Seminar

Institute for Plasma Research

Title: Deposition and characterization of titanium nitride (TiN) coating on stainless steel and zircaloy-4 deposited by cylindrical magnetron sputtering for improved oxidation resistance

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Abstract

Zircaloy-4 (Zr-4) has been used as fuel cladding material in nuclear power plants (NPPs) due to their low neutron absorption cross-section, adequate mechanical strength, and excellent corrosion resistance properties. In order to address the Loss of Coolant Accident (LOCA) condition in NPPs, Accident Tolerant Fuel (ATF) concept has been introduced which emphasizes on delaying the oxidation of Zr-4. A protective coating on the Zr-4 is one of the possible ATF approach to delay oxidation and hydrogen generation under LOCA conditions. Towards development of coatings for ATF, the Physical Vapour Deposition (PVD) by magnetron sputtering method is used as it can produce adherent and uniform coatings which are also scalable for nuclear application.

In this work titanium nitride (TiN) coatings have been developed on AISI 316L and Zr-4 material using plasma assisted cylindrical magnetron sputtering (PA-CMS) technique. Adhesion of the TiN with SS 316L and nuclear grade Zr-4 was optimized by employing plasma etching at different durations prior to coating deposition. Thereafter, thickness of TiN coating on Zr-4 was optimized for dense coating with minimal residual stress. The performance of the coatings was evaluated in high temperature and high-pressure steam as per ASTM G2 standard where the TiN coated Zr-4 samples were exposed to steam at 400ºC, 10 MPa for extended durations up to 521 hrs. The oxidation studies showed significant reduction in weight gain (1/3rd) and lower oxidation rate by two orders in TiN coated Zr-4 compared to uncoated Zr-4 samples. Further, oxidation studies were also carried at high temperature (500-700ºC) on TiN/TiAlN coated Zr-4 samples. The bilayer architecture of TiN/TiAlN coating indicated lower weight gain at 600 ºC. However at 700ºC the coating showed limited oxidation resistance due to formation of cracks and spallation. With the optimized process parameter, TiN coating was demonstrated on Zr-4 tubes (15mm diameter and 100mm length). In order to study the performance of these coating in high temperature steam environment simulating accident conditions further optimization of multilayer coating architecture is needed.