The effect of Si on phase fractions and transition temperatures of a TiAl-Mo alloy

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Intermetallic TiAl alloys were developed to replace Ni based alloys as a material for low-pressure turbine blades in jet engines. To expand the field of application, a new alloy concept for low-cost parts was conceived, which is based on a high content of β-stabilizing alloying elements. These alloys are expected to exhibit supreme deformability at elevated temperatures due to their high β-phase content.[1][2] Data on the effect of different alloying additions in these alloys, however, are scarce and to the knowledge of the authors, the effect of Si in highly β-stabilized alloys has not been investigated so far.

Two alloys with a nominal composition of Ti-45 Al-3 Mo (alloy A) and Ti-45 Al-3 Mo-0.5 Si (alloy B) were provided by GfE Metalle und Materialien GmbH, Nuremberg, Germany. In-situ diffraction experiments were performed at the HARWI II beamline of the HZG.[3] The specimens were heated in a dilatometer (DIL 805 by Bähr) while temperature control was achieved by means of a type S thermocouple. A monochromatic X-ray beam with a mean energy of 104.7 keV and a cross section of 0.5×0.5 mm^2 at the sample position illuminated the specimen. For recording the diffracted intensity, a mar 555 detector was employed. Specimens were rapidly heated to 1000°C held at this temperature for two minutes and subsequently heated to 1400 °C at a rate of 2 K/min. Recorded patterns were azimuthally integrated by means of the fit2D software package.[4] Fractions of the individual phases were determined by the intensity ratio method where the weighting factors were derived from Rietveld analysis with the commercial software package TOPAS (Bruker AXS).

In Figure 1, the development of phase fractions with temperature is presented for both alloys. Three main phases are shown to occur which are the α_2/α phase ($D0_{19}$/A3), the β_o/β phase (B2/A2), and the γ-phase ($L1_0$). Both, α_2 and β_o-phase disorder at high temperatures while the γ-phase remains ordered up to its dissolution temperature. Comparison of the two graphs reveals that the course of phase fractions is similar for both alloys. One major difference, however, is that at temperatures between 1000 °C and 1200 °C, no α_2/α-phase could be detected in alloy B while alloy A exhibits α_2/α-phase contents in the range of 10 %. Consequently, the phase fractions of β_o/β and γ-phase are shifted, which is slightly more noticeable for the γ-phase. Furthermore, the γ dissolution temperature has increased by the addition of Si.

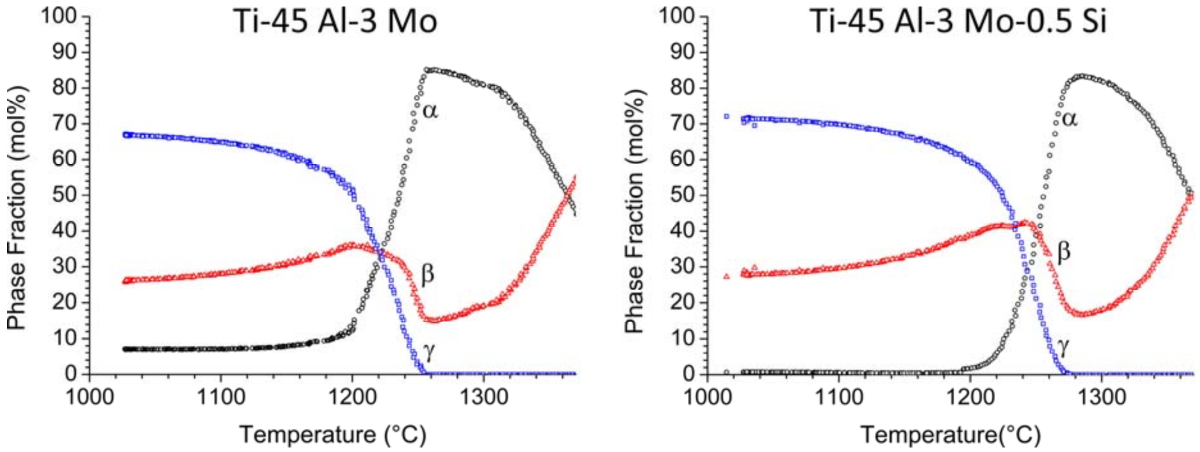

Figure 1: Evolution of phase fractions with temperature for a Ti-45 Al-3 Mo (a) and Ti-45 Al-3 Mo-0.5 Si (b). The graphs were obtained by continuously recording diffraction patterns while heating at a rate of 2 K/min.

Frequently, the non-zero heating rate used in experiments that aim at determining phase fractions and transition temperatures in equilibrium conditions raises concerns. However, in this experiment the effect of the heating rate on transition temperatures is negligible, since the same heating rate was used for both alloys. For the case that Si affects the transformation kinetics, the results of these investigations yield valuable data for the processing of these alloys nonetheless, since equilibrium conditions cannot be obtained in a commercial production process. The microscopic investigation of heat-treated and quenched specimens, however, provided data, which suggest, that the transition temperatures found at a heating rate of 2 K/min correspond to thermodynamic equilibrium conditions. Furthermore, differential scanning calorimetric experiments have shown that the dependence of transformation temperatures on heating rate is limited.

These in-situ experiments with the newly commissioned dilatometer at HARWI II highlight the influence of Si additions on phase fractions and transition temperatures of a TiAl-Mo alloy. The pieces of information obtained are crucial if an industrial production process for low-cost TiAl parts is to be designed and, therefore, will promote the understanding of the Ti-Al-Mo alloy system.

References

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