Radon-Induced ^{210}Po Surface Contamination and Cleaning Studies on Copper for AMoRE-II

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LOW RADIOACTIVITY TECHNIQUES 2026 WORKSHOP X

CENTER FOR UNDERGROUND PHYSICS ibs

Less Muon Better Flavor

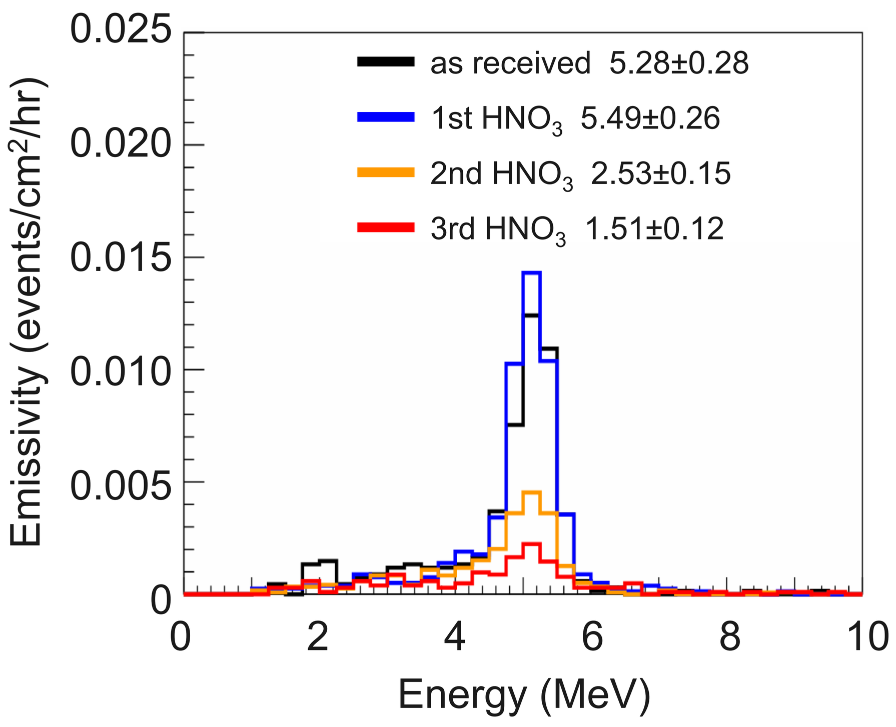
Highlights

- ^{222}Rn exposure equivalent to 49 days at Yemilab (~205 Bq/m^3) produces clear ^{210}Po ingrowth in the 5.3 MeV α peak:
  Counting: **1.96 ± 0.23,** ingrowth fit: **1.21 ± 0.17 ×10^{-2} count/hr/cm^2**
- Surface sanding reduced the surface α activity by a factor of ~3.

