Novel processing of Mo-Si-B intermetallics for improved efficiency of power systems

The Vision 21 plan strives to improve efficiency of fossil fuel power plants, in part by developing materials capable of operating at 3000°F for at least 1000 hours. This project strives to develop novel Mo-Si-B intermetallic composites capable of withstanding the aggressive fossil fuel combustion environment. A key objective is to develop a detailed understanding of the oxidation/corrosion mechanism for the ternary Mo-Si-B system and to then understand how alloying additions and control of microstructure can be used to improve oxidation resistance. Initial results show the potential for Mo-Si-B alloys to meet the demanding Vision 21 requirements.

Compositions rich in Mo possess good mechanical strength and fracture toughness due to the body-centered cubic α-Mo phase, but the metal phase compromises the oxidation resistance. Oxidation resistance in the silicides is due to the formation of a protective glassy scale. In dry air at 1000°C, the alloy readily forms a protective scale, even for the highest Mo containing alloy, but the formation of the protective scale is heavily influenced by water vapor. Additional volatilization of MoO_x is induced in wet air, even after formation of a protective scale in dry air. The alloy further loses its oxidative stability at 1000°C in a synthetic combustion atmosphere of N_2-$13CO_2$-$10H_2O$-$4O_2$. A duplex scale forms, with a 60 μm external glassy scale containing MoO_x inclusions, and a 20 μm interlayer of MoO_2. On heating to 1600°C in dry air, the rate of mass loss is nearly three orders of magnitude higher compared to 1000°C in dry air. With a mass loss rate of 2.1 mg/cm^2/hr, the alloy is quickly consumed. These alloys will require additional coating or alterations in chemistry to meet the Vision 21 goals.

Compositions rich in Si possess good environmental resistance, but compromise mechanical strength and fracture toughness. These alloys form a protective glassy scale in all test atmospheres at 1000°C. In both dry and wet air exposures at 1000°C, the alloy exhibits a slow mass loss of about 3 x 10^{-3} mg/cm^2/hr. This mass loss is attributed to the consumption of Mo from the base alloy by the slow upward movement of MoO_x inclusions through the glassy scale. The alloy also retains is oxidative stability in synthetic combustion atmosphere, forming a relatively thin glassy scale of 5-10 μm. On exposure to dry air at 1600°C, the alloy shows excellent oxidation resistance, with a parabolic rate constant comparable to $MoSi_2$.

These results show that significant work is still required to understand and improve the oxidation behavior of the Mo-rich alloy without loss of its promising mechanical properties. The Si-rich alloy appears most suitable for exploitation, and so its potential to function as a protective coating for the Mo-rich alloy must be further investigated.

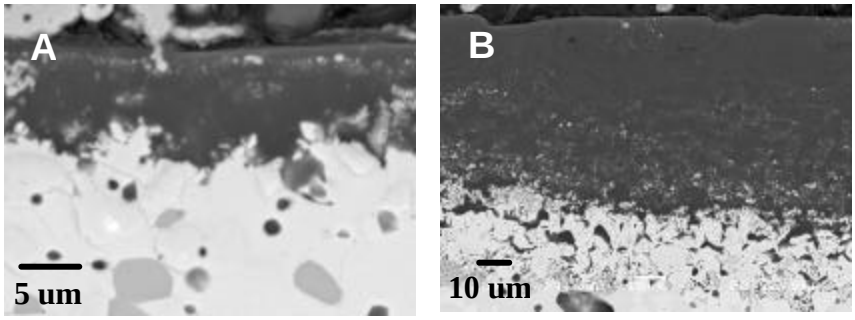

Figure 1: Cross-section of scale formed at 1000°C during exposure to combustion gas atmosphere for 300 hours. (A) Si-rich alloy forms a thin protective scale, and (B) Mo-rich alloy forms a thicker, less protective scale and undergoes increased Mo consumption.