Removal of long-lived ^{222}Rn daughters by electropolishing thin layers of stainless steel

Syracuse University: R.W. Schnee, M.A. Bowles, R. Bunker, K. McCabe, J. White

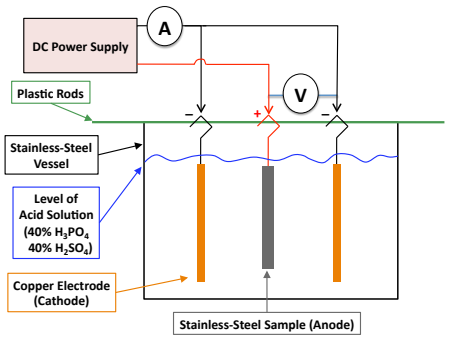
University of Minesota: P. Cushman, M. Pepin **University of South Dakota: V.E. Guiseppe**

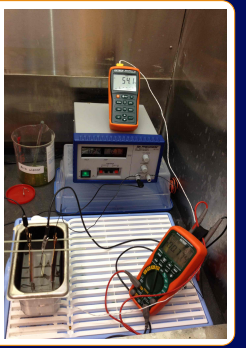
Long-lived alpha and beta emitters in the Rn-222 decay chain on detector surfaces may be the limiting background in many experiments attempting to detect dark matter or neutrinoless double beta decay. Removal of tens of microns of material via electropolishing has been shown to be effective at removing radon daughters implanted into material surfaces (Zuzel and Wójcik 2012). Some applications, however, require the removal of uniform and significantly smaller thicknesses. Here, we demonstrate that electropolishing < 1 micron from stainless steel plates efficiently reduces surface contamination. Examination of electropolished wires with a scanning electron microscope confirms that the thickness removed is reproducible and reasonably uniform. Together, these tests demonstrate the effectiveness of removal of radon daughters for a proposed low-radiation, multi-wire proportional chamber (the BetaCage), without compromising the screener's energy resolution. More generally, electropolishing thin layers of stainless steel may be an effective means of removing radon daughters without compromising precision-machined parts.

Sample Preparation

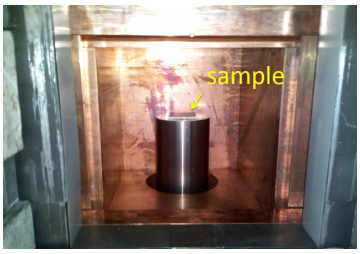
- 4 unpolished (mill finish) 316 stainless steel samples, 2" x 2" x 0.1875" thick
  - ~8.6 µm surface roughness (AFM)
- One 1.5" x 1.5" #2B finish in progress for dependence on surface roughness
  - ~0.4 µm surface roughness
- Exposed to 5.42 x 10^6 Bq m^{-3} day^{-1} at University of South Dakota
- Electropolished in small bath (see figure to right)
  - Thickness removed determined from precision scale (guarded against drifts by massing standard immediately before and after samples)
  - 4 nm/second on average
- Sample #1 counted in HPGe and alpha counter after electropolishing
- Sample #2 (control) counted in HPGe and alpha counter wo/electropolishing
- Other samples counted in alpha counter before and after every ~50 nm removed by electropolishing

Electropolishing Set-up





Detection Systems

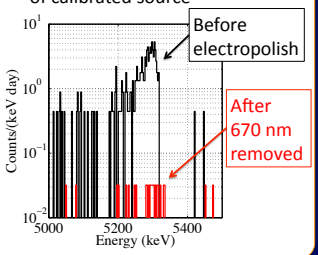


UMinn GOPHER n-type HPGe

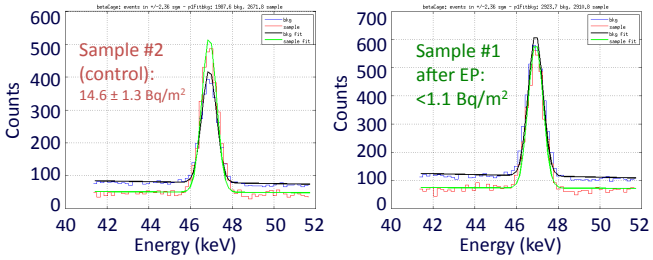
- 25% relative detection efficiency
- samples directly on 1.6 mm aluminum window
  - 36% efficiency for ^{210}Pb 46 keV x-ray emitted down

ORTEC alpha counter for ^{210}Po

- 1.6 ± 0.2 background events / day in ^{210}Po energy region
- 14% efficiency for these samples (geometrical), confirmed by rate of calibrated source

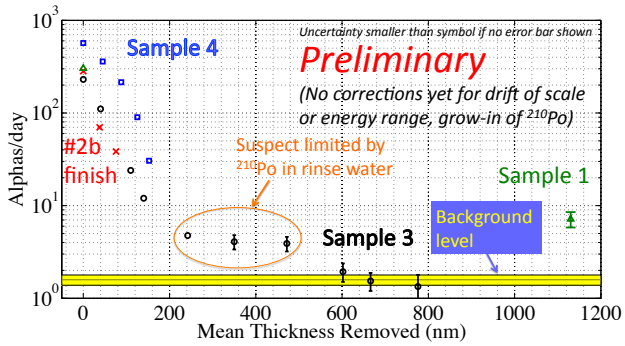


Results

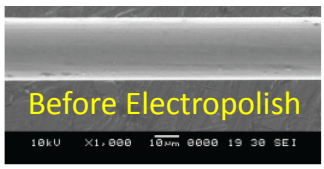


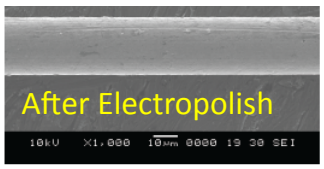
- Removal of 1.1 microns from Sample #1 reduced
  - ^{210}Pb rate from 13.5 ± 1.3 Bq/m² to <1.1 Bq/m²
    - reduction factor of >12
  - ^{210}Po rate from 11.5 ± 1.5 Bq/m² to 0.22 ± 0.05 Bq/m²
    - reduction factor of ~50

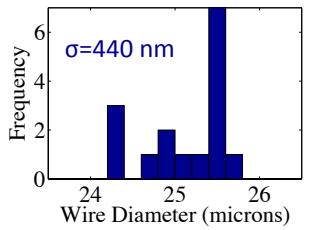
  (initial activity from alpha counting and calculations)
- Removal of 160 nm from samples reduced alpha rate by factor ~20
  - Roughly exponential profile
  - Rate of reduction with thickness removed shows some variation
- Reduction of ^{210}Po by > 100 (to level consistent with counter background) demonstrated by removing 660 nm
  - Reduction stalled at level of 5 alphas/day until improved technique
- Rate of "unexposed" steel sample ~2x higher than background rate

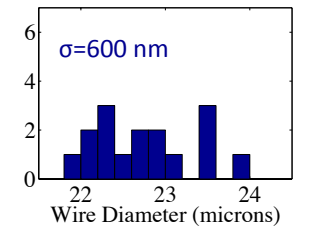


Uniformity of Electropolished Wires









- Electropolishing reduced diameter of SS fine wire by 2 microns per minute.
- Nonuniformity may be dominated by handling deforming wire to oval cross-section.
- Even for 2 microns removed, uniformity is sufficient to provide <10% gain variation, meeting BetaCage specification for gain uniformity.