Preparation of Cr-N coatings on stainless steel via pack chromizing and gas nitriding, and enhanced compatibility of coatings to liquid metal

Shuwei Guo, Lintao Liu, Shaopeng Wang

Northwest Institute for Non-ferrous Metal Research, Xi'an 710016, China

anassy@sina.cn

Abstract The lead-cooled fast reactor (LFR) and sodium-cooled fast reactor (SFR) are advanced reactors that are included in Generation IV nuclear energy systems, which use lead-bismuth eutectic (LBE) and liquid sodium as the reactor coolant, respectively. However, liquid metal corrosion (LMC) is one of the key factors that have to be considered in LFR and SFR, which involves species dissolution and transport, chemical reactions and new phase formation. In order to fully utilize the oxide-forming element Cr to form a dense self-passivating oxide film to protect the substrate in liquid metal, as well as the high-temperature stability, high strength, high hardness, and wear resistance of nitride, Cr–C and Cr–N coatings were prepared on 316H stainless steel via pack chromizing and gas nitriding. Then the corrosion behavior in contact with oxygen-saturated static liquid LBE at 550 °C and liquid sodium containing 200 ppm of oxygen at 470 °C were investigated. On the one hand, pack-chromized coating and pack-chromized + gas nitride coating did not undergo obvious consumption in LBE in the early stages. Cracks in the pack-chromized coating promoted the preferential diffusion of oxygen and Pb–Bi. The Cr in the pack-chromized + gas nitride coating slightly diffused outward to combine with oxygen to form Cr-oxide scale on the coating surface. These coatings act as a barrier to LBE corrosion, making the surface of the coating impermeable to LBE. On the other hand, sodium and dissolved oxygen were contact with the nitride layer directly and diffused toward into it of nanoscale, while Cr diffused outward to form a Na-affected scale composed of Na-Cr-O compounds that slow down the corrosion of sodium. Na exposure induced three main microstructural changes in Cr_2N coatings, including a slightly increased surface roughness; the formation of a surface oxide scale with lower mechanical properties than the intrinsic coating; and a reduced grain size. Sodium had a very limited influence on the Cr_2N coatings microstructure, the coatings showed little degradation in liquid sodium and remained chemically inert and structurally intact, proving to be highly compatible with liquid sodium.

Keywords liquid metal corrosion; LBE; liquid sodium; coating; Cr_2N; oxidation