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Preliminary research for estimating homogeneity of Ni-63 foil source by using peeled-off EBT3 film

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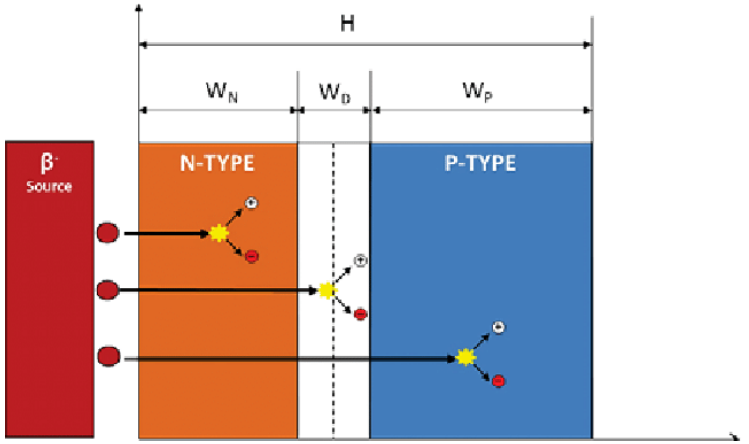
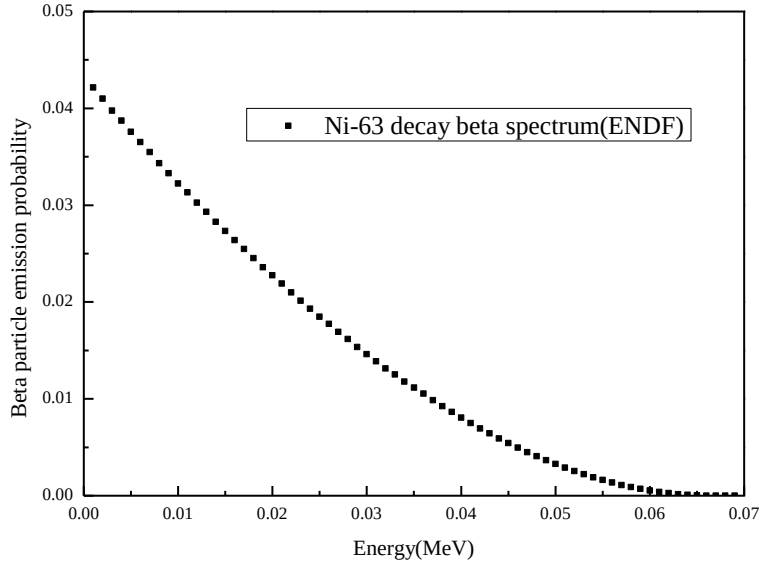
Introduction (1) : Nickel-63 for beta-voltaic battery

- Pure beta sources as used for radioisotope battery
  - To produce electricity using the energy of β^- isotope
  - Convert e^--h^+ hole pairs by the ionization of beta particles traversing a semiconductor
  - Activity of the Ni-63 source is related to the power of the battery.
  - Fabricating Ni-63 thin source using self-developed electroplating device

