Constitution of the Al–Cr–Fe phase diagram in the compositional range above 60 at. % Al

D. Pavlyuchkov,1,2, B. Grushko1, D. Kapush1, W. Kowalski1, V. Khorujaya1, K. Korniyenko1 and T. Ya. Velikanova1

1. N. Frantsevich Institute for Problems of Materials Science, 03680 Kyiv 142, Ukraine
2. Institut für Festkörperforschung, Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany
3. Institute of Material Science, University of Mining and Technology, 09599, Freiberg, Germany
4. Institute of Material Science, University of Silesia, 40007 Katowice, Poland

INTRODUCTION

The literature on the constitution of the Al-Cr-Fe alloy system since 1932 was recently reviewed in [1]. The ternary space of this phase diagram is mainly occupied by a bcc solid solution of the three constituent elements, ranging at 1150°C and below this temperature from the Fe-Cr terminal up to more than 40 at.% Al. In the Al-rich compositional region the most recently published isothermal 1000°C section [2] and those determined earlier for 600 to 900°C (see the references in [1]) also did not contain ternary compounds. On the other hand, a great number of ternary compounds with complex crystalline structures were reported in other studies dealing with individual, usually multiphase as-cast Al-Cr-Fe alloys (see [1] for details). The compositions of these phases were not consistent in different studies and their liquidus and solidus surfaces of Al–Cr–Fe were determined. The reaction scheme, liquidus and solidus surfaces of Al–Cr–Fe were determined. The FCC phase at about 1090, 1070, 1045 °C respectively, while the H-phase is formed by peritectic reaction:

RESULTS

The alloys were produced from the constituent elements by levitation induction melting in a water-cooled copper crucible under an Ar atmosphere. The purity of Al was 99.999%, of Fe and Cr 99.995%. The ingots were typically of 5 to 10 g. Parts of the samples were annealed under an Ar atmosphere or vacuum (p<10⁻³ mBar) at 700 to 1160 °C for up to 850 h. The samples were examined by powder X-ray diffraction (XRD) and scanning electron microscopy (SEM). The compositions of these phases were measured with precision of ±0.5 at.% by energy-dispersive X-ray analysis (EDX) in SEM on polished unetched surfaces. Powder XRD was carried out using Cu radiation with a step of either 0.05° or 0.2° and acquisition time of 10 or 20 sec. The TEM samples were examined by using electron diffraction in the transmission electron microscope (TEM) operated at 200 and 400 kV. The TEM samples were powders spread on Cu grids covered by carbon films. Differential thermal analysis (DTA) was carried out for selected samples at typical rate of 20°C/min.

EXPERIMENTAL

The reaction scheme, liquidus and solidus surfaces of Al–Cr–Fe were determined. Fourteen ternary reactions involving the liquid phase were revealed: three eutectic, two peritectic and nine transition reactions. The D, O, and c-α-Al(Fe,Cr) phases are formed by reactions between the liquid and the Al-Cr γ-phase at about 1090, 1070, 1045 °C respectively, while the H-phase is formed by peritectic reaction:

L + γ-Al, Fe → H at 980°C. The lowest temperature of the liquid phase 655°C corresponds to the binary eutectic between (Al) and Al2Fe.