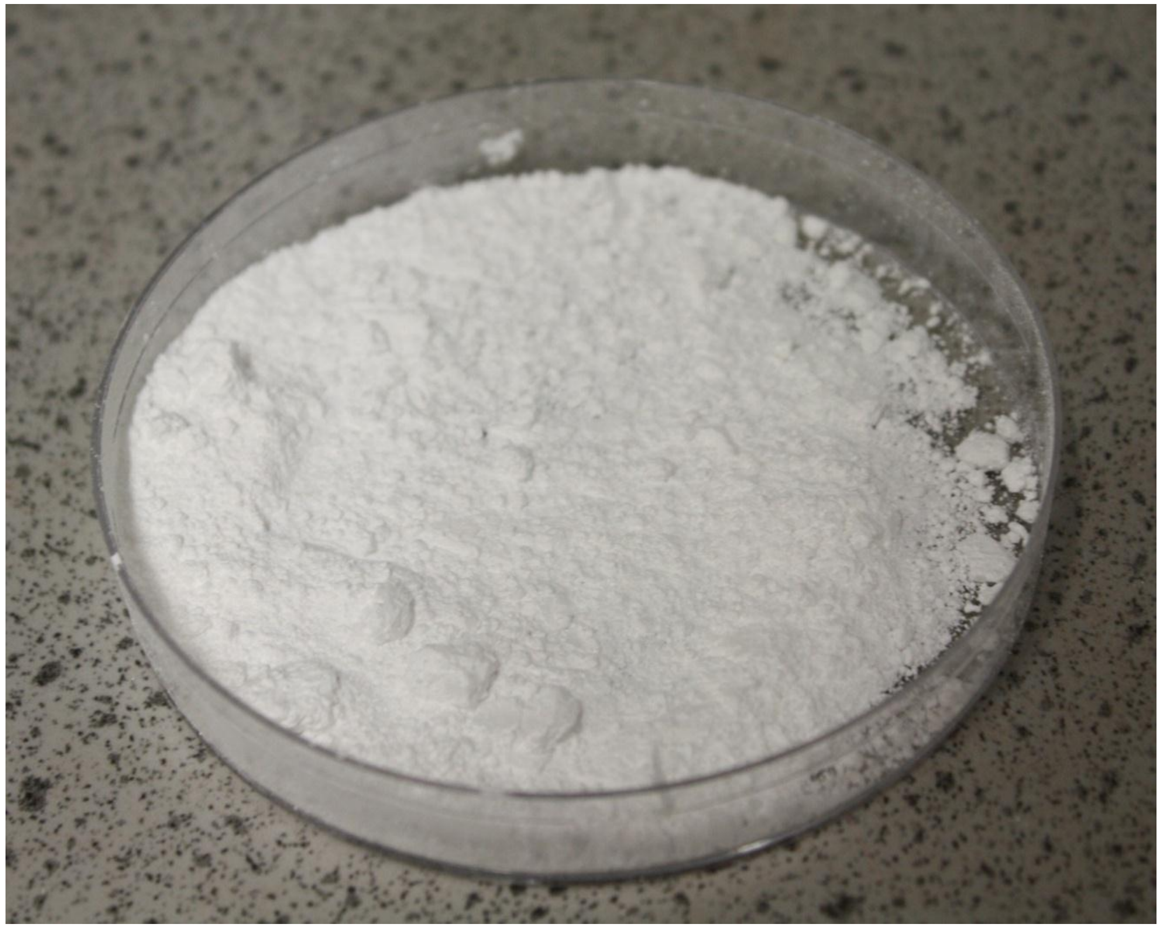