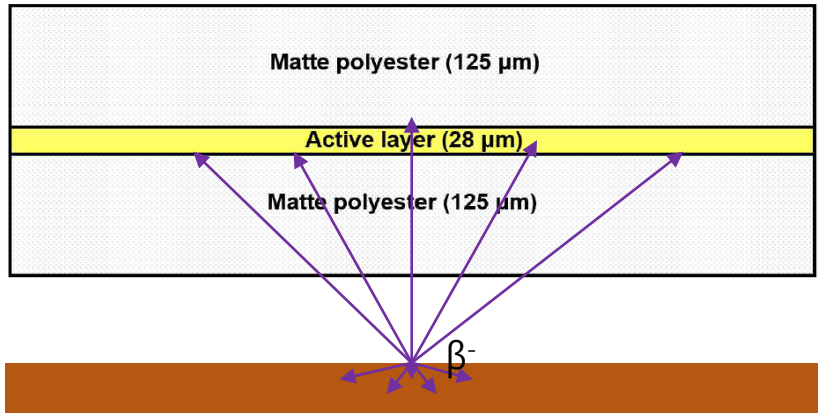


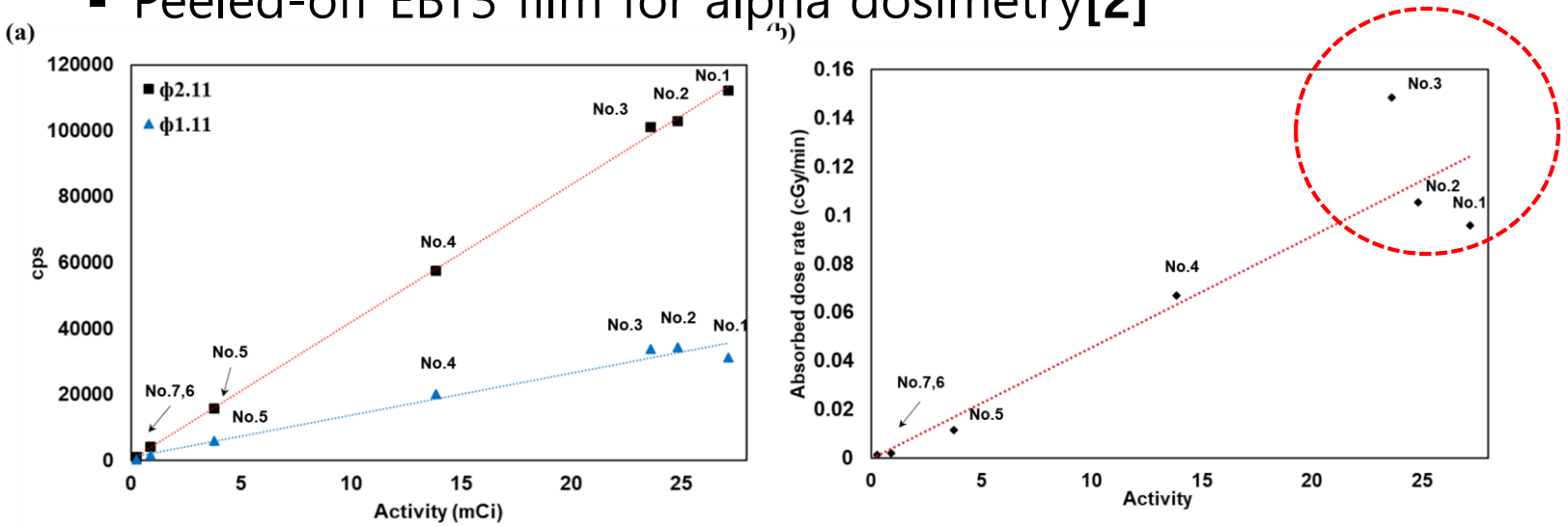
- Low energy beta spectrum
  - Liquid Scintillation Counter (LSC)
    - ➢ destructive method
    - ➢ taking time to measure
  - Film dosimetry using Gafchromic™ EBT3 film
    - ➢ inaccurate measurement

