NITRIDATION DURING OXIDATION AS A CHALLENGE FOR CR-BASED ALLOYS AND ITS MITIGATION BY ALLOYING

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The high temperature behavior of pure chromium above 1000°C shows very interesting features such as vaporization, scale spallation and worst of all extreme nitridation when exposed to air. A detailed investigation of the different mechanisms can explain the wide range and controversial results given in the literature when the oxidation and its oxidation rates are reported for pure Chromium. Especially, the attack by nitridation deteriorates the mechanical properties by severe embrittlement. It also has a huge impact on the mass change during oxidation. To mitigate this embrittlement an alloying strategy is developed by the addition of silicon and germanium. The oxidation behavior of binary Cr-Si and ternary Cr-Ge-Si alloys at ultra-high temperatures (T=1200°C-1350°C) is reported (see also Figure 1) and the morphological evolution of the oxide scale and the metal subsurface zone was investigated using scanning electron microscopy, electron probe micro-analysis, and X-ray diffraction techniques. The A15-phase Cr3Si is shown to have a crucial influence on prevention of nitridation. During oxidation of a two phase Crss-Cr3Si system an A15 barrier develops in form of a continuous intermetallic layer underneath the surface. The in-situ formed barrier layers shown to be able to successfully prevent nitridation and the same time to improve the oxidation kinetics. Beyond that, ternary additions of Ge to the Cr-Si system strengthens this effect even more and significantly improves the oxidation kinetics of the chromium alloys at ultra-high temperatures to a level comparable to alumina formers (Figure 2).

Figure 1. Mass gain during exposure in air at 1200°C for pure Chromium in comparison to eutectic Cr-Cr3Si and modified Cr-Cr3(Si,Ge) alloys.

Figure 2. Scatter bands for literature values of the parabolic rate constants for chromia scale formation in binary chromium alloys compared to Cr-Ge-Si alloys and alumina-formers. Modified after [3].