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Development of New Alloys for High-Temperature Applications

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Abstract – The alloys being used in high-temperature systems such as stationary gas turbines and aircraft engines are iron-, cobalt and nickel-based superalloys, amongst which the latter is the most widely used for highest temperatures. However, the use of Ni-based alloys is limited to temperatures below 1100°C. Two new alloy concepts using the Mo-Si-B and Co-Re systems for ultra-high temperature (>1100°C) applications are discussed. Those alloys have very high melting points, while retaining good mechanical properties and oxidation resistance in the desired temperature range.

Six model Co-based alloys were investigated in this study: (i) two binary alloys Co-Cr and Co-Re, (ii) two ternary Co-Re-Cr alloys and (iii) two quaternary alloys Co-Re-Cr-C.

For the system Mo-Si-B, three alloy systems based on Mo-9Si-3B with and without oxide dispersions of La_2O_3 and ZrO_2 were used. La_2O_3 helps to increase ductility. ZrO_2 decreases grain growth during sintering in order to obtain higher strength and ductility. In this work, implications due to microalloying of La_2O_3 and ZrO_2 on the oxidation behaviour of Mo-9Si-8B were studied.

This study reveals that an amount of 17at.% of Re has a negative influence on the oxidation resistance of Co-based alloys due to the evaporation of rhenium oxide(s). Discontinuously performed thermogravimetric studies showed that the vaporization rate of rhenium oxide(s), however, decreases considerably, when the Cr content is increased from 23at.% to 30at.%. That can be attributed to the formation of more protective Cr_2O_3 scale. The addition of carbon to the ternary alloy Co-17Re-30Cr seems to improve the oxidation resistance by decreasing the rate of vaporization. This beneficial effect of C was only found for short oxidation times in the ternary Co-17Re-23Cr alloys.

In this study two important factors for a further improvement of the oxidation behaviour of Mo-Si-B alloys were investigated. The first aspect dealt with the oxidation resistance of Mo-9Si-3B alloys at moderate temperatures. In the temperature range of 750-820°C, the formation of two competing oxides (SiO_2, MoO_3) excludes the formation of a homogeneous silica scale. The formation of MoO_2 and the damage of the silica scale is drastically reduced by lowering the oxygen diffusity through the silica scale at temperature higher than 820°C as a consequence of adding La_2O_3. The Mo-9Si-8B alloy shows excellent oxidation resistance in the temperature regime around 1100°C except of an initial mass loss, which is the second important factor. ZrO_2 addition to Mo-Si-B seems to have no direct effect on the oxidation behaviour but due to the finer microstructure formed, different oxidation behaviour as compared to the conventional alloy was identified which is especially beneficial at temperatures around 1100°C, but detrimental at temperatures around 1300°C.

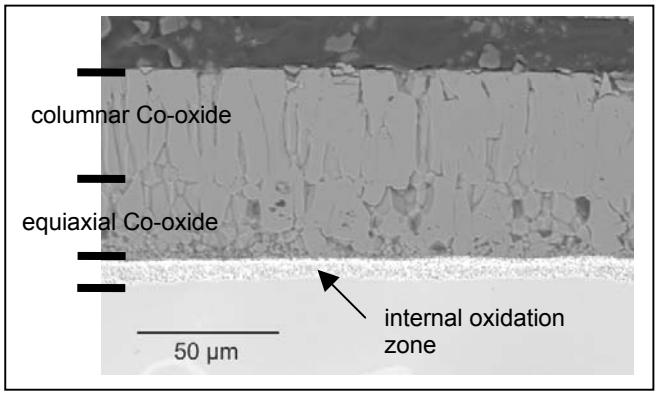

Figure 1: cross section of the alloy Co-17Re exposed to laboratory air at 1000°C for 1h.

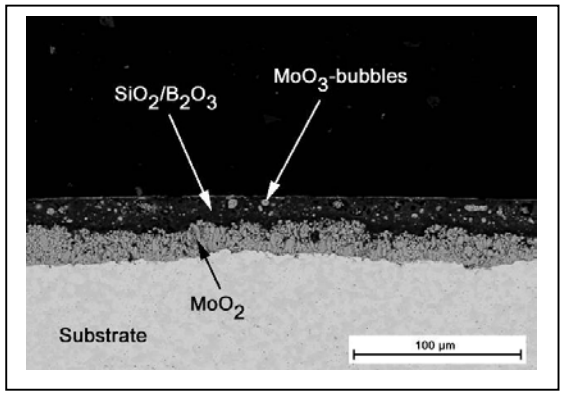

Figure 2: cross section of the alloy Mo-9Si-8B-La_2O_3 exposed to laboratory air at 820°C for 7h.