Depolarization in the diffraction of polarized neutrons by a tungsten-186 single crystal

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An observation of a depolarization of neutrons upon diffraction confirms that the paramagnetic phase of tungsten containing a microscopic cobalt impurity has regions in which the magnetic moments are ordered (magnetic clusters).

Experiments[1,2] carried out in 1968–69 on the diffraction of low-energy neutrons ($\lambda = 1.15$ Å) by single crystals synthesized from isotopic mixtures of tungsten with anomalously short coherent-scattering lengths revealed a slight additional scattering (on the order of a few percent). This scattering was attributed to magnetic clusters in the paramagnetic phase of tungsten, which arise near a microscopic cobalt impurity.[3,4] That such clusters exist has now been confirmed by the observation of a scattering of long-wave neutrons ($\lambda \cong 8.8$ Å) through small angles, accompanied by depolarization,[4] in these samples.

Our purpose in this study was to find a change in the degree of polarization of a neutron beam ($\lambda \cong 1.06$ Å) which undergoes Bragg reflection from the (110) plane of one of the tungsten single crystals used in Refs. 1 and 2. The observation of such an effect would be direct evidence for the existence of magnetic clusters in this tungsten.

Figure 1 shows the overall arrangement of the apparatus, which uses the SPN-100 spectrometer[5] of the Institute of Nuclear Physics, Czechoslovak Academy of Sciences (Řež, Czechoslovakian SSR). The experiments involve measuring the polarization ratio $R = I_+/I_-$, where I_+ and I_- are the rates at which the detector counts neutrons with spins directed parallel to and opposite the magnetic field of the analyzer. A reference point for this experiment was the value measured for R with a single crystal made from natural tungsten. In this case, there should be essentially no change in the neutron polarization upon diffraction, since the contribution of the additional scattering to the Bragg peaks would be negligible in comparison with the nuclear scattering.

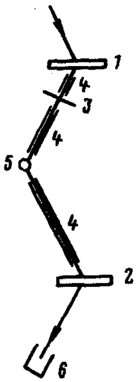

FIG. 1. Overall layout of the apparatus. 1—Polarizing monochromator; 2—analyzer [cobalt-iron (8%) single crystals, (111) reflection]; 3—spin flipper; 4—magnetic path; 5—tungsten single crystal, (110) reflection; 6—neutron detector.

The dimensions of the neutron beam exceeded those of the single crystals, and the single crystals were placed at the same point for the measurements. The results of the measurements of R for various positions of the single crystal in the beam agree within the measurement errors.

The measurements yield the following values for R: (a) for natural tungsten, $R_{\rm nat} = 34.4 \pm 0.8$, and (b) for tungsten enriched to 90.7% in the isotope ^{186}W, $R_{186} = 25.8 \pm 1.5$. Using the known relation between R and the polarizing powers of the polarizer (P_1) and the analyzer (P_2), $R = (1 + P_1P_2D)/(1 - P_1P_2D\phi)$ (see Ref. 6, for example; ϕ is the spin-flip efficiency, and D is the depolarizing power of the sample), we find that the difference between $R_{\rm nat}$ and R_{186} corresponds to a change of $2.9 \pm 0.5\%$ in the initial polarization of the neutron beam. This figure is about half that which would be expected in the case of elastic Bragg scattering of neutrons in a magnetic crystal for a ratio $\sigma_m/\sigma_n = 0.06$ of the cross sections for magnetic and nuclear scattering [the case of scattering by a tungsten-186 single crystal; see Eq. (23.10) in Ref. 7]. A possible explanation is that the magnetic clusters do not fill the entire volume of the single crystal.

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