Taggants in Future Nuclear Fuels by Design as an Enabling Technology to Track Nuclear Materials

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ABSTRACT: The nuclear safety and security community has long been interested in identifying and quantifying nuclear material signatures to understand a material's provenance, use, and ultimate applications. The project aims to develop an innovative materials accounting and control technology by adopting an approach of "safeguard by design" during fuel fabrication to fill nuclear control technology gaps in tracking nuclear fuels and improve their safety and security attributes. The project is based on the concept of "taggants in fuels" that can greatly increase their intrinsic safeguardability for advanced nuclear fuel cycles. Particularly, we will incorporate taggants during fuel fabrication that could provide fingerprint signatures, allowing effectively tracing and tracking fresh and used fuels and improving the safety and security of nuclear fuels.

A critical issue to implement the "safeguard by design" concept for tagged fuels is to engage fuel vendors during the early stage of fuel manufacturing and understand the impacts of taggants on fuel performance. The proposed project will focus on ADOPT fuel and UN fuel, the near-term and long-term solutions of Westinghouse Electric Company for current LWRs, future fast reactors and micro reactors. Inclusion of these fuels is imperative since fast reactor fuels are likely to be considered for reprocessing which increases proliferation risks. By their very nature, microreactors will also be a large safety risk due to their widespread application in remote, unguarded locations and relatively small size and low burnup.

In this program, we propose to tag ADOPT and UN fuels to enhance their safeguardability and simultaneously improve fuel properties and performance. Specifically, we will focus on following aspects: (1) exploring homogeneous solid solution or heterogeneous micro-particle tagging strategies by a powder metallurgy process, and optimizing the best strategies for tagging the fuel; (2) incorporation of taggants into fuels by advanced manufacturing technologies and studying how they impact sintering, microstructure, and interaction with other dopants; (3) characterizing properties and performance of the tagged fuels; (4) verification and assessment of taggants by both non-destructive (e.g., imaging) and destructive chemical and isotopic analytic analysis; and (5) understanding the fate of taggants upon sintering, manufacturing, chemical reprocessing and neutron activation/irradiation.

The project will also engage with Westinghouse, the leading fuel manufacturer, to evaluate cost and fuel performance during the early stage of technology development to consider security and safeguard by design. The success of this project will serve as the cornerstone to the safeguard and security program to demonstrate its feasibility of using taggants in a wider range of fuel forms for current and future advanced nuclear reactors. The "taggants in fuels by design" concept offers a potentially effective strategy to trace, track and identify the lost and stolen nuclear fuels during the front end of fuel cycle and monitor mishandling/misuse of used fuels, e.g., during chemical reprocessing, and thus could potentially become an ultimate safety and security solution for nuclear fuels.

The educational goal of this NEUP program is to train graduate students and young scientists as a sustainable pipeline of workforce to national laboratories to support future safety and security needs for advanced fuel cycles. It is imperative to train the next generation workforce with the knowledge and expertise on the critical issue of safeguardability and non-proliferation resistance, an important goal of advance fuel cycle initiative. As such, the project is committed to enhancing energy equity and contributing to the Justice40 initiative by developing new control technologies, investing American workforce and engaging minority serving institutes or disadvantaged communities.