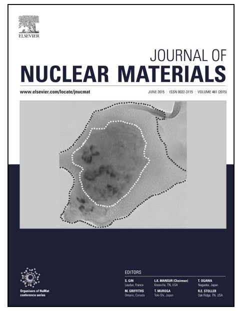
Accepted Manuscript



Early progress on additive manufacturing of nuclear fuel materials

A. Bergeron, J.B. Crigger

PII: S0022-3115(18)30678-0

DOI: 10.1016/j.jnucmat.2018.05.058

Reference: NUMA 50988

To appear in: *Journal of Nuclear Materials*

Received Date: 15 May 2018

Revised Date: 22 May 2018

Accepted Date: 25 May 2018

Short Communication: Early Progress on Additive Manufacturing of Nuclear Fuel Materials

A. Bergeron[a], J.B. Crigger[a]

[a]Canadian Nuclear Laboratories (CNL), Chalk River, Ontario, Canada

Abstract:

Additive manufacturing of thorium dioxide has been investigated using a commercially available stereolithography-based 3D printer and photopolymer resin. Three-dimensional thorium dioxide objects have been printed with good dimensional accuracy. High-density thorium dioxide parts (>90% theoretical density) were achieved by sintering the 3D-printed parts. Despite significant shrinkage, the overall shape of the objects was maintained during sintering with slight distortion. Additive manufacturing is seen to have potential application for advanced nuclear fuel concepts with complex geometries.

Main Body:

Advanced nuclear fuel concepts may offer better performance, increased safety margins, and greater accident tolerance. Often these concepts are based on advanced materials, have inhomogeneous structures, or have complex geometries. Many of these next generation fuels cannot be manufactured via the conventional processes applied to traditional ceramic nuclear fuels. Therefore, new methods are required to manufacture these fuels.

One such manufacturing method is additive manufacturing, e.g. 3D printing. The term additive manufacturing encompasses a wide variety of technologies used to build three-dimensional objects by adding layer upon layer of material. In 3D printing, models of an object are developed using computer-aided design software (CAD). Additional software is used to slice the model into individual layers of a defined height for printing and to develop the set of instructions required for a machine to deposit the material of each layer. These technologies have been applied to a variety of materials including plastics, metals, composites and ceramics [1]. New developments in additive manufacturing using nuclear fuel materials open the doors for innovative fuel designs with complex geometries that could not have otherwise been manufactured using conventional methods [2].

In this study, fabrication trials of thorium dioxide objects using stereolithography at Canadian Nuclear Laboratories (CNL) are reported. Thorium dioxide was chosen as the first fuel material to print (as opposed to the more commonly employed uranium dioxide) due to its similar optical properties to materials such as alumina and zirconia, which have been fabricated using similar stereolithography-based methods [3]. For example, the refractive index for ThO_2 is 2.20 (n_α) [4], and those of ZrO_2 are 2.13 (n_α), 2.19 (n_β) and 2.20 (n_γ) [4].

Stereolithography uses an ultraviolet laser to selectively polymerize a photosensitive liquid resin [5]. A build platform is lowered into a vat of resin, and the laser traces the design of each layer of the object through a window at the bottom of the vat. The first layer adheres to the build platform and each successive layer adheres to the previous one as the build platform indexes. A schematic for the process is provided in Figure 1.