Fabrication of massive crack-free delta-phase zirconium hydride for high-performance moderator application

Xunxiang Hu* and Kurt Terrani

Oak Ridge National Laboratory, Oak Ridge, TN 37831

*hux1@ornl.gov

Abstract:

The use of zirconium hydride (ZrH_x) as a high-performance moderator in advanced reactors has strong precedent. Examples include the Systems Nuclear Auxiliary Power (SNAP) Program, Training, Research, Isotopes, General Atomic (TRIGA) research reactors, and nuclear thermal propulsion reactors. The successful implementation of ZrH_x moderator in advanced reactors requires consistent and affordable production along with hydrogen retention throughout the reactor life. Fabrication of crack-free delta-phase ZrH_x is challenging since the absorption of hydrogen into alpha-zirconium induces significant volume expansion, resulting in cracking. A fully programmable system with continuous hydrogen partial pressure and flow control to facilitate processing of massive delta-phase zirconium hydride has been developed at Oak Ridge National Laboratory. In this presentation, the working principle of this hydriding system will be first introduced. Characterization of the produced ZrH_x includes X-ray powder diffraction to identify the present phases, LECO H and O analysis to quantify hydrogen, and X-ray Computed Tomography to visualize the possible cracks. The results indicate that crack-free $ZrH_{1.6\pm0.1}$ with >10 cm^3 have been successfully produced by using the new hydriding system. Fabrication of ZrH with various geometries (disks, tensile testing specimen, rod) was also attempted. The high equilibrium hydrogen partial pressure (>1 atm) associated with delta-phase ZrH_x at elevated temperatures (>700°C) points at the limited thermal stability of ZrH_x system for advanced reactor applications. Maintaining constant hydrogen concentration in ZrH_x throughout reactor life is necessary to ensure safe, economic, and reliable operation. The strategies to mitigate hydrogen release during normal operation will be discussed. A possible solution used in the past is to develop cladding materials that prevent hydrogen release at elevated temperatures. Thermal stability of the encapsulated ZrH_x will also be assessed through characterizing the hydrogen concentration before and after heat treatments.