Novel Tensioned Metastable Fluid Detector Technology for Multifarious-Multiscale Ionizing Radiation Sensing Applications

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The nuclear sciences world involves multiscale (10^{20}:1)/ multifarious challenges, which involve the need for low-cost, high-efficiency spectroscopic sensing of alpha-neutron-fission ionizing radiation signatures; for example, to identify U/Pu/Am/Rn/Po isotopes – which may be terrestrial-air-fluid borne, moving/ stationary, shielded-unshielded, etc., and which may need to be identified at ultra-trace (~10 nSv/h) levels, even under intense (>10^4 R/h) gamma-beta radiation fields (as in X-Ray cancer therapy CLINACs), which saturate most detectors. The novel tensioned metastable detector (TMFD) sensor technology[1] offers unique, cost-effective complement/alternative solutions for gaps in 80-year-old state-of-the-art systems. Not well known is that ordinary fluids (like solids), can indeed be tensioned and placed under negative (sub-vacuum) pressure (*Pneg*) states at desired ambient temperatures. The greater is the *Pneg*, the weaker become the intermolecular fluid bonds such that external stimuli) can provide the required excess energy to snap the bonds, leading to nano-to-macro space-time scale cavitation - manifesting as audible-visible-recordable detection events. In this regard, TMFD sensors are unique and offer significant enabling attributes and unique enabling features (summarized in Table 1). The talk will introduce TMFD developments and present results of studies comparing TMFDs vs state-of-art systems for: (1) H*10-neutron (spectroscopy weighted) radiation health dosimetry for continuous and pulsed source spectra; (2) Air and/or liquid-borne trace (10^{-3} Bq/mL) quantity, high (keV) resolution hybrid mass-alpha Rn/Po/U/Pu/Am isotope assay; (3) Directionality enabled active-passive special nuclear material interrogation; (4) ~100% (10,000 R/h) gamma-beta rejected alpha-neutron-fission signals -low cosmic intensity (nSv/h) to high (multi Sv/h) environments, covering ranges of interest in diverse fields.

Table 1 Why TMFDs for Nuclear Fuel Cycle?

- ✓ Thermal (eV) and Fast (1-100 MeV) Neutron Detection in single TMFD
  → Without need for moderators, nor pulse-shape discrimination
- ✓ Tunable on demand (10^{-3} - 80%) intrinsic neutron detection efficiency
- ✓ ~95-100 %+ intrinsic (alpha/fission) efficiency – incl. trace mBq/mL levels.
- ✓ ~1.4 keV energy resolution
- ✓ 100% gamma-beta-muon blind (to 15,000+ R/h fields)
- ✓ Real-time neutron-alpha spectroscopy (without need for peak shape fitting)
- ✓ On-Off within seconds to microseconds – pulse mode enabling
- ✓ 10^{-9}s event timing and multiplicity potential
- ✓ Directionality/source positioning with 1/2 TMFD units
- ✓ Air/fluid borne U/Am/Pu monitoring (100% Rn+progeny rejected)
- ✓ Rn+Po progeny (pCi/L) in air spectroscopy monitoring (< 2 min. air sampling)
- ✓ Active and Passive SNM Standoff Interrogation of stationary-moving SNMs
- ✓ Operation Space: Temperatures (0-50^{o}C); >95% RH; Shock Tolerant
- ✓ Low-cost sensing material (<< 0.1$/g)
- ✓ Open to Synergistic Collaborations

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References (Sample – Front Cover)

1. C. Harabagiu, N. Boyle, B. Archambault, D. DiPrete, R. P. Taleyarkhan, "High resolution Pu-230/240 mixture actinide spectroscopy using CTMFD technology," Royal Society Journal of Analytical Atomic Spectroscopy, Vol.37, No.2, 264-277, Feb.2022.