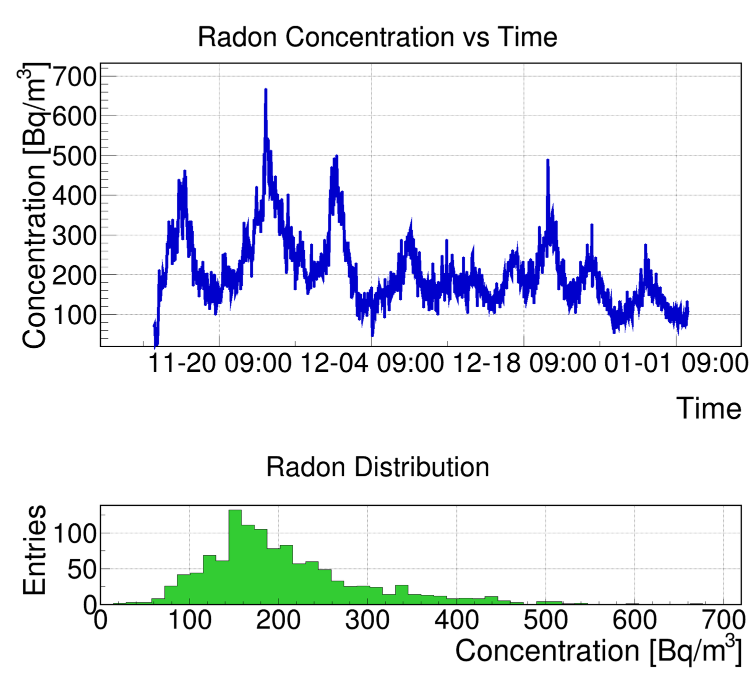
Motivation & sample environment

- AMoRE-II cans were stored underground at Yemilab for 2–3 years, where the air Rn level is 205.7 Bq/m³ — about 4× the ~50 Bq/m³ of a ground-level (non-cleanroom) laboratory area.
- Even stored in a ground-level laboratory, Lemer Pax Pb developed a high surface α rate within only 1–2 years. HNO_3 etching removed most of this activity, showing that the ²¹⁰Po is confined to a thin surface layer with a steep depth profile.
- The cans therefore received a staged cleaning and re-exposure sequence: Surface sanding → stored at Yemilab (49 d) → acid cleaning
- The Rn-induced surface α rate (²¹⁰Po) is measured at each stage for background study and as input to the AMoRE-II background model.