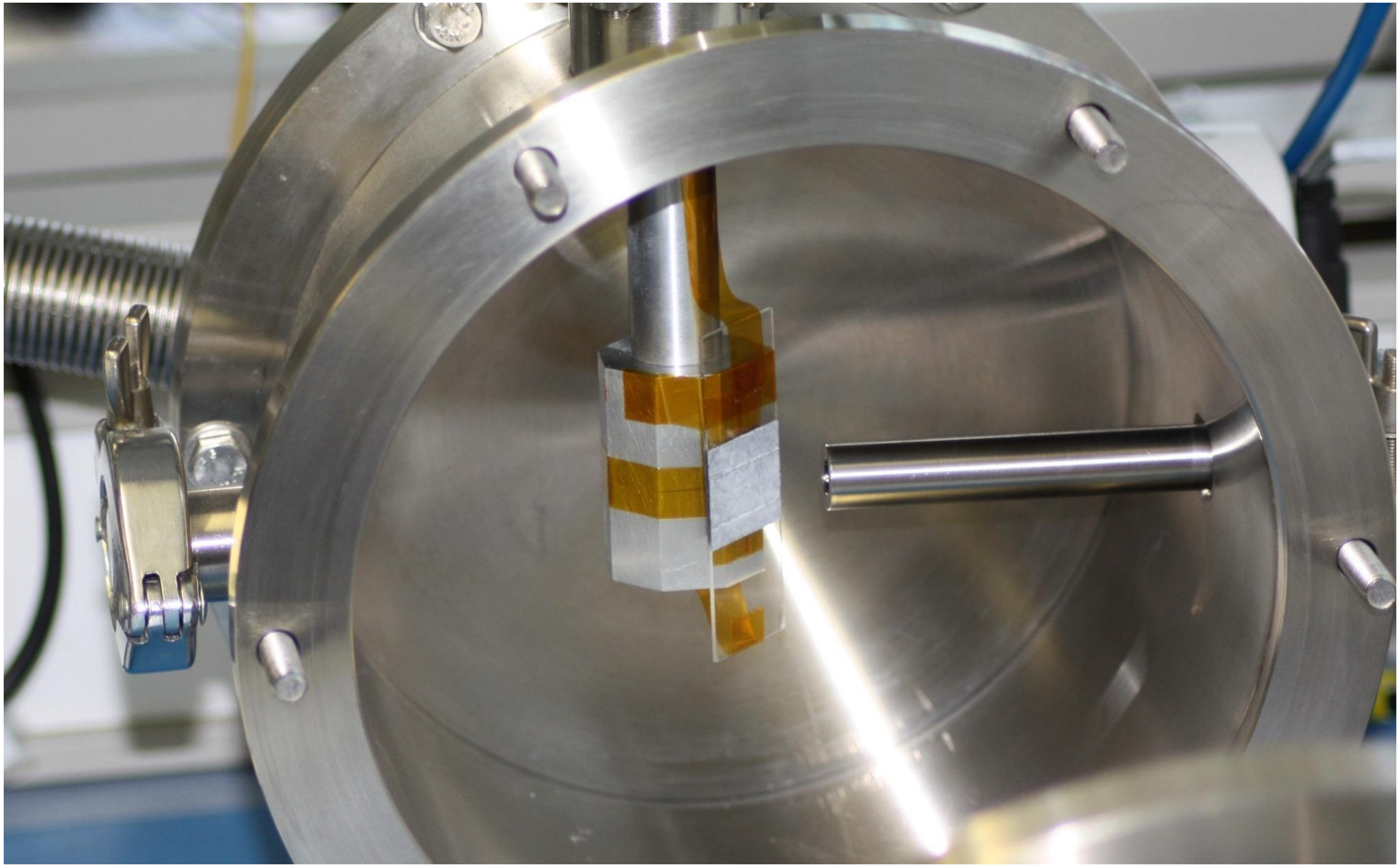


