NMRON studies of cold rolled cobalt foils

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Abstract

Mössbauer effect and modulated adiabatic passage on oriented nuclei spectroscopic studies of cold rolled cobalt foils are presented. The EQI distribution for such foils is compared with single crystal hosts. $B_{hyp}(\mathrm{Fe}Co_{fcc}) = 32.60(4)$ T was also measured via NMRON of beta-emitting ^{59}Fe in Co(fcc).

Key words: Ferromagnets; Nuclear Orientation; Nuclear Magnetic Resonance; Quadrupole Interaction

Single crystal hexagonal (hcp) cobalt is an ideal host for electric quadrupole interaction (EQI) and therefore nuclear quadrupole moment (Q) measurements [1]. In particular such use has increased with the advent of modulated adiabatic passage on oriented nuclei (MAPON) [2]. The MAPON technique, an extension of nuclear magnetic resonance on oriented nuclei (NMRON), can measure EQI distributions even in the presence of masking magnetic inhomogeneity. The Co(hcp) host provides a large lattice generated electric field gradient unique amongst the 3d ferromagnets. Generally the radioactive probe atoms required for NMRON are implanted into the Co(hcp) host since the phase change to cubic (fcc) at ∼400 °C precludes thermal diffusion into single crystals. However damage due to the implantation can be a clouding issue for the smaller EQI's of lighter (eg. 3d) probes and thermal preparation is desirable. These conflicting demands may be satisfied potentially by using a cold-rolled Co foil instead of a single crystal. It has been demonstrated, via Mössbauer effect spectroscopy (MES), that cold rolling not only restores polycrystalline Co foils to hcp but also creates preferential alignment [3]. It is the purpose of this note to explore the EQI distributions of such rolled foils with MAPON precision to evaluate their potential use as hosts for Q measurements. In particular the measurement of Q(^{59}Fe) by comparison of MAPON with MES results of appropriate Fe-loaded Co foils is of future interest. The cold rolling technique may also have wider interest since it is applicable to some other hexagonal materials, for example Gd, foils of which are used in perturbed angular correlation studies [4].

Co(hcp) foils, preferentially aligned with c axis out of the plane, containing ^{57}Co and ^{60}Co probes were prepared for MES and NMRON measurement, respectively. The activity was diffused into high purity commerical foils at 1000 °C, melted in an Ar atmosphere and then cold rolled back to thin foils between tungsten sheets. The resulting hcp foils were etched to remove ∼1 μm of surface material, consistent with the approach of [3] who found this to improve the aligned fraction. The final thickness of foils were 11 μm and 4.2 μm for MES and NMRON, respectively. The coordination and gross alignment were confirmed with x-ray diffraction. Hcp foils containing Fe probes can be prepared in the same way, while the $^{59}\mathrm{Fe}Co$(fcc) NMRON test foil was made by rapidly cooling a Co foil, following thermal diffusion, to retain the cubic structure. MES (source geometry) at room temperature and in zero applied magnetic field on the $^{57}\mathrm{Co}Co$ rolled

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foil verified the findings of [3]. The spectrum (figure 1) has peak ratios of approximately 3:0.5:1 c.f. 3:2:1 for random magnetic axes or 3:0:1 for complete out of plane alignment of magnetic moments (and the easy c-axis). The fit gives B_{hyp}=31.91(1) T and isomer shift of 0.01(1) mm/s relative to α-Fe.

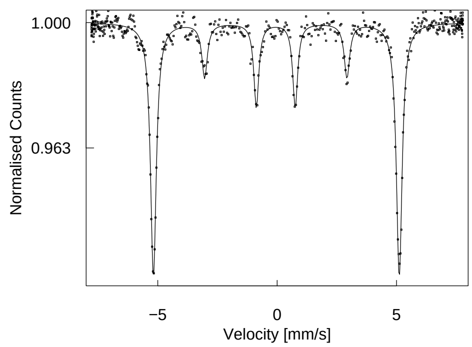

Fig. 1. Room temperature Mössbauer spectra for ^{57}Fe in a cold rolled Co foil.

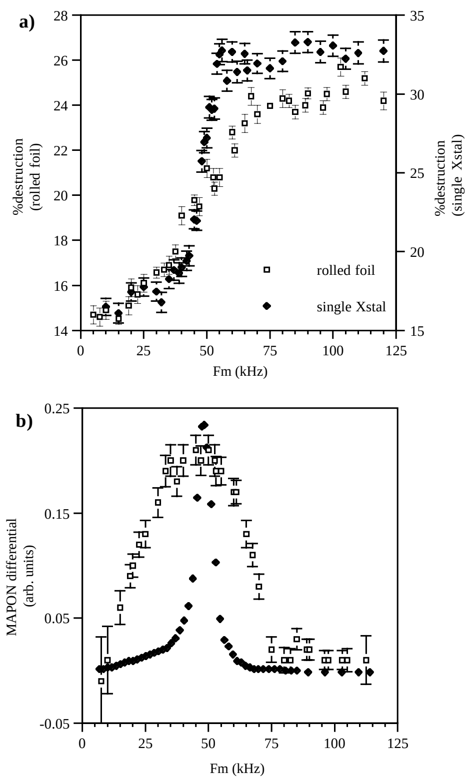

Fig. 2. MAPON raw data (a) and differential (b) for ^{60}Co probes in a cold rolled Co foil in zero applied field. The result for a Co(hcp) single crystal is also shown [5,6].

The ^{60}CoCo rolled foil was cooled to ∼8 mK for the NMRON measurements. Adiabatic fast passage sweep asymmetry indicated a negative EQI consistent with that for single crystal Co(hcp) with magnetisation along the c axis [6]. MAPON was therefore done with sweep up passes only. The post passage spectrum plus its differential, indicative of the EQI distribution, are shown in figure 2a and b, respectively. MAPON of an *in situ* neutron activated single crystal ^{60}CoCo(hcp) is also shown for comparision. The rolled foil distribution is about 6 times broader than the single crystal but the mode value is similar at -45(2) kHz c.f. -48.5(5) kHz. This result implies that the rolled foil host will be useful for the Q(^{59}Fe) measurement. ^{59}FeFe NMRON via beta detection, including the experimental setup, has been described previously [7]. We have extended beta-detected NMRON to Co foils via a measurement on ^{59}FeCo(fcc) (figure 3). The ^{59}FeCo(fcc) resonant frequency is 55.12(2) MHz in 0.3T from which B_{hyp} = 32.60(4) T is derived using μ(^{59}Fe) from [7]. NMRON and MAPON on ^{59}Fe in rolled Co(hcp) foil will proceed after reconfiguration of the beta NMRON setup to allow for the larger applied field required to polarise the foils out of the plane (and therefore create the necessary beta-ray anisotropy).

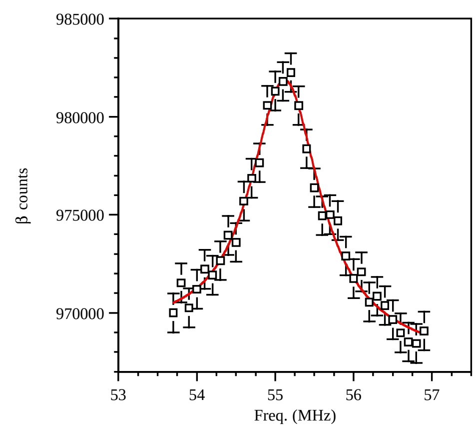

Fig. 3. Beta detected NMRON resonance for ^{59}Fe in fcc cobalt foil with an applied field of 0.3 T.

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