# Critical Heat Flux Studies for Innovative Accident Tolerant Fuel Cladding Surfaces

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**ABSTRACT:**

In reaction to the Fukushima Daiichi accident, efforts are underway by the DOE and industry to develop fuel cladding that is more oxidation resistant and hence more accident tolerant than the presently used zirconium alloys (Zr-alloys). Two accident tolerant fuel (ATF) cladding strategies are being pursued – a long-term approach involving the replacement of Zr-alloys with other cladding materials such as SiC-$SiC_f$ ($SiC_f$ stands for SiC fiber) composite and FeCrAl, and a near-term approach that involves coating commercial Zr-alloy cladding material with oxidation-resistant materials. As a part of the ATF development efforts, it is important to understand the role of the surface characteristics of these ATF cladding designs on heat-transfer behavior. In this regard, the critical heat flux (CHF) phenomenon is an important metric as it represents the thermal limit of the high heat transfer rates during boiling and is an important figure of merit defining LWR safety margins.

In the proposed research, CHF phenomenon and physics of the boiling behavior will be investigated for various ATF cladding material concepts that are at the forefront of consideration by DOE and industry. These will include materials being considered as structural replacements for Zr-alloys, namely, SiC-$SiC_f$ composite and FeCrAl. The surface coating approaches being developed at the University of Wisconsin will also be tested. These will include Cr and FeCrAl coatings deposited on a Zr-alloy by the powder spray process, and coatings deposited by the physical vapor deposition (PVD) process. Both pool boiling and quench experiments will be performed to generate key data that can be used to screen and compare new ATF materials to the presently used Zr -alloys. This will expand the knowledge-base on the interrelationships between CHF physics and materials' surface characteristics. To quantify these importance of materials' surface characteristics on CHF and boiling behavior, a suite of materials analysis techniques including, optical measurement for contact angles, profilometry, atomic force microscopy, and electron microscopy will be used to characterize the surfaces in order to effectively correlate materials' surface characteristics to CHF and boiling behavior. Additionally, the thermal properties of the ATF cladding materials will be measured and correlated to CHF data. Experiments will be performed using various surface roughnesses as well as for the as-received samples and samples oxidized in prototypical water autoclave conditions. With this basic understanding, the next task is to conduct reactor prototypical tests under flowing pressurized water conditions at the facilities of our industrial partner, Westinghouse. These experiments will be important as actual heater rods clad will undergo prototypic testing at PWR flows, pressures and temperatures. This prototypic test data will then be used to model boiling behavior for various ATF cladding materials using computer codes such as TRACE and COBRA-TF.