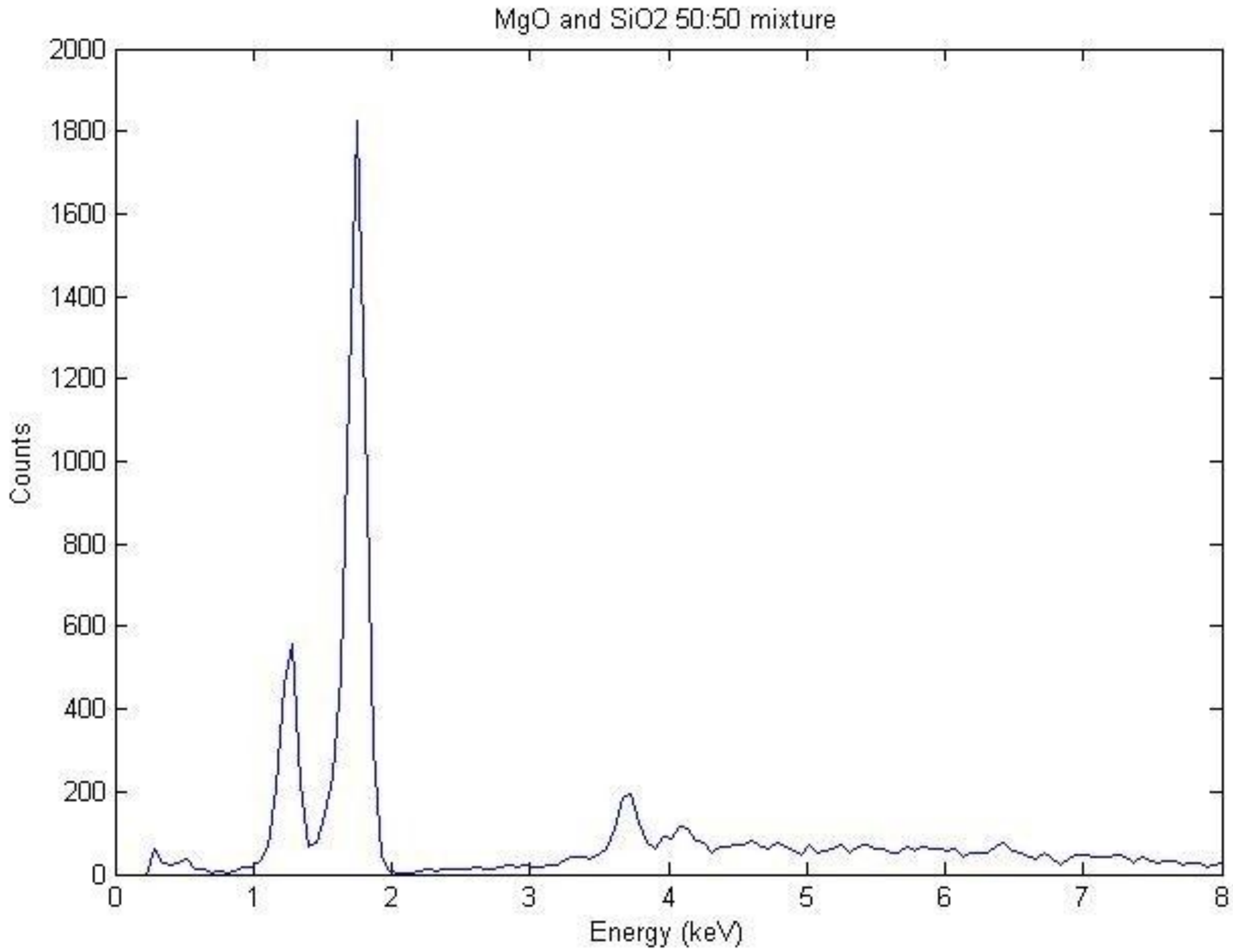


Grain size < 44 microns
Purity >99.9%

Brunel C1XS Test Facility