Lemer Pax Pb alpha spectrum

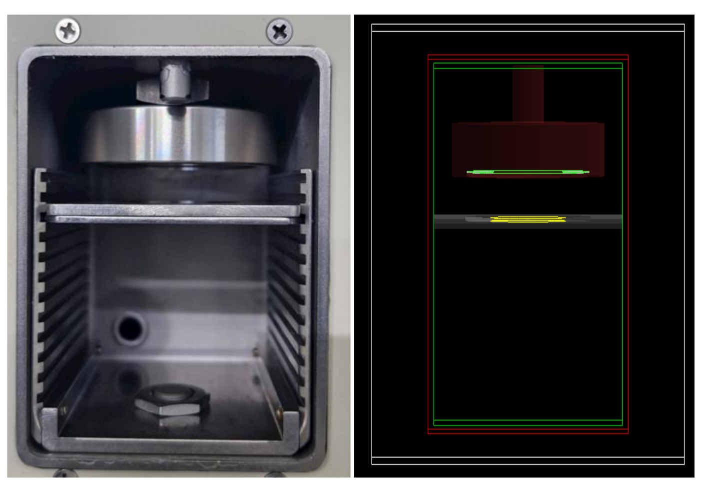


Yemilab hall ^{222}Rn

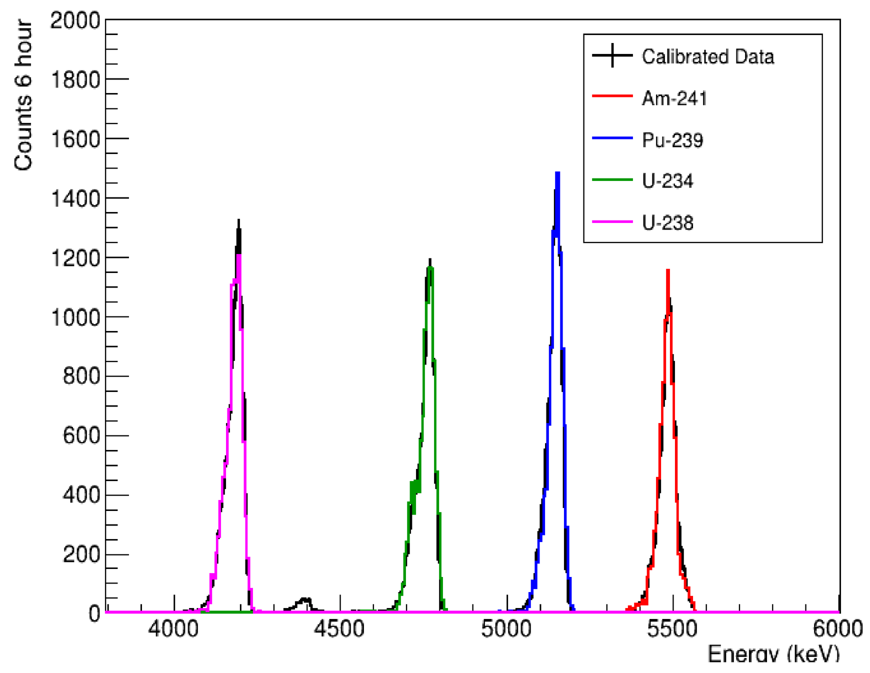


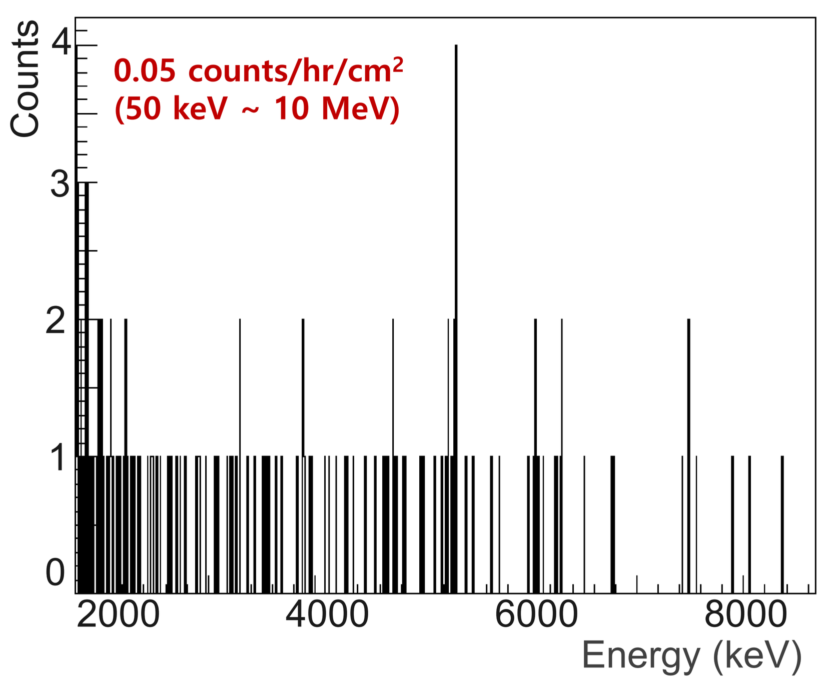
Setup: Si alpha counter

- 12 cm^2 Si semiconductor counter, ~50 keV – 10 MeV, background **0.05 counts/hr/cm^2**
- Geant4 model of the detector response: dead layer implemented.
- Detection efficiency from source data vs simulation (ongoing)



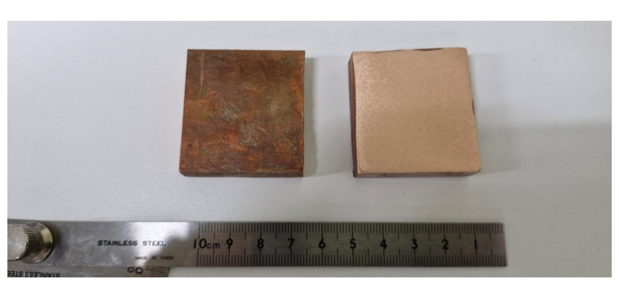
Detector housing

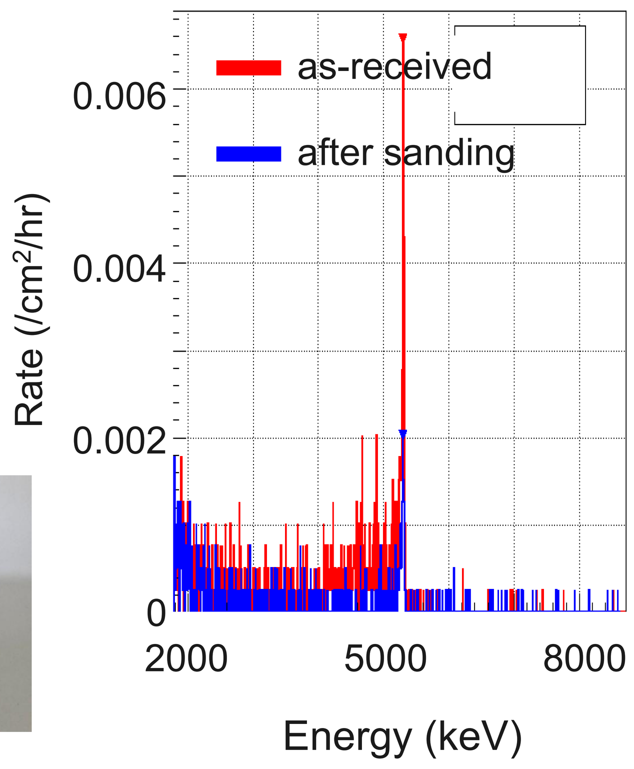




Sample preparation & surface sanding

- Cu 4×4 cm^2, two surface states:
  - as-received
  - after sanding
- 5.3 MeV: 0.66 → 0.21 ×10^{-2} counts/hr/cm^2



