Experimental Evidence for a Large Collinear Electric Field Gradient of Ir in hcp-Co ◇

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It is well known that an electric field gradient (EFG) exists at the nuclear site of atoms dissolved as dilute impurities in the cubic ferromagnetic hosts Fe, Ni, and fcc-Co. The existence of an EFG in a cubic ferromagnetic host lattice has been attributed to an unquenched orbital momentum caused by the spin-orbit interaction of the nd electrons. The principal axes system of this EFG is given by the direction of the magnetization; the electric and magnetic hyperfine interactions are thus collinear. Especially for 5d elements the collinear EFG (CEFG) $eq^{(c)}$ is relatively large. Experimental data exist for Ir$\underline{\text{Fe}}$, Ir$\underline{\text{Ni}}$, Au$\underline{\text{Fe}}$, Au$\underline{\text{Ni}}$, Au$\underline{\text{Co}}^{(\text{fcc})}$, Pt$\underline{\text{Fe}}$, and Pt$\underline{\text{Co}}^{(\text{fcc})}$. As the CEFG originates from the spin-orbit interaction of the nd electrons at the impurity site, such a CEFG could exist also for nd elements as dilute impurities in hcp-Co. In hcp-Co, however, a relatively large EFG exists because of the noncubic lattice structure, denoted as lattice EFG (LEFG) $eq^{(\text{L})}$. Both contributions can be separated due to the different transformation properties against rotation of the magnetization $\vec{M}$ with respect to the crystal axis c. Whereas the CEFG is (to first approximation) invariant against rotation of the magnetization, the LEFG has second-order-tensor transformation properties. In this way we determined $eq^{(c)}$ and $eq^{(\text{L})}$ for Ir in hcp-Co.

Our measurements were performed on ^{188}Ir. Samples of ^{188}Ir$\underline{\text{Co}}^{(\text{hcp})}$ were prepared at the mass-separator ISOLDE/CERN by implanting the precursor isotope ^{188}Hg with $E = 60$ keV into a hcp-Co single crystal disk. ^{188}Ir has $I = 1$, which means that the quadrupole subresonance structure consists of two subresonances, ν_1 and ν_2. Both resonances were measured with NMR on oriented nuclei (NMR-ON), as function of the angle between the electronic magnetization and the single-crystal c-axis, which was varied via the external magnetic field B_{ext}. NMR-ON spectra for $B_{\text{ext}} \perp c$ are shown in Fig. 1.

Additional measurements were performed for $B_{\text{ext}} \parallel c$. The angular dependence of the quadrupole interaction is shown in Fig. 2.

Taking $Q(^{188}\text{Ir}) = +0.484(6)$ b the LEFG and CEFG for Ir in hcp-Co are

$$eq^{(\text{L})} = -1.790(23) \times 10^{17}\ \text{V/cm}^2,$$
$$eq^{(c)} = -0.378(7) \times 10^{17}\ \text{V/cm}^2.$$

In comparison to all known CEFG's of 3d, 4d, and 5d elements in Fe, Ni, fcc-Co the CEFG for hcp-Co shows a completely different behaviour: Whereas the CEFG of Pt, Au, and Hg is very small – the experimental results are consistent with zero – a very large CEFG acts for Ir in hcp-Co. This could be due to a symmetry of the electronic wave function at the impurity site which is broken only for Ir, i.e. near midshell. These findings should stimulate theoretical work on this subject.

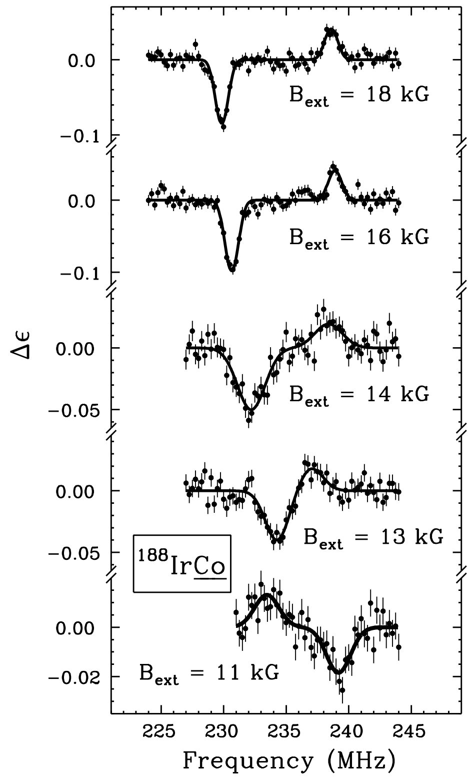

Fig. 1: NMR-ON spectra of ^{188}Ir$\underline{\text{Co}}^{(\text{hcp})}$ measured in 90°-geometry for different values of B_{ext}. It is obvious that the effective quadrupole interaction changes sign between $B_{\text{ext}} = 13$ and 11 kG.

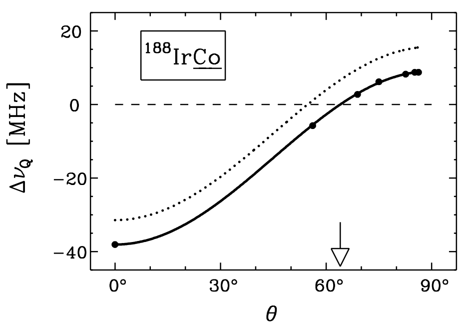

Fig. 2: Dependence of the effective quadrupole splitting on the angle θ between the electronic magnetization $\vec{M}$ and the single crystal c-axis. The zero passage occurs at 64.4(1.2) ° which proves the existence of a collinear EFG of Ir in hcp-Co. The dotted curve represents the lattice contribution to the effective quadrupole splitting

A full description of this work is given in Ref. [1].

References

[1] G. Seewald *et al.*, Phys.Rev.Lett **80** (1998) 3638

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