SCP5.3

Microstructure and mechanical properties of V-Si-B alloys with chromium additions

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Introduction

The V-Si-B system has gained scientific interest as a new low-density, refractory metal-based structural intermetallic alloy system. The alloy design is strongly influenced and driven by the developments in the field of Mo-Si-B alloys and shares some interesting structural and microstructural features. Very recently, the formation of ternary eutectic V_{SS}-V_3Si-V_5SiB_2 microstructure has been reported which contains the same isomorphous phases as the ternary eutectic in the well-studied Mo-Si-B system: a refractory metal-based solid-solution phase (Mo_{SS} or V_{SS}) and the two intermetallic phases with either an A15 (Mo_3Si and V_3Si) or a $D8_l$ (Mo_5SiB_2 and V_5SiB_2) structure. However, while the Mo-Si-B-based ternary eutectic shows some oxidation resistance due to its intermetallic character, oxidation of the V-based eutectic is an even more serious issue. To address this problem, different amounts of Cr were added to a eutectic V-Si-B alloy to study the microstructural influence on the ternary eutectic reaction, the phase stability as well as the mechanical and oxidation properties as a function of Cr concentration. Alloys with Cr additions between 5 – 30 at.% were fabricated by conventional arc-melting and were analyzed in the as-cast state or heat-treated at 1400 °C for 100 hrs.

Materials and Methods

The present study is focused on the compressive stress-strain behavior of ternary eutectic V-Si-B alloys with 10, 20 and 30 at.% Cr additions. Compression tests were performed using an electro-mechanical universal testing machine and a constant crosshead speed corresponding to an initial (engineering) strain rate of 10^{-3} s^{-1}. The yield stresses were determined by the 0.2% offset method. The temperature dependence of its compressive yield stress between room temperature and 1000 °C was investigated in the as-cast and annealed state (1400 °C for 100 hrs) and compared to the Cr-free ternary eutectic alloys V-9Si-6.5B as well as V-Si-B alloys taken from the literature.

Results and Discussion

Prior to the mechanical compression tests the microstructures of the Cr-added ternary eutectic alloys V-9Si-6.5B were investigated. Even at high Cr-additions of 30 at.% the eutectic V_{SS}-V_3Si-V_5SiB_2 microstructure could be maintained. Thus, Cr has almost no influence on the solidification behavior in this part of the V-Si-B system, which seems to be plausible since Cr stabilizes all three eutectic phases [1]. As an example, the microstructures of the base alloys and an alloy with 30 at.% Cr additions is shown in Fig. 1, including a heat treatment at 1400 °C for 100 hrs. According to XRD analysis, the newly discovered phase V_8SiB_4 could also be detected in all eutectic alloys with Cr additions after the heat treatment.

The ternary eutectic alloy V-9Si-6.5B features the ductile V_{SS} phase as the major phase. Thus, first compression test revealed a deformability even at room temperature. However, the yield strength decreases quickly with increasing test temperatures and is even more pronounced in the heat-treated state. In order to develop a comparably low-density materiel for high temperature structural applications, the high-temperature strength (and later on, the creep resistance) should be further improved by Cr-additions. Cr dissolves in all the ternary eutectic phases and, as mentioned before, does not influence the eutectic formation. This fact makes Cr an ideal candidate to study the strengthening behavior of the alloys by subsequently increasing its Cr content. With increasing Cr-additions the compressive yield strength increased, too. Accompanied with the hardening effect, Cr leads to a drastic increase of brittle-to-ductile transition temperature (BDTT) of the alloys investigated. The strengthening effect is mainly attributed to solid-solution strengthening of the V_{SS} phase, which forms the major phase (about 50-60% phase fraction) in the Cr-free and Cr-added alloys. Since Cr is also dissolved in the intermetallic phase, a strengthening effect may also occur in these phases. However, the intermetallic phases already act as second phase strengthener and have an even higher BDTT as compared to the solid-solution phase.

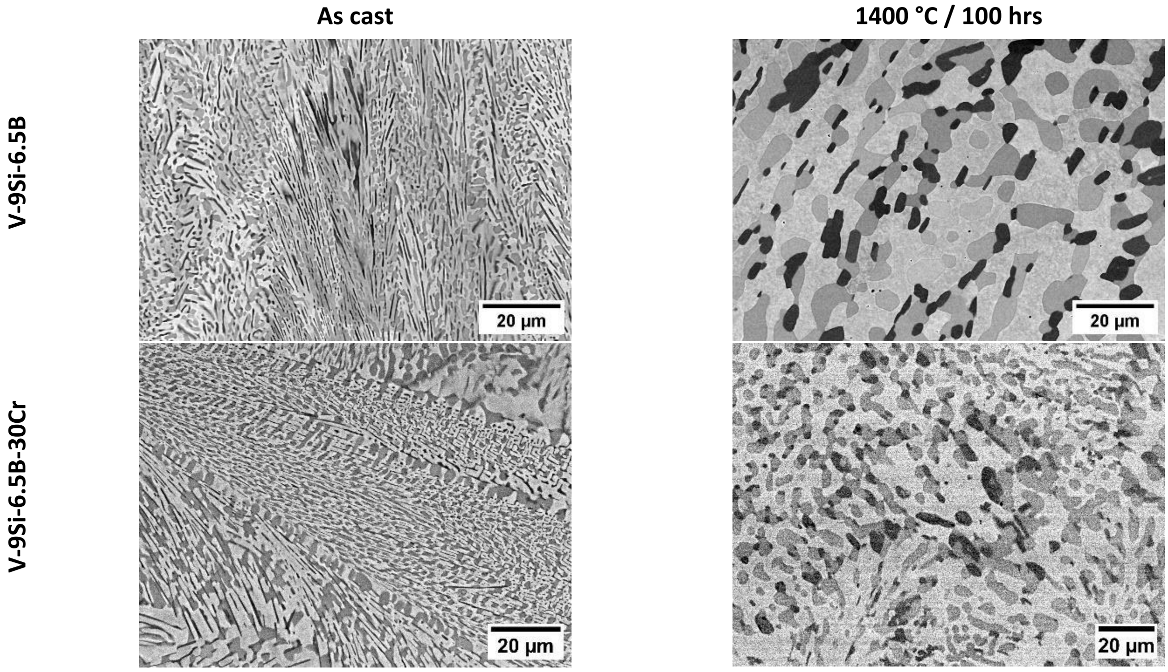

Fig 1: Exemplary microstructures auf the ternary eutectic base alloy V-9Si-6.5B (top) and theV-9Si-6.5B-30Cr alloys (bottom) in the as-cast or heat-treated state.

References

[1] R. Sakidja, J.H. Perepezko, S. Kim, N. Sekido, Acta Mater. 56 (2008) 5223–5244.