Preparation of drop deposited sources in $4\pi$ absorbers for total decay energy spectrometry ($Q$ spectrometry)

Introduction

- **α** spectrometry with semiconductor detectors cannot quantify some actinides due to overlapping α peaks (e.g. $^{239}$Pu and $^{240}$Pu)
  - Measurements must be combined with other techniques
- **Q** spectrometry
  - **Advantages**
    - One peak per radionuclide at:
      $$E = E_{0} + E_{x} + E_{\text{recoil}} - E_{\text{rel}}$$
    - Minimize the overlap between peaks
    - One measurement can quantify all actinides
  - **Constraints and conditions:**
    - All radiation must be absorbed
    - Absorber sized to absorb all the radiation from the decay
    - All radiations must be converted to heat
    - Self absorption of the nuclear recoil deforms the peak and enlarges the resolution [1-2]
  - Very thin and homogeneous source deposit required

Source deposition techniques

- **Electro-deposition and electro-precipitation**
  - Very thin (nm scale) and homogeneous radioactive deposit
  - $Q$ spectrum with energy resolution of 1.25 keV was demonstrated [3]
  - Deposition yield depends on the element → Loss of activity traceability
  - More complex implementation required
- **Drop and dry deposition**
  - Thick, inhomogeneous and unreproducible deposit
  - Dispersion of rise time
  - Yield depends on the element
  - To keep the drop and dry deposition attractive, we are investigating more complex implementation required
  - Drop deposition on gold with latex pad [4]
  - Drop deposition on nanoporous gold [5]

Surface preparations for source deposition

- **Gold surface with latex pad [4]**
  - Latex particles of 70 nm electrosprayed on a Au disk of 12 mm diameter.
  - $^{239}$Pu radioactive solution dropped and dried using a micropipette.
  - The hydrophilic latex pad produces a homogeneous spreading and drying of the drop.
  - 1 mm$^2$ (~1 Bq) cut and enclosed between two 25 μm thick Au foils.
- **Nanoporous gold (NPAu)** prepared by dealloying AuAg [6]
  - Ag$_{90}$Au$_{10}$ (wt%) foil welded on half of the Au absorber.
  - Ag is dissolved by nitric acid → A NPAu layer remains on the half absorber.

- **MMC prototypes with $^{239}$Pu in 4π absorbers**
  - 4x Au absorber
  - Radioactive sample
  - AuEr sensor
  - Pick-up coil
  - Pulse area:
  - $^{239}$Pu: 9.7 ± 0.2 keV
  - $^{240}$Pu: 21.9 ± 0.4 keV
  - Relative uncertainties of 8.6% and 8% respectively

Q spectra and results

- **Absorber with source on latex pad**
  - Square mesh ($^{239}$Pu) 4 keBq/g
  - Dispersion of rise time and dependence of pulse height on rise time
  - Peak shape deviates from Bortel function + peak overlap → No quantification possible

- **Absorber with source in NPAu (embedded in 2x25 μm)**
  - Smaller dependence of pulse height on rise time
  - Bortel function peak shape
  - Resolution insufficient to separate $^{239}$Pu and $^{241}$Pu

- **Absorber with source in NPAu (embedded in 2x50 μm)**
  - No rise time dependence
  - Bortel function peak shape
  - Better resolution resolves partially $^{239}$Pu and $^{241}$Pu
  - Isotopic quantification possible

Further results are available in the references.

Conclusions and perspectives

- We successfully produced alternative surfaces on gold for source deposition
- A dependence of pulse height on rise time was observed and has been suppressed
- Precise Pu isotopic quantification is possible using drop deposition in NPAu
- Resolution is far from baseline resolution → must be understood and improved

References


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