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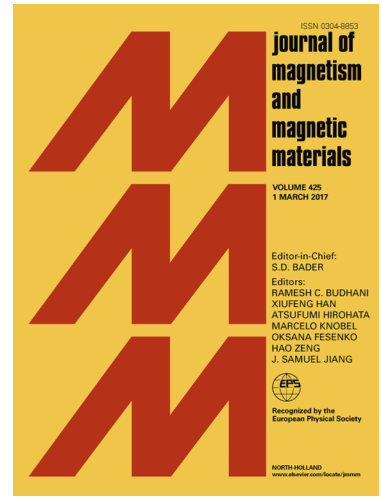

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ACCEPTED MANUSCRIPT

Magnetic Phase Coexistence in $DyNiAl_4$

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Abstract
The magnetic structure and properties of the rare earth intermetallic $DyNiAl_4$ have been determined. Two magnetic phase transitions have been observed at $T_N = 20.2(1)$ K and $T_{N'} = 14.6(1)$ K. Analysis via neutron diffraction has revealed that these correspond to the formation of two distinct magnetic phases, a low temperature collinear antiferromagnetic phase with $\boldsymbol{k_C} = (0,1,0)$ and a higher temperature incommensurate phase with $\boldsymbol{k_I} = (0.1745(6), 1, 0.0313(6))$. The incommensurate phase consists of a sinusoidal modulation of the magnetic moment along the *a*- and *c*-axis directions. In addition, both of these phases have been found to coexist between 14.5 K and 16.1 K.

Keywords: Rare earth intermetallics, neutron powder diffraction, incommensurate magnetic phase

1. Introduction
The $RNiAl_4$ ($R = Ln^{3+}$) series has shown a remarkable variety of magnetic properties and structures all dependent on the particular rare earth ion present within the compound [1-10]. All have the *YNiAl₄* structure type and belong to the *Cmcm* space group and common to all members of the series thus far studied is an incommensurate magnetic phase, with the exact configuration of the moments varying between different ions. For example, in $TbNiAl_4$ the incommensurate magnetic structure consists of an elliptical helix type structure with the moments rotating close to the *ab*-plane while moving along the *c*-axis [1-3]. In $PrNiAl_4$, the structure consists of a sinusoidally modulated moment along the *a*-axis, the same direction in which the moments point [4]. In both of these cases, the magnetic structure transitions to commensurate antiferromagnetism once the temperature is low enough [1, 5]. In contrast the magnetic structures of $ErNiAl_4$ [6] and $NdNiAl_4$ [7, 8] remain incommensurate to the lowest measured temperatures. This suggests that Kramer's degeneracy may play a role in the number of phase transitions a series member may have. $DyNiAl_4$ is a Kramer's ion but has been found previously to possess two phase transitions ($T_N \approx 18$ K and $T_{N'} \approx 15$ K) [9], behaviour only seen thus far amongst non-Kramer's ions of the $RNiAl_4$ series. New heat capacity and neutron diffraction measurements have been carried out on $DyNiAl_4$ in order to determine both the number and nature of its magnetic phases to compare and contrast with other compounds in the series, both Kramer's and non-Kramer's based.

2. Experimental
$DyNiAl_4$ was synthesised by combining stoichiometric amounts of the constituent elements (Dy 99.9%, Ni 99.99%, Al 99.999%) before melting in an argon arc furnace several times to ensure homogeneity. The buttons obtained were then wrapped in tantalum foil before being placed in an evacuated quartz tube and annealed for 1 week at 1030°C. Phase purity was checked via X-ray diffraction using a PANalytical Empyrean X-ray Diffractometer with Cu radiation. Heat capacity measurements were carried out using a Quantum Design Physical

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