Uranium Nitride Corrosion

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Abstract

Abstract stuff

1. Introduction

Uranium nitride (UN) is considered a prospective fuel for both light water reactors (LWRs) and Generation IV reactors [1, 2]. The higher fissile density of UN as compared to uranium dioxide benefits fast reactors with their lower neutron cross section [3]. This higher actinide density additionally benefits LWRs because UN pellets can remain in the reactor longer, leading to longer time between shut downs, and reducing money lost [4]. For all reactor types, the high thermal conductivity and high melting temperature make UN an optimal material to resist accidents [4].

While nuclear power initially developed uranium dioxide for the fuel pellet, the call for accident tolerant fuels (ATF) after Fukushima has drawn attention back to nitrides [5]. However, ATF materials must maintain current operational standards as well as improve safety [6]. Despite the beneficial properties of UN, it is unstable the presence of steam or even air [5, 7, 4]. In the event of cladding failure in a LWR, the pellet will come into contact with steam. As UN degrades, fission products will be released from the fuel matrix, free to interact with the containment structure.

In the case of Generation IV reactors, most designs use alternative coolants. However, the instability of UN in air hinders fabrication into a fuel pellet [4]. Short of solving UN corrosion at high temperatures and pressures for LWRs, corrosion in air must be mitigated for use as a Generation IV fuel.

To assess the current state of UN corrosion research, this review examines six studies from within the past decade. The first two studies work to better understand UN oxidation in the presence of air [5] and steam [7]. Next, Lu et al. [8] and Lopes et al. [4] each investigated a method to mitigate UN corrosion: nitriding and introduction of an intermetallic phase, respectively. The last two studies use computational modeling to probe the atomistic initiation of UN corrosion, studying oxygen [10] and water [9] at UN surfaces.

2. Review

To better understand uranium nitride corrosion, Jolkkonen et al. [7] and Johnson et al. [5] have analyzed UN subjected to steam or air.

Lu et al. [8] and Lopes et al. [4] each investigated a method to mitigate UN corrosion.

Density functional theory has been used in several studies to probe the atomistic UN corrosion mechanism, notably by groups Bo et al. [9] and Bocharov et al. [10].

3. Discussion

Arkush and Liu report NO while Jolkonnen does not - environment? Combination of nitriding, adding dopants, intermetallics Nitriding reduces interactiong at room temperature, however at higher temperature higher stoichiometric UN decays to UN. Add intermetallics for ease of fabrication, nitride for room temp handling

Bo et al. [9] used DFT towards determining the initiating of UN corrosion, but while they report optimally water species and adsorption sites, this does little to reveal a reaction mechanism like (1).

Computational studies at odds with experiment: experiment changes starting conditions, comp changes type of study

	Starting Material	Temperature	Pressure
Jolkkonen et al. [7]	UN pellets (77 - 97%TD)	400 - 425 °C	0.05 MPa
Johnson et al. [5]	UN powder (≈20 mg)	800 °C	not reported
Lu et al. [8]	UN films	AFG	UHV
Lopes et al. [4]	UN pellets (95 - 99 % TD)	300 °C	9 MPa

4. Summary

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