Simple Oxide Mixture Results



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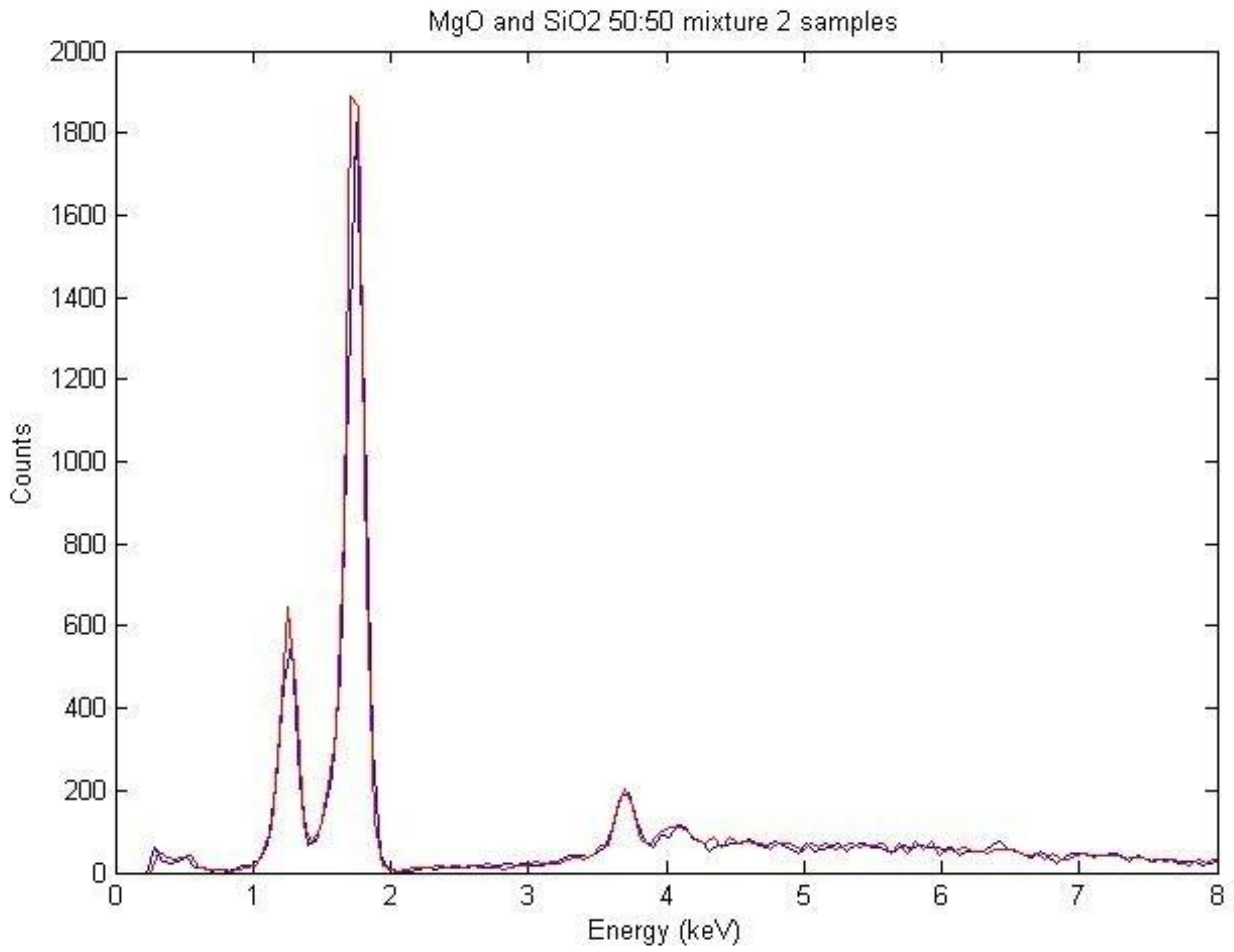

