



**U.S. Department of Energy**

## Development of Innovative Accident Tolerant High Thermal Conductivity UO<sub>2</sub> Fuel Pellets with a Diamond Dopant

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### ABSTRACT

On-going research by the current team on addition of Silicon Carbide particle (SiC<sub>p</sub>), SiC Whiskers (SiC<sub>w</sub>) and Carbon Nano-tubes (CNT) to UO<sub>2</sub> have revealed significant improvements in thermal conductivity of these UO<sub>2</sub> composite pellets compared to pure UO<sub>2</sub>. An increase in thermal conductivity by almost 55% at 100°C and 62% at 900°C was measured in these UO<sub>2</sub> composites. These results have excited us to the potential benefit of a nano-particle diamond addition to the UO<sub>2</sub>, which we believe will have an even more positive effect on the UO<sub>2</sub> thermal conductivity (See Table 1). We believe that the addition of diamond nano-particles to the UO<sub>2</sub> will produce a pellet which will be resistant to not only high temperature but also radiation effects<sup>1,2</sup>, while providing an even higher thermal conductivity than that measured for the SiC additions. Diamond has a *sp*<sup>3</sup> structure and has been known to survive the radiation exposure quite satisfactorily. Diamond has been found to have a high durability in severe radiation environments. The thermal conductivity of natural diamond has been measured to be about 22 W/(cm•K) and is the highest of any known solid at room temperature, four times more than copper and seven times more than SiC. Because diamond has such high thermal conductance, it is already used in semiconductor systems to prevent silicon and other semiconducting materials from overheating. Therefore, in this proposal we propose to utilize its high thermal conductivity and radiation stability to produce an accident tolerant fuel pellet. Our preliminary cost estimates suggest that the diamond nano-particles will add one dollar to the cost of a pellet and \$150 to the cost of a rod. These costs are expected to go down with higher volume and more efficient processing methods. With the reduction in stored heat, a major loss of coolant accident (LOCA) will not produce an initial clad temperature sufficient to cause the zircaloy-water reaction, which produces heat and hydrogen to be a concern. The reduced thermal expansion, thermal cracking and fission gas releases are expected to produce a better performing, higher burnup and more accident tolerant fuel.

Fuel Type	Avg. Thermal Conductivity of Pellet (W/cm*K)	Fuel Centerline Temp (top of core-best case)	Fuel Centerline Temp (top of core- worst case)
UO <sub>2</sub>	.03	1781	1943
UO <sub>2</sub> +SiC	.04	1520	1682
UO <sub>2</sub> +Diamond	.06	1259	1421



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In the current proposed work, the research team will utilize the Spark Plasma Sintering process to sinter UO<sub>2</sub> powder mixed with nano-diamond particles of various sizes and at different volume fractions. The finished pellets will be evaluated for thermal, nuclear and mechanical properties and will be subjected to quasi-reactor conduction tests to ensure that the diamond benefits will survive reactor operation. The team has had extensive experience on a previous EPRI contract researching nano-diamond particles as an addition to the reactor coolant for improved plant thermal performance. An economic study of the benefit resulting from the higher discharge burnup expected with this fuel will be conducted.