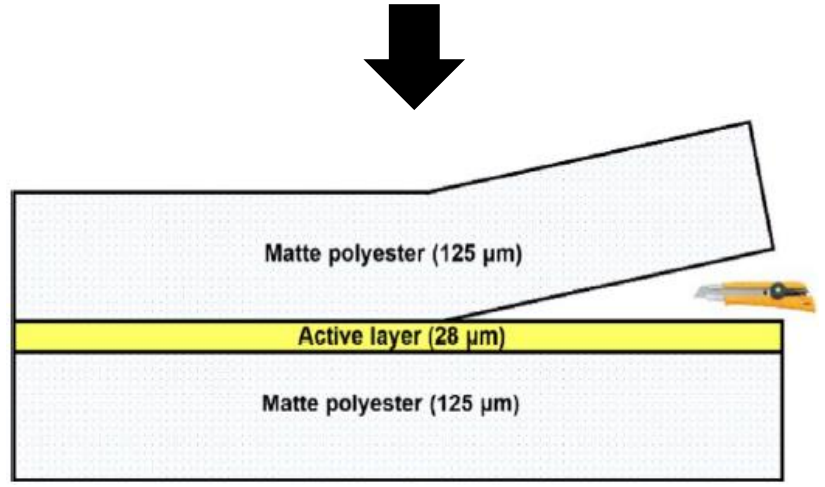


Introduction (2) : Dose measurement using peeled-off EBT3 film

- Measuring count rate at surface using the beta detector**[1]**
  - Count rate was proportional to the radioactivity
- EBT3 film dosimetry
  - Absorbed dose was not correlated well for highest activity sources.
  - Due to the characteristics of EBT3 film (proportional film)
- Peeled-off EBT3 film for alpha dosimetry**[2]**







[1] Ji, W. O. and Kim, J. B., Development of rapid beta detector using PIN diode to be used in quality control of Ni-63 beta-voltaic battery, Journal of Radioanlysis Nuclear Chemistry, Vol.330, pp.245-252, 2021.
[2] Lee, K. H., Shin, J. Y. and Kim, E. H., Measurement of activity distribution in an Am-241 disc source using peeled-off Gafchromic EBT3 films, Applied Radiation and Isotopes, Vol. 135, pp.192-200, 2018.

Method and Results (1) : Estimating beta range from Ni-63

- Range of beta in water**[3]**
  - low energy of Ni-63 (E_{max}=67 keV)
  - Max. range = 70 μm (10 μm at 18keV)

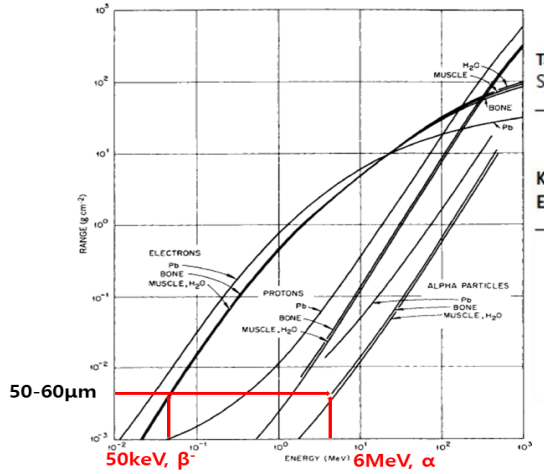
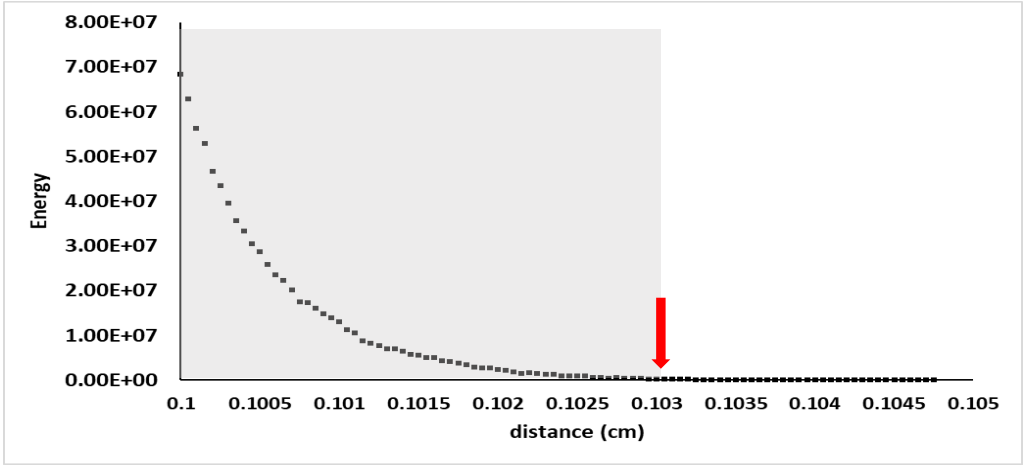