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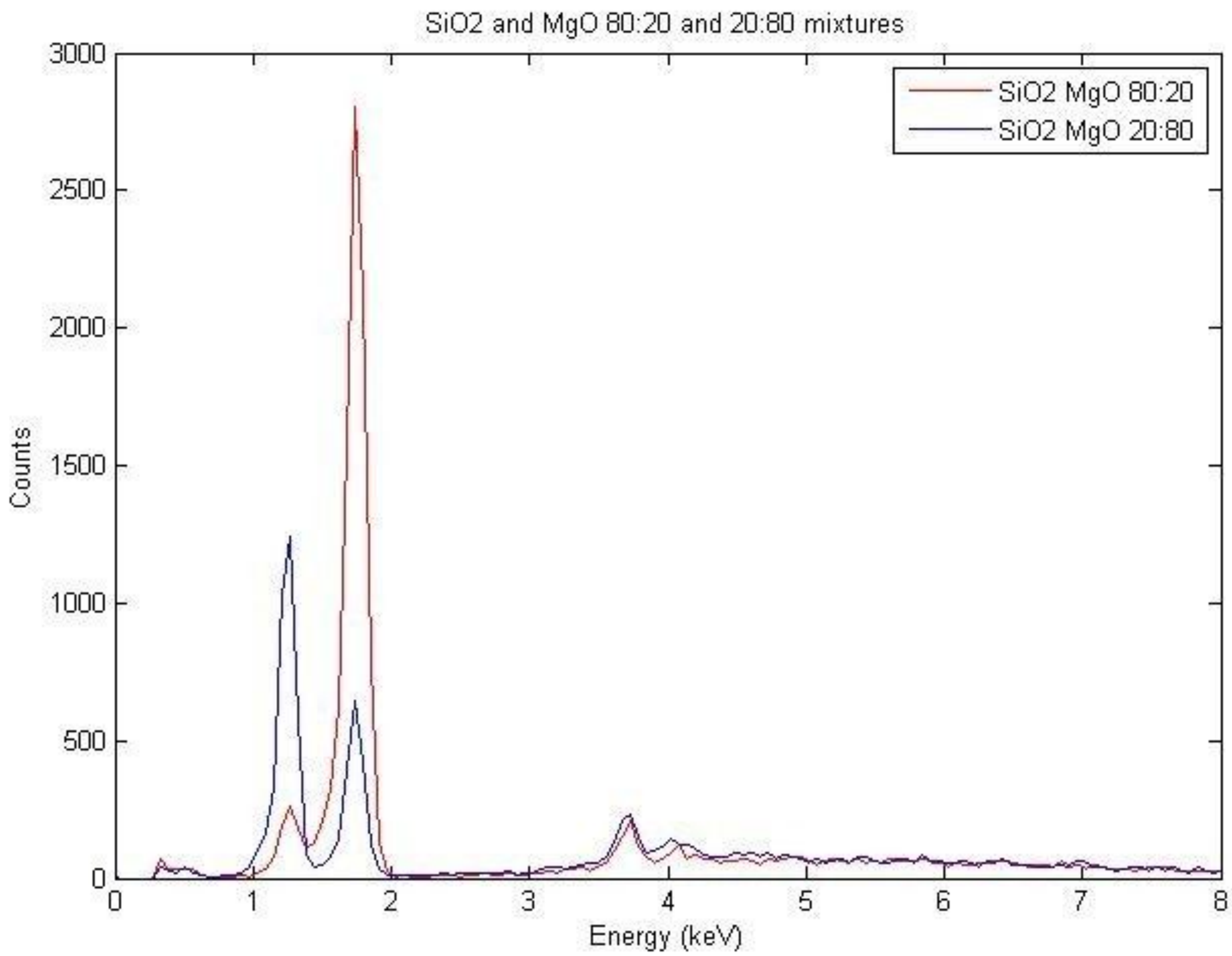
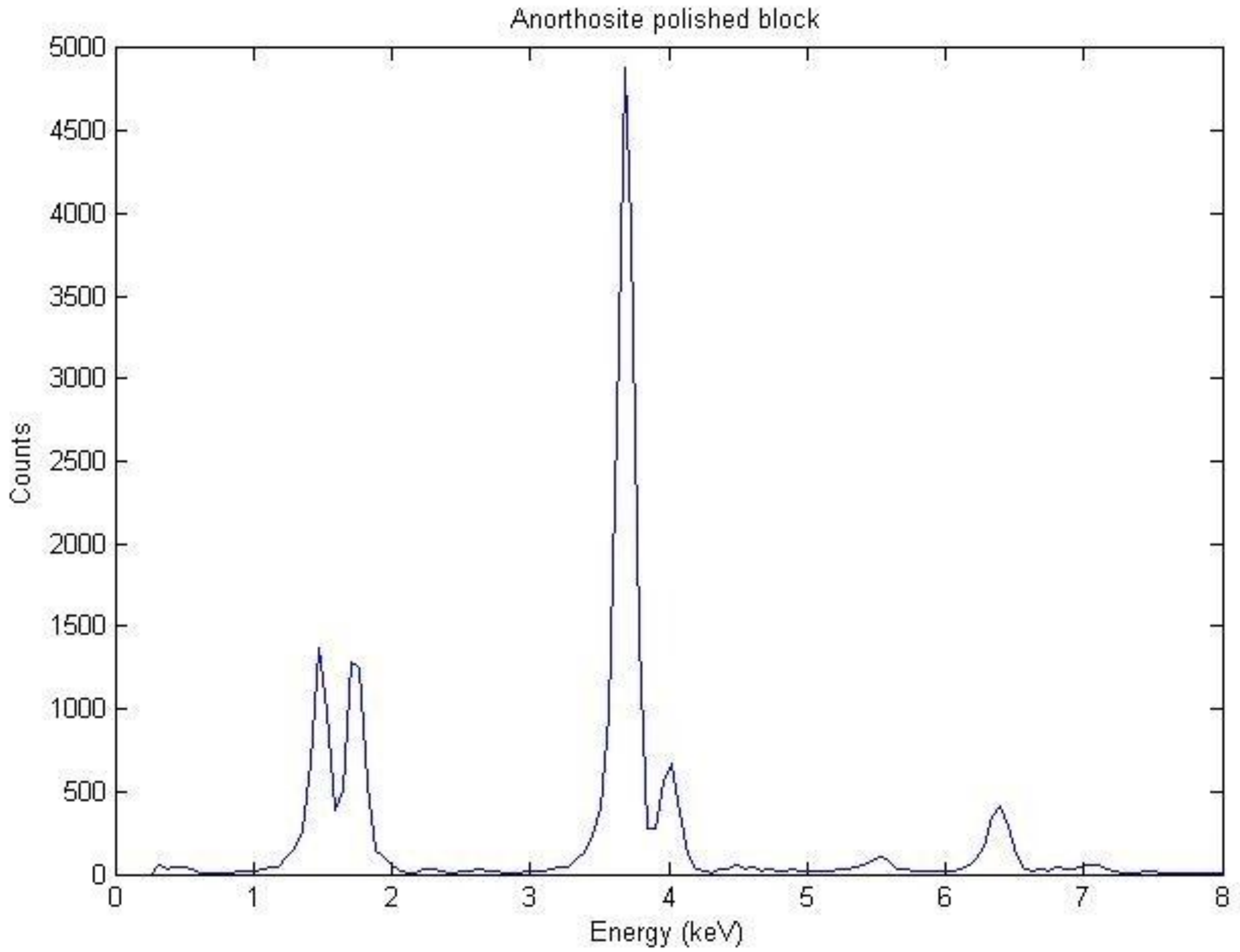
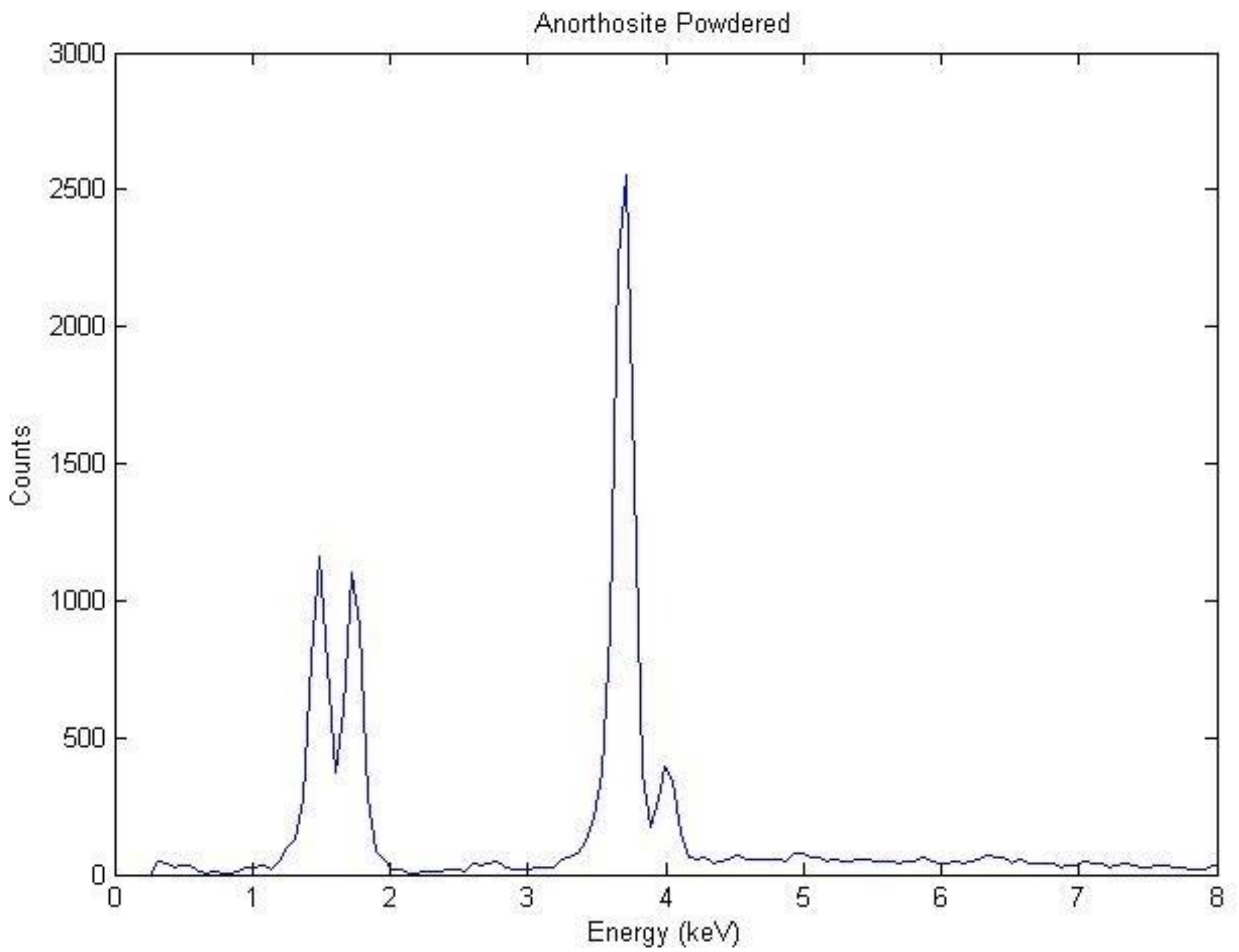


Anorthosite Sample Results



Anorthosite Sample Results



Study Results

- Kit and sample preparation techniques are giving repeatable reliable results

- Initial results show that the 'RAL' algorithm interprets mixtures of 50:50 ratio of SiO_2/MgO correctly, but as the ratio varies to 80:20 SiO_2/MgO, the algorithm gets the wrong answer

Conclusions

- Sample preparation is important!
- A wider range of ratios need to be analysed with the algorithm (or similar abundance algorithms) to understand fully how the algorithm works when presented with two different elements in different grain fractions when the grain populations have very different abundances

Further Work

- Improve sample preparation (use of SEM)
- Prepare different ratio samples, and repeat for Al_2O_3/SiO_2 and Fe_2O_3/SiO_2 mixtures
- Understand if it is necessary to take into consideration the 'matrix' effect when analysing XRF data

Questions?

Special thanks to Shoshana Weider and Bruce Swinyard for their continued input into my analysis

Science & Technology Facilities Council

Thank you for listening!