Abstract

Chromium oxide provides an inexpensive and practical means of increasing the corrosion resistance of austenitic stainless steel in most environments. However, the oxide is prone to dissolve in reducing acids and in chloride containing solutions, which compromises the durability and effective operation of structures made of austenitic stainless steel.

This research project explored the use of thin ruthenium surface alloys produced by ion implantation, RF sputtering and pulsed electrodeposition (PED) to improve the corrosion resistance of AISI 304L austenitic stainless steel in reducing acids and chloride solutions via a technique known as cathodic modification. The properties of the alloyed 304L stainless steel were evaluated using a number of tools including X-ray diffraction (XRD), field emission scanning electron microscope (FESEM), potentiodynamic polarisation, and electrochemical impedance spectroscopy (EIS).

Preliminary tests in 1 M sulphuric acid showed that the ruthenium surface alloys sufficiently raised the corrosion potential of 304L stainless steel to ranges where the stability of chromium oxide is guaranteed. Surface alloys produced by RF sputtering and PED were associated with the best corrosion resistance, and protection efficiencies of at least 85%, but they spalled during corrosion exposure rendering them unsuitable for corrosion application. The corrosion of the ruthenium implanted surface alloys exhibited a strong dependence on the surface roughness of the stainless steel, with the least corrosion rates achieved on rough 304L stainless steel samples implanted with 10^{16} Ru/cm^2 at 50 keV.

Corrosion characterisation of these ruthenium implanted surface alloys was studied in various corrosive media including sulphuric acid, sodium chloride, magnesium chloride and simulated fuel cell solutions. Their corrosion rates in sulphuric acid decreased with increase in acid concentration, and exhibited non-Arrhenius behaviour in the acid solutions; corrosion rates were unaffected by increasing exposure temperature from 25 to 50°C. In 3.5 wt% sodium chloride,

addition of ruthenium via ion implantation changed pit morphology from elongated to circular, indicating a diminished tendency for pits to initiate at manganese sulphide stringers. Corrosion rates of the ruthenium implanted stainless steels in the simulated fuel cell solutions were at least 69% lower than the target corrosion rate for use in polymer electrode membrane fuel cells (PEMFCs), thus presenting a possible practical application of ruthenium surface alloyed austenitic stainless steel.