Table 6.1 Electron Collisonal, Radiative, and Total Mass Stopping Powers; Radiation Yield; and Range in Water

Kinetic Energy	β^2	$-\frac{1}{\rho}\left(\frac{dE}{dx}\right)^-_{col}$ (MeV cm^2 g^{-1})	$-\frac{1}{\rho}\left(\frac{dE}{dx}\right)^-_{rad}$ (MeV cm^2 g^{-1})	$-\frac{1}{\rho}\left(\frac{dE}{dx}\right)^-_{tot}$ (MeV cm^2 g^{-1})	Radiation Yield	Range (g cm^{-2})
1 keV	0.00390	126.	—	126.	—	5×10^{-6}
2	0.00778	77.5	—	77.5	—	2×10^{-5}
5	0.0193	42.6	—	42.6	—	8×10^{-5}
10	0.0380	23.2	—	23.2	0.0001	0.0002
25	0.0911	11.4	—	11.4	0.0002	0.0012
50	0.170	6.75	—	6.75	0.0004	0.0042
75	0.239	5.08	—	5.08	0.0006	0.0086

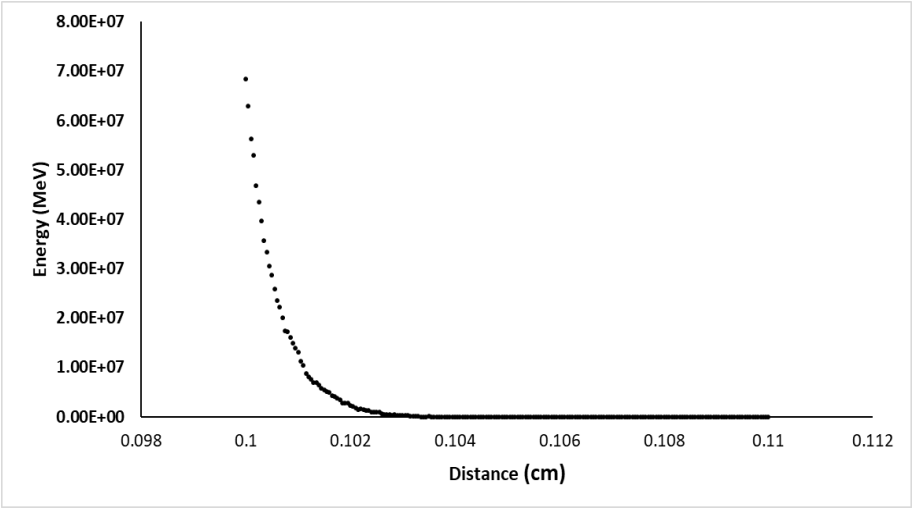
- MCNP simulation for original EBT3 film
  - Most beta particle are absorbed in 30 μm depth
  - Thickness of protective layer = 125 μm



[3] G. F. Knoll, Radiation detection and measurement 4th edition, John Wiley & Sons, New York, 1999.

Method and Results (2) : simulation for peeled-off EBT3 film

- Electron range and Energy deposition depth
  - shorter depth in AL than PL for atomic composition
    - ✓ AL (H:0.58 C:0.3 O:0.1,Cl, Br), ρ=1.2 g/cm^3
    - ✓ PL (H:0.36 C:0.45 O:0.18), ρ=1.35 g/cm^3
  - Most electrons are absorbed in AL and transfer energy in AL (28 μm)



- Dose estimation
  - 25 mCi Ni-63 source
  - 0.075 Gy in 95 hrs in previous research (with original EBT3 film)
  - MCNP simulation result : 0.093 Gy/s

Conclusions

- The simulation results showed that measurement of absorbed dose with peeled-off EBT3 film would be possible.

- Dose calibration for peeled-off EBT3 film will be conducted with electron microscope which 40 keV of electron is emitted.

- Peeled-off EBT3 film will be applied for estimating radioactivity of Ni-63 and homogeneity of the electroplated Ni-63 source.