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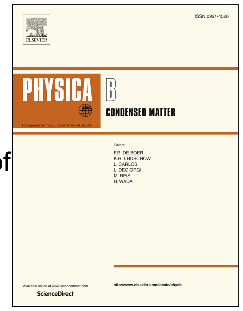

Thermal transport properties, magnetic susceptibility and neutron diffraction studies of the $(Cr_{100-x}Al_x)_{95}Mo_5$ alloy system

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Thermal transport properties, magnetic susceptibility and neutron diffraction studies of the $(Cr_{100-x}Al_x)_{95}Mo_5$ alloy system

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Abstract

Previous electrical resistivity (ρ) and specific heat (C_{P}) studies on the ternary $(Cr_{100-x}Al_x)_{95}Mo_5$ alloy system suggested that it harbours two quantum critical points (QCPs). This study reports comprehensive investigations of this alloy system through Seebeck coefficient (S), thermal conductivity (κ), magnetic susceptibility (χ) and neutron diffraction (ND) measurements in the concentration range $0 \leq x \leq 8.6$. The results of S and χ show that spin-density-wave (SDW) antiferromagnetism is suppressed to temperatures below 2 K for concentrations in the range $1.4 \leq x \leq 4.4$. Plots of $\mathrm{d}S/\mathrm{d}T$ in the limit as $T \to 2$ K depict two minima, i.e. just above $x = 1.4$ and 4.4. This parameter has been used as a key indicator of quantum critical behaviour (QCB) in Cr alloys. Analyses against the Nordheim-Gorter relationship demonstrates a positive slope for the incommensurate (I) SDW alloys and a negative slope for the commensurate (C) SDW alloys. Extrapolations of these two slopes intercept at a concentration of 3.2 at.% Al indicating the occurrence of band structure modifications when Al is added into the $Cr_{95}Mo_5$ base alloy. The Lorenz number (L) for the alloys with $x = 0$ and 0.5 shows interesting anomalous behaviour associated with band structure effects and SDW magnetic ordering. ND measurements as a function of temperature confirm that alloys with $x < 1.4$ order in the incommensurate (I) SDW phase whilst alloys with $x > 4.4$ show commensurate (C) SDW order. Power law fits of the form $T_{\mathrm{N}} \propto (1.40 - x)^{0.35 \pm 0.05}$ for the ISDW to P phase transition and $T_{\mathrm{N}} \propto (x - 4.40)^{0.63 \pm 0.03}$ for the P to CSDW phase transition rendered the critical exponents 0.35 ± 0.05 and 0.63 ± 0.03 respectively. Overall the results of S, κ, χ and ND corroborate the existence of two QCPs at $x \approx 1.4$ and 4.4.

1. Introduction

The magnetic phase diagram of the $Cr_{100-x}Al_x$ alloy system given by Fawcett *et al*. [1] and recently by Sheppard *et al*. [2] is unique amongst Cr alloy systems. The addition of Al in the Cr matrix initially rapidly decreases T_{N} down to 0 K at a concentration just above $x \approx 1.9$ at.% Al. With increased alloying the magnetic order reappears at higher concentrations with a corresponding increase in T_{N} [2]. Sheppard *et al*. [2] suggested the existence of a triple point (TP) at a concentration x_{t} within a concentration range $1.9 < x < 2.2$ at.% Al and at a temperature $T_{\mathrm{t}} \approx 0$ K, where the ISDW, CSDW and the paramagnetic (P) phases converge. Alloys with $x < x_{\mathrm{t}}$ order in the ISDW phase, whilst those with $x > x_{\mathrm{t}}$ order in the CSDW phase [2, 3]. Electrical transport and specific heat measurements suggested that this triple point concentration may also be a special type of a critical concentration [2, 4] that corresponds to a quantum critical point (QCP). This warrants further investigation.

The unique magnetic properties of the $Cr_{100-x}Al_x$ alloy system were also explored by the addition of 5 at.% Mo to the matrix to form a ternary $(Cr_{100-x}Al_x)_{95}Mo_5$ alloy system [5, 6]. Electrical resistivity and magneto-elastic measurements show that the SDW antiferromagnetism is suppressed to below 4 K (the minimum temperature of the measurements in this investigation) in the concentration range 2