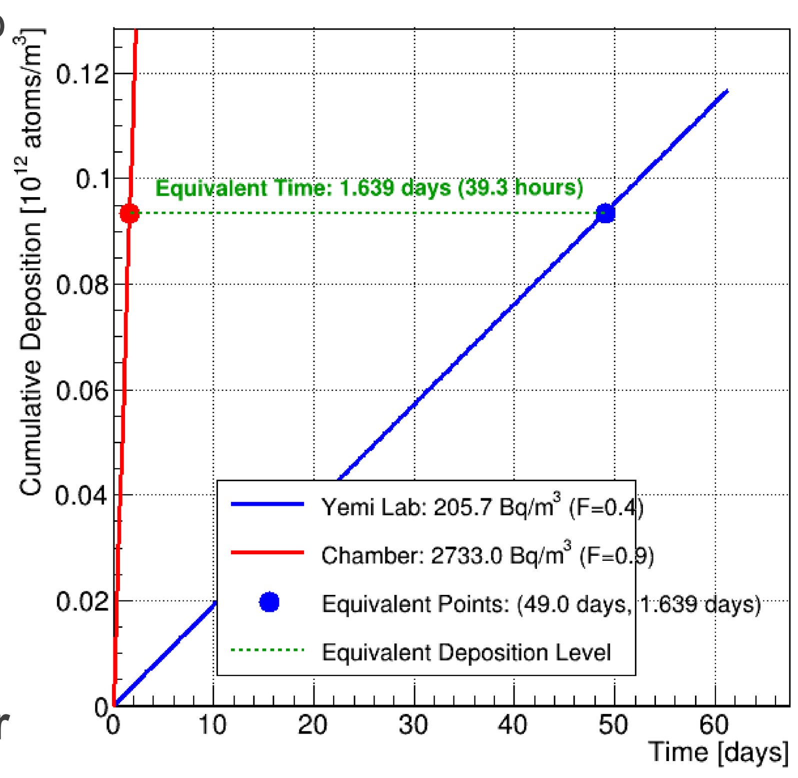


Radon exposure & data coverage

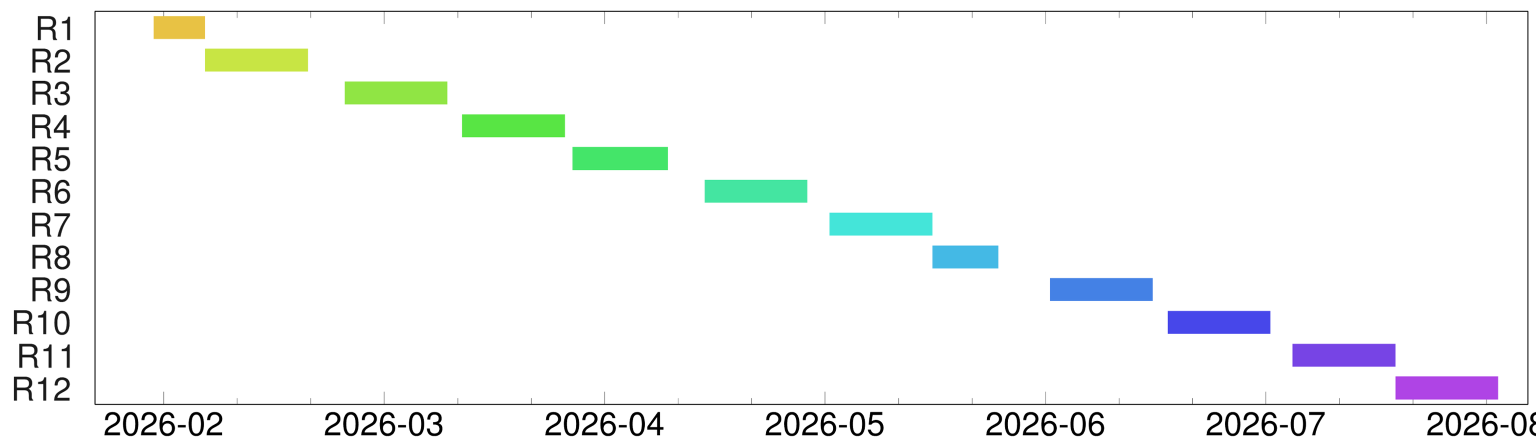
Sanded samples exposed to a ²²²Rn source in a sealed chamber, matching the ²¹⁸Po areal density of the underground-lab environment.

