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Grain size and phase purity characterization of U_3Si_2 fuel pellets

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Abstract. Characterization of U_3Si_2 fresh fuel pellets is important for quality assurance and validation of the finished product. Grain size measurement methods; phase identification methods, using scanning electron microscopes equipped with energy dispersive spectroscopy, and x-ray diffraction; and phase quantification methods, via image analysis, have been developed and implemented on U_3Si_2 pellet samples. A wide variety of samples were characterized that fall into 3 fabrication periods: 1.Representative pellets from an initial irradiation experiment, 2. Small scale batches that improved upon experience from the first period, and 3. Pellets fabricated at a slightly larger scale using optimized methods to enhance phase purity. The average grain size for pellets from the first period of fabrication was between 16 and 18 µm. The typical average grain size for pellets from the second period of fabrication was between 20 and 30 µm. In the third period of fabrication samples exhibited irregular grain growth with a bimodal grain size distribution consisting of coarsened grains (>80 µm in most samples) surrounded by the typical (20-30 µm) grain structure around the surface. Phases identified in the first period uranium silicide pellets included: U_3Si_2 as the main phase composing about 80 vol. %, Si rich phases (USi and U_5Si_4) composing about 13 vol. %, and UO_2 composing about 5 vol. %. U_3Si_2 pellet samples from the second period of fabrication had similar phases and phase quantities. Pellet batches from the third period of fabrication did not contain Si rich phases, and had between 1-5% UO_2: achieving U_3Si_2 phase purity between 95 vol. % and 98 vol. % U_3Si_2. The amount of UO_2 in sintered U_3Si_2 pellets is correlated to the length of time between U_3Si_2 powder fabrication and pellet formation. These measurements provide information necessary to optimize fabrication efforts and a baseline for future work on this fuel compound.

Keywords: U_3Si_2, grain size, phase purity.

1. Introduction

Optimization of light water reactor (LWR) fuel technology is fundamental to ensure continued economically competitive use of the existing fleet of commercial nuclear reactors. These reactors must be operated within the boundaries defined by existing fuel safety criteria, designed for UO_2 [1]. Zhou et al provides a comprehensive review of ten proposed enhanced thermal conductivity accident tolerant fuel systems [2]. As new fuel forms mature to the point of evaluation within a commercial reactor, confidence in characterization measurements and reliable characterization methods become critical. U_3Si_2 is being pursued as an optimized LWR fuel due to its higher/increasing thermal conductivity at elevated temperatures and its superior uranium loading when compared with UO_2.