An Integrated Elemental and Isotopic Detector for Real-Time Molten Salt Monitoring

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ABSTRACT:

The development and commercialization of advanced nuclear reactors utilizing molten salts will require a real-time elemental monitoring molten salt detector for enabling material accountancy and improving the efficiency of salt fabrication and electrochemical separation. The remote operation of an elemental detector must be compatible with an extreme molten salt environment that includes high temperatures, irradiation, and corrosion. Constructing and validating a molten salt detector that can operate under these conditions and have a feasible path toward engineering scale deployment would be a significant step forward. The overarching goal of the proposed research is to advance the Plasma-Bubble Spectroscopy (PBS) method by developing two unique geometries that combine fiber optic collection with high voltage discharges, and then demonstrating their capabilities in realistic molten salt environments. To achieve this goal, our proposed detector will be applied to 3 scenarios that will test its Longevity, Limits, and Latency. The proposed research will advance a new technique that has recently undergone proof-of-concept feasibility studies, the results of which demonstrate the potential for isotopic discrimination of actinides as evidenced by the extremely narrow spectral linewidths (<40 pm). The proposed detectors feature a coaxial architecture that contains both plasma creation and optical readout within the same subassembly, thus reducing the design complexity and potential failure points. The complex line emission acquired over the entire visible spectrum for "real" salts will be analyzed using chemometric methods, which identify principal components for generating calibration models. First, the detector's robustness will be tested by long duration studies in uranium chloride salts (Longevity). Second, the detector sensitivity and discrimination (Limits) will be tested on complex salts from pyroprocessing equipment used to process irradiated MOX and LWR fuels. Third, the detector responsiveness (Latency) will be demonstrated in an evolving, flowing, thorium fluoride salt. The desired outcome of the proposal is to advance the PBS online salt monitoring platform to an engineering scale, where eventual industrial deployment would enable safeguards and enhance processing.