MuSR STUDY OF WEAKLY MAGNETIC Y(Co$_{1-x}$Al$_x$)$_2$

J.G.M. ARMITAGE $^1$, R.G. GRAHAM $^1$, P.C. RIEDI $^1$, H. FIGIEL $^2$, S.F.J. COX $^3$, C.A. SCOTT $^3$, J.S. ABELL $^4$ and K. YOSHIMURA $^5$

$^1$ Department of Physics and Astronomy, University of St Andrews, St Andrews, Fife KY16 9SS, Scotland, U.K.
$^2$ Solid State Physics Department, University of Mining and Metallurgy, al. Mickiewicza 30, 30-059 Cracow, Poland
$^3$ Rutherford Appleton Laboratory, Chilton, Didcot, Oxon OX11 0QX, U.K.
$^4$ Department of Metallurgy and Materials, University of Birmingham, PO Box 363, Birmingham B15 2TT, U.K.
$^5$ Department of Chemistry, Faculty of Science, Kyoto University, Kyoto 606, Japan

All previous experiments have suggested that Y(Co$_{1-x}$Al$_x$)$_2$ is a weak itinerant ferromagnet for $0.12 < x < 0.20$. The muon transverse damping rate ($\lambda$) increases rapidly near the Curie point for $x \geq 0.155$ and for one sample with $x = 0.145$. The value of $\lambda$ increases with decreasing temperature for other samples with $x < 0.155$ but shows no feature at the Curie point.

1. Introduction

The cubic Laves compound YCo$_2$ is a Pauli paramagnet but Y(Co$_{1-x}$Al$_x$)$_2$ is believed to be a weak itinerant ferromagnet, for $0.12 < x < 0.20$, with the maximum value of the Curie point ($\sim 25$ K) and spontaneous moment at 0 K ($\sim 0.15 \mu_B$/Co) occuring near $x = 0.15$. Yoshimura and Nakamura showed that the temperature and magnetic field dependence of the susceptibility and magnetisation of Y(Co$_{1-x}$Al$_x$)$_2$ were in good agreement with the spin fluctuation theory of itinerant magnetism [1] and subsequent NMR experiments, [2], were also shown to be in agreement with the theory.

The addition of Al to YCo$_2$ expands the lattice and decreases the number of d electrons; from band structure calculations it is clear that both effects are favourable to ferromagnetism [3]. It has been shown [4,5] that the lattice expansion is essential for the transition to ferromagnetism since for $0.14 < x < 0.18$, a pressure of $\sim 9$ kbar is sufficient to destroy the spontaneous moment at 0 K, and to reduce the Curie point to zero, while the lattice expansion for $x = 0.15$ is equivalent to a chemical pressure of $\sim -40$ kbar.

The muon transverse damping rate ($\lambda$) as a function of temperature has already been reported [6] for Y(Co$_{1-x}$Al$_x$)$_2$ with $x = 0.155$ and 0.175. It was found that $\lambda$ increased rapidly, to the maximum observable value, at a temperature close to the Curie point found from a.c. susceptibility measurements, and
that the asymmetry of the muon signal decreased rapidly at lower temperatures, indicating that the material had become ferromagnetic in agreement with the macroscopic measurements.

We now report the surprising result that muon experiments in the transverse geometry show no evidence of a phase transition near the macroscopic $T_c$ for $x = 0.143$ and 0.150. In these two samples the value of $\lambda$ increases with decreasing temperature to the lowest temperature available ($\sim 14$ K) but shows no feature near $T_c$ ($\sim 24$ K). Samples from two different laboratories showed the same change of behaviour for $x < 0.155$ so this is unlikely to be due to an inadequate sample preparation technique.

2. Experimental

Samples of $Y(Co_{1-x}Al_x)_2$ were prepared at the University of Birmingham and the University of Kyoto, see [1,5] for details. The data shown in fig. 1 was obtained for samples from Kyoto and is in good agreement with earlier work on samples from Birmingham [6 and unpublished]. The Curie point of each sample was measured in a separate a.c. susceptibility experiment.

Experiments were performed using the RAL pulsed muon beam in a transverse field of 220 G. The original ingots of $Y(Co_{1-x}Al_x)_2$ were powdered for use in the muon experiments. The powdered metal was pressed into a recessed OFHC copper block bolted to the cold finger of a closed cycle helium cryostat. The metal was held in place by a mylar film and spring clip. The large cryostat window required to admit the muons leads to a very unfavourable geometry for the precise control and measurement of the sample temperature during the 20 minutes required for each muon measurement, and in the current set-up at RAL this problem is compounded by a long thermal path between the temperature control thermometer and the sample. For the measurements reported here temperatures were derived from a carbon glass thermometer embedded in the copper block as close to the sample recess as possible. The muon rotation data were recorded in 32 counters and analysed to give the frequency of muon precession, the asymmetry and the transverse damping factor.

3. Discussion

The temperature dependence of the frequency, asymmetry and transverse damping rate of paramagnetic $YCo_2$ in a field of 220 G is shown in fig. 1 for the temperature range 14–50 K. It will be seen that all these properties are almost independent of temperature, as expected for a Pauli paramagnet. Above 50 K the damping value of $\lambda$ for $YCo_2$ remained almost constant at $\sim 0.3$ MHz to about 200 K and then decreased with increasing temperature, presumably due to