Beyond TRISO: Applications and Opportunities for Particle Fuels in New Reactor Systems

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Particle fuels have a long tradition of successful service in reactor applications when deployed in coated architectures. They are ubiquitous as 'TRISO' fuels for high temperature gas reactor concepts. The maturity of this concept has led to it being the primary fuel option for numerous commercial reactor designs, deployed as compacts, pebbles and other forms in both traditional and novel configurations.

However, particle fuels themselves have potential for reactor designs beyond the above. Broad interest in deployment of diverse reactor types and exploration of nontraditional manufacturing methods has prompted re-visitation of the possibilities that particle fuels may offer. Most applications of particle fuels begin with a sol-gel synthesis route. While mature and industrially deployable, the sol-gel fabrication method has known limitations with respect to attainable particle size, chemistry, and yield. Historically this was an accepted limitation in the possible particle fuel microstructure. Modern advanced and additive manufacturing methods are suited to specific particle sizes beyond the reach of traditional large scale fuel fabrication processes. Advancements to the sol-gel process including microfluidics and online diagnostics provide the opportunity to overcome these traditional limitations as well as enable new fabrication processes.

Optimization of fuel kernels/particles allows for design and optimization of final fuel forms beyond those historically associated with particle fuels. Recent years have seen advancements in the available particle fuel uranium density achieved by carbonitride and nitrides. Use of these compositions to produce particle fuel architectures realized through nontraditional coatings and matrices has been shown to broaden the available application space beyond gas cooled reactors. Particle fuel feedstocks can also be used to generate monolithic fuel forms to overcome limitations inherent to traditional processing with regard to dopant retention, inert secondary phases, or other features. Finally, pairing of particle fuels and advanced manufacturing methods will be discussed with respect to production of novel microstructures and fuel designs that have the potential to overcome the limitations of monolithic fuels without the inhibited uranium density provided by historic particle fuel concepts. The opportunities presented by these approaches and their current status will be summarized.