- ^{222}Rn(3.82 days)→^{218}Po(3.10 min) → ^{214}Pb
  - ^{222}Rn: Inert gas.
  - ^{218}Po: Positive Ion, capable of surface adsorption.
- ^{218}Po Cumulative Deposition
  - $Deposition = C_{eff} \times \lambda_{dep} \times t$
  - $C_{eff} = Cpo \times F$
    : Effective ^{218}Po concentration
  - $F = \frac{Actual\ 218Po\ concentration}{Theoretical\ equilibrium\ concentration}$
    - Underground lab: F = 0.4 *(ICRP 137)*
    - Sealed chamber: F = 0.9
  - Equivalent Time: **1.64 day in chamber**

Po-218 Cumulative Deposition vs Time



measurement continued to the **153-day live time (12 runs).**



Analysis method

Purpose

- How long until ^{210}Po saturates, and at what level

Count extraction

- Counting: Covell net-area rate
- Fitting: Gaussian + flat background (preliminary)

Saturation

- Full Bateman eq for the ^{210}Pb → ^{210}Bi → ^{210}Po

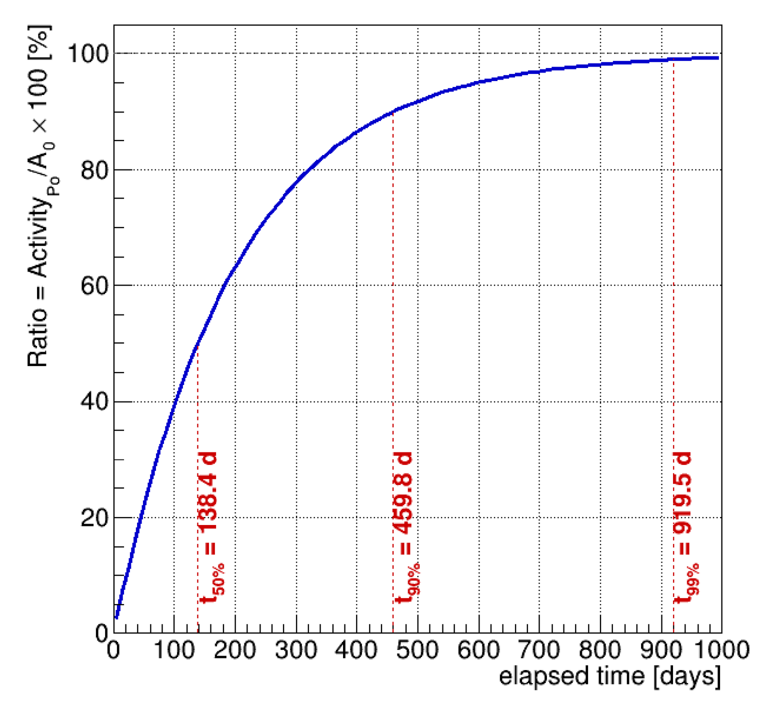
$$N_3(t) = \lambda_1 \lambda_2 N_1(0) \sum_{i=1}^{3} \frac{e^{-\lambda_i t}}{\prod_{j \neq i}(\lambda_j - \lambda_i)}$$

- For a quasi-constant ^{210}Pb source ($\lambda_1 t \ll 1$) and t ≫ 5 d this reduces to the per-run growth model:

