Corrosion of Alloys Suitable for Very High Temperature Systems (VHTRs) Exposed to High Temperature Helium

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Background and Aims

During operation of Very High Temperature Reactor (VHTR) systems, the temperatures will be operating at above 700°C where having a high creep strength and corrosion resistance to the high temperature atmosphere is of vital importance [1].

Helium is used within the VHTR systems as the gas is "inert" and helium, in comparison to other potential coolants, does not become radioactive when exposed to neutron radiation. Complications occur due to the presence of carbon (from the graphite in the reactor), any impurities within the helium gas and potential water ingress from the environment[2,3]. These factors, coupled with the very high temperatures of operation, can lead to complex interactions taking place between the helium coolant gas and the metal. These can include oxidation, carburization and decarburization [1,4] and in certain high temperature alloys, for example on Alloy 800 the surface corrosion layer can delaminate which will have a detrimental effect on the physical properties of mechanical components.

These interactions will affect the physical properties of the alloys as the chemistry is altered during exposure to helium at high temperatures and may negatively affect the physical properties of the alloys, for example decarburization will lead to a reduction in carbides which may affect the physical properties of the alloys.

The work here has characterized three high temperature nickel based alloys (Alloy 617, Alloy X and Alloy 800) using advanced microscopy techniques after exposure to high temperature helium (740°C) for various durations with the aim to better understand the interactions taking place within high temperature helium systems.

Methods

Various nickel based alloys have been exposed at 750°C to a helium atmosphere for various durations inside a high temperature tube furnace. These alloys (Alloy 617, Alloy 800 and Alloy X) were selected based on their physical properties and corrosion resistance. Upon removal from the furnace, samples were characterised using advanced microscopy techniques including Scanning Electron Microscopy (SEM) and Focused Ion Beam Microscopy (FIB). These techniques allowed for characterisation of the changes taking place during their exposure to high temperature helium. Elemental Dispersive X-Ray Spectroscopy (EDS) was used to characterise the elements within the corrosion layer and to highlight the elemental changes which take place at these high temperatures.

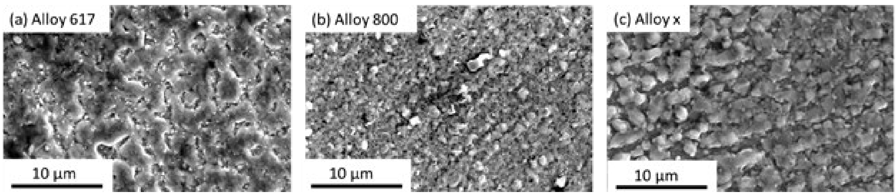
Results

Analysis of the samples shows differences in the oxidation/corrosion behaviour of the different alloys dependant on exposure duration. A comparison between three alloys exposed at 750°C to helium for 1000 hours is shown in the Figure where different morphologies can be seen across the surface of the alloys. The corrosion layer thickness and morphology varied for the different materials with precipitates and oxide nodes developing near to the surface of the exposed surface.

Conclusion

The corrosion behaviour of alloys exposed to high temperature helium is of importance to understand for use within VHTR systems. The work here has characterised three alloys and shown the differences in the oxidation characteristics for each alloy. This will help to better understand corrosion process taking place within a high temperature environment when exposed to helium.

Graphic:



Keywords:

Oxidation, High Temperature Corrosion, Microscopy

Reference:

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