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Lattice distortions measured in actinide ferromagnets PuP, NpFe$_2$ and NpNi$_2$ (*)


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Abstract. — X-ray low-temperature measurements indicate that: (1) cubic PuP distorts to tetragonal below $T_c = 125$ K with accompanying line broadening, (2) NpFe$_2$ exhibits a rhombohedral angle distortion from 60° to 60.53° below $T_c \sim 500$ K, and (3) in NpNi$_2$ the rhombohedral angle changes 0.19° (± 0.02°) below $T_c = 32$ K.

Actinide U and Np ferromagnets have been shown [1] to exhibit a large distortion from cubic symmetry below $T_c$, with all previous examples exhibiting a rhombohedral symmetry compatible with the (111) easy axes of magnetization found in these compounds. We report here the results of X-ray experiments at low temperature to examine the symmetry of PuP ($T_c = 125$ K), NpFe$_2$ ($T_c \sim 500$ K), and NpNi$_2$ ($T_c = 32$ K).

In PuP a (100) easy axis was found with neutron measurements [2] and, as expected, we find a tetragonal distortion such that

$$(c - a)/a = -(31 \pm 1) \times 10^{-4}$$

at 5 K. The variation of the lattice parameters and the strain are shown as functions of temperature in figures 1 and 2, respectively. Below $T_c$ the diffraction peaks also broaden, presumably a consequence of strain induced by the magnetoelastic interactions (see Fig. 3).

In NpFe$_2$ neutron experiments [3] determined a (111) easy axis and we find a rhombohedral distortion such that the rhombohedral angle changes from 60° to 60.53°. An alternative description of the rhombohedral distortion is to define a length $c$ as a distance along the unique trigonal axis and $a$ as a distance in the plane perpendicular to $c$ such that $c/a = 1.00$ in the cubic phase. This definition is especially useful when comparing the magnitude of trigonal and tetragonal distortions. In this case the strain in NpFe$_2$ is $-(120 \pm 5) \times 10^{-4}$, which is the largest found in any actinide compound.

In NpNi$_2$ the quality of the powder patterns is rather poor, but we estimate the change in the
rhombohedral angle to be $0.19^\circ \pm 0.02^\circ$ from the broadening of the lines below $T_c$. The absolute value of the strain is then $(43 \pm 5) \times 10^{-5}$. Our results are compatible with the theory that all actinide ferromagnets exhibiting localized $5f$ moments reduce their symmetry below $T_c$ as a consequence of strong magnetoelastic interactions. PuP is the first system to be found with a tetragonal distortion, and NpFe$_2$ has the largest rhombohedral distortion found so far.

The behaviour of the ferromagnetic compounds is in contrast to the actinide antiferromagnets, in which the distortions are either small or negligible [1, 4]. This difference between the ferro- and antiferromagnets is not understood.

Fig. 3. — Diffraction peak broadening observed in selected reflections from PuP as a function of temperature.

References