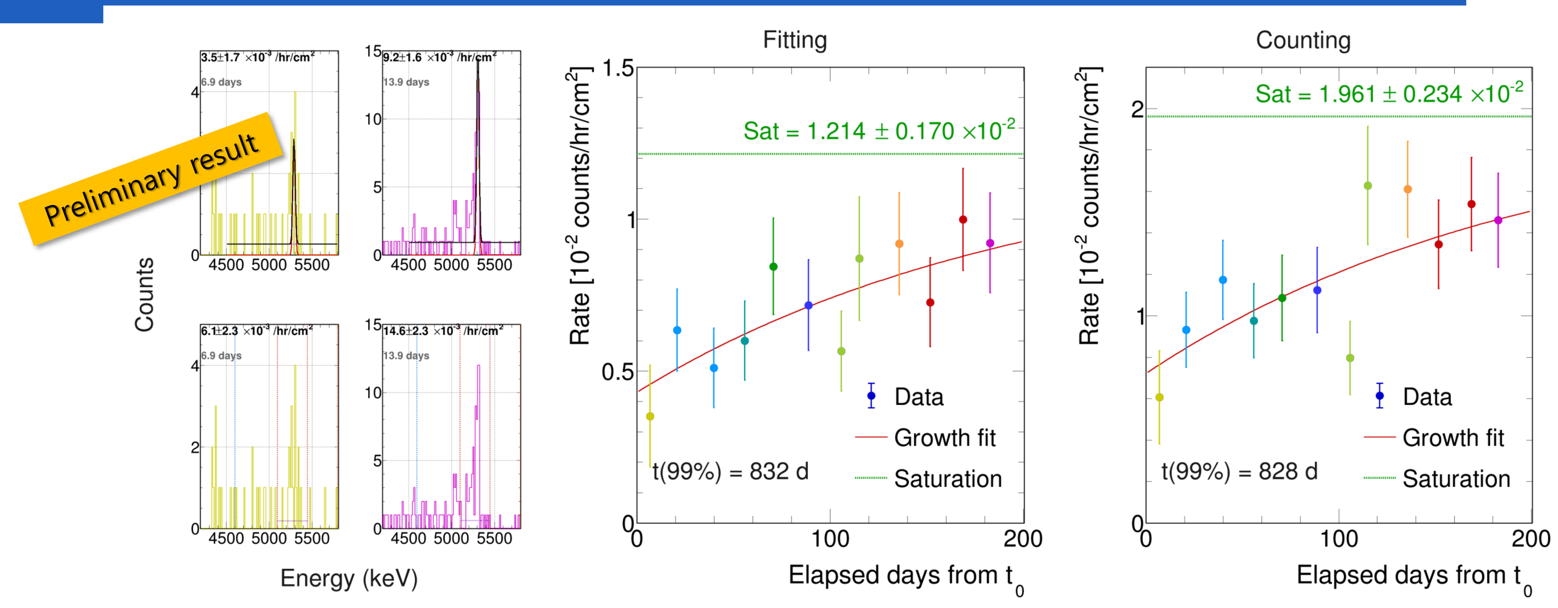
$$R(t) = A_{bg} + A_{new}(1 - e^{-\lambda t})$$

λ = ln 2 / 138.4 d, A_{bg} = pre existing ^{210}Po, A_{new} = saturated activity.
$T_{½}$ = 22.3 y (Pb), 5.01 d (Bi), 138.4 d (Po)

^{210}Po/^{210}Pb decay-rate ratio vs time



Results: saturation of Po-210



- Same timescale from both methods: **t_{99} ≈ 830 d** for the total rate (incl. pre-existing ^{210}Po)
- Levels 1.96 ± 0.23 vs 1.21 ± 0.17 ×10^{-2} counts/hr/cm^2: same order, not yet precise
- Detailed fit to follow — **preliminary**

Summary & next plan

Summary

- Staged sequence on Cu 4×4 cm^2 samples: surface sanding → chamber Rn exposure (≡ 49 d at Yemilab) → acid cleaning
- Sanding cut the 5.3 MeV rate **0.66** → **0.21 ×10^{-2} counts/hr/cm^2**; 153-day live time (12 runs, Feb–Aug 2026) then tracked the ^{210}Po ingrowth
- Both extractions agree on the timescale (**t_{99} ≈ 830 d**); levels 1.96 ± 0.23 vs 1.21 ± 0.17 ×10^{-2} — same order, detailed fit pending

Plan

- Simulate the α detection efficiency → absolute surface activity for the AMoRE-II background model
- Acid cleaning and re-measurement to quantify the removal efficiency (in progress):
  Citronox 24 h → Nitric acid 1.5 h → Oxalic acid 24 h → Nitric acid ~1 h → Oxalic acid 24 h
- Depth profile by step-by-step etching; extend the procedure to Pb and STS