Pressure dependent magnetization of $DyCu_2$ single crystals

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Abstract

We present magnetization measurements on $DyCu_2$ single crystals at different isotropic pressures up to 0.72 GPa in order to investigate the influence of a change of the atomic distances on the magnetic properties. The magnetization along the orthorhombic a axis (the easy axis of the system) is very sensitive to pressure resulting in a more complicated magnetic phase diagram under pressure. No change of magnetization by pressure has been observed for the b and c axes at low fields. Special interest has been focused on the influence of pressure on the conversion of the easy magnetic axis from a to c (associated with giant magnetostriction) if a critical field parallel c is applied. The magnetization measurements at T= 30 K (i.e. for $T > T_N$) show a decrease of the magnetic anisotropy between the a-axis and c-axis with pressure which results in a vanishing of the conversion effect at approximately 0.5 GPa. This is discussed in a microdomain model where pressurizing leads to an equal population of domains.

Key words: magnetization;high pressure;giant magnetostriction;$DyCu_2$

The magnetic properties of intermetallic orthorhombic $DyCu_2$ single crystals have already been investigated extensively at ambient pressure [1,2] resulting in a complex magnetic phase diagram for fields along the crystallographic a axis. In magnetic fields along the c-axis a conversion of the easy axis was discovered [3]. That means, after a critical magnetic field (e.g. 13 T at T= 4 K, 5 T at T= 30 K) has been applied parallel to c the magnetization along this axis closely resembles that along the (original easy) a axis and vice versa. Because of the strong magnetoelastic coupling the effect is associated with a giant magnetostriction (GMS) of approximately 4 % (at T= 4.2 K). This discovery has led to several new studies of the high field magnetism in the orthorhombic RCu_2 series [2–4].
We performed magnetization measurements on $DyCu_2$ single crystals under isotropic pressure up to 0.72 GPa. The aim was to investigate the dependence of the magnetic interactions on lattice strain as reflected by pressure dependence. $DyCu_2$ single crystals (2x2x2 mm^3) were mounted in a Cu-Be pressure cell and measured using the dc extraction method.

Fig. 1 shows the pressure dependence of the magnetization along the main crystallographic axes at 2 K. The two step magnetization at zero pressure becomes a three or more step process above 0.3 GPa. Arrows indicate the main transition points. Generally, the transitions are less sharp under pressure. This may be caused by strain inhomogeneities in the sample. For the a axis the moment at the maximum field 5 T decreases from 8 μ_B to 6 μ_B at 0.5 GPa, due probably to an increase in the magnitude of the crystal field. Another explanation for the smaller moment would be a further transition above 5 T. To observe this measurements in higher fields are necessary. All curves show a absence of hysteretic effects. In contrast to the changes

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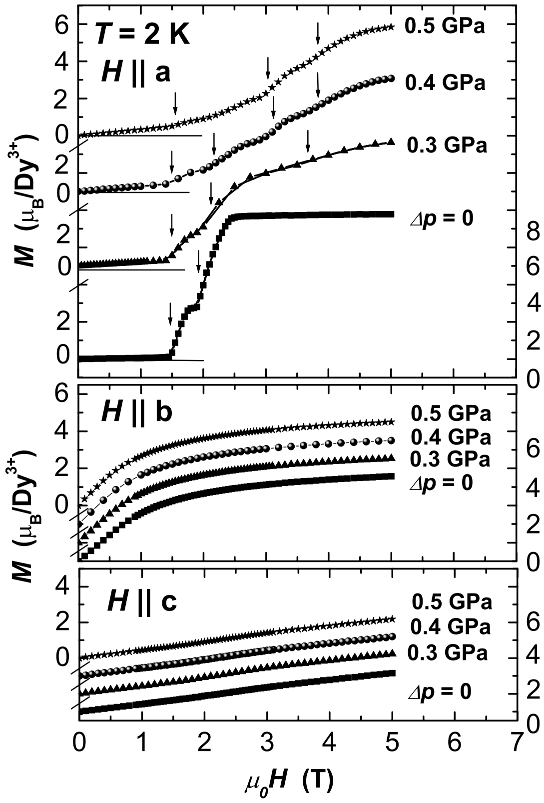

Fig. 1. Pressure dependence of the magnetization of $DyCu_2$ along the main crystallographic axes at $T = 2$ K [meas. ONRI Okazaki]. Arrows indicate the metamagnetic transitions.

in a direction, the magnetization along the hard b and c axes is not influenced by pressures up to 0.5 GPa. Also the Néel temperature $T_N = 27$ K does not change within the experimental error up to 0.5 GPa.

To study the influence of pressure on the easy axis conversion the measurements along c were repeated at 30 K. At this temperature it is possible to perform the conversion at a field of 4 T without external pressure, as shown in Fig. 2. The decreasing field curve resembles the a axis magnetization at this temperature. At 0.43 GPa the conversion occurs less pronounced at a lower critical field 3.5 T and at 0.72 GPa it is almost suppressed. The curves indicate that the magnetic properties in the ac plane get more isotropic under pressure.

The pressure dependence of the conversion process may be discussed in the frame of a microdomain model: The original one-domain orthorhombic $DyCu_2$ crystal may be converted in an external magnetic field parallel to the hard c axis into a three domain crystal by populating the two other 120^o orthorhombic domains. This behaviour is consistent with the experimentally found

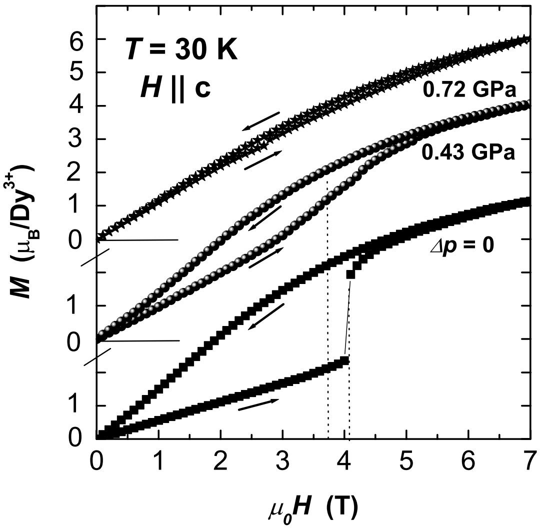

Fig. 2. Pressure dependence of the magnetization of $DyCu_2$ along the c axis at $T = 30$ K illustrating the effect of easy axis conversion [meas. University College London]. At 0.72 GPa the conversion effect is almost suppressed.

overall hexagonal symmetry in the converted state [5]. The energy of the transition of about 100 K was estimated from thermal reconversion [6]. Our experiments indicate that this barrier may be reduced by isotropic pressure resulting in a more equal population of all three domains at 30 K and a more isotropic magnetization. Therefore, the conversion disappears. The proposed scenario has to be confirmed by scattering experiments in the original and in the converted state.

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