Antiferromagnetism and PAC

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In recent years the PAC technique has frequently been applied to investigate magnetically ordered systems. Using implanted ^{111}In tracers the local magnetic environment is probed. This can give access in particular to the magnetic hyperfine fields (MHF) acting in antiferromagnets (AF). In the present contribution some PAC experiments in antiferromagnetic ABO_2 compounds with Delafossite structure measured with ^{111}In probes will be shown. These experiments nicely demonstrate the local character of MHF´s.

PAC measurements in magnetically ordered systems are easy to analyze if no combined interactions arise as in a cubic defect-free lattice. Such conditions are found in metallic ferromagnets as Fe, Co and Ni, but also in most monoxides which crystallize in the NaCl-structure like NiO [1,2], CoO [3,4], FeO [5] and MnO [6]. In these oxides the strong magnetic coupling is due to the super-transfer by the oxygen ions [7]. In PAC measurements the cubic AF´s show a similar behavior as ferromagnetic materials: Below the Néel temperature T_N, in the antiferromagnetically ordered phase, probes on substitutional cation sites sense a MHF which has a temperature dependence according to a modified Curie-Weiss-Law : $\omega_L(T) / \omega_{L0} = (1 - T / T_N)^{\beta}$. Such measurements allow the determination of the critical parameters T_N and β [8]. In most cubic AF oxides the experimental value for β is close to 0.38 [3,9,10], the theoretical value expected for 3d Heisenberg-magnets. Finally, the AF phase transition can be very useful in the identification of the substitutional lattice site among other disturbed sites (for example in NiO [2]) or in the case of combined interaction (for example CuO [11]). Fig. 1 is to demonstrate why ^{111}In(EC)^{111}Cd probes observe the

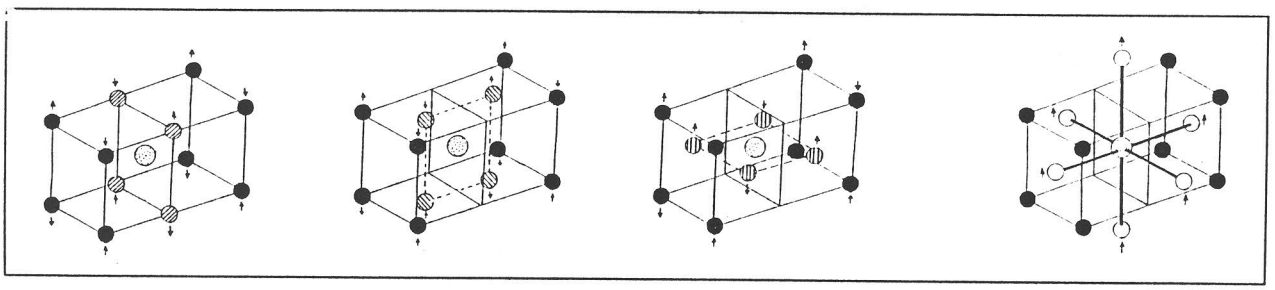

Fig. 1: Spin directions in a cubic AF oxide: Only the six second next neighbors contribute to the MHF at the probe (dotted circle)

MHF in a cubic AF oxide like in a ferromagnetic metal. Only the cations are shown which build an fcc-lattice in the NaCl-structure. The probe atom is dotted, the arrows indicate the spin directions. The first three pictures show that in all cases the four of the twelve next neighbor cations in a single plane cancel their spins.

Only the six second next neighbors have parallel spins and produce the MHF at the probe. In fact, only these cations are bound directly via oxygen ions to the probe atom.

Delafossites crystallize in a hexagonal layered structure. The trivalent B cations are at the center of regular oxygen octahedra which are connected by monovalent A ions. $^{111}In^{3+}$ ions were implanted and they were expected to substitute the B elements in the Delafossite structure. For several of the compounds Cu(Al, Cr, Fe, Nd, Y)O_2 and Ag(Cr, In)O_2 the temperature dependence of the EFG for ^{111}Cd at the B-site was measured in the range 14 -1073 K. At least one EFG with axial symmetry was found in each compound [12]. Its hyperfine parameters revealed only a weak dependence on the measuring temperature T_m. Typical spectra taken with $CuFeO_2$ are shown in Figs. 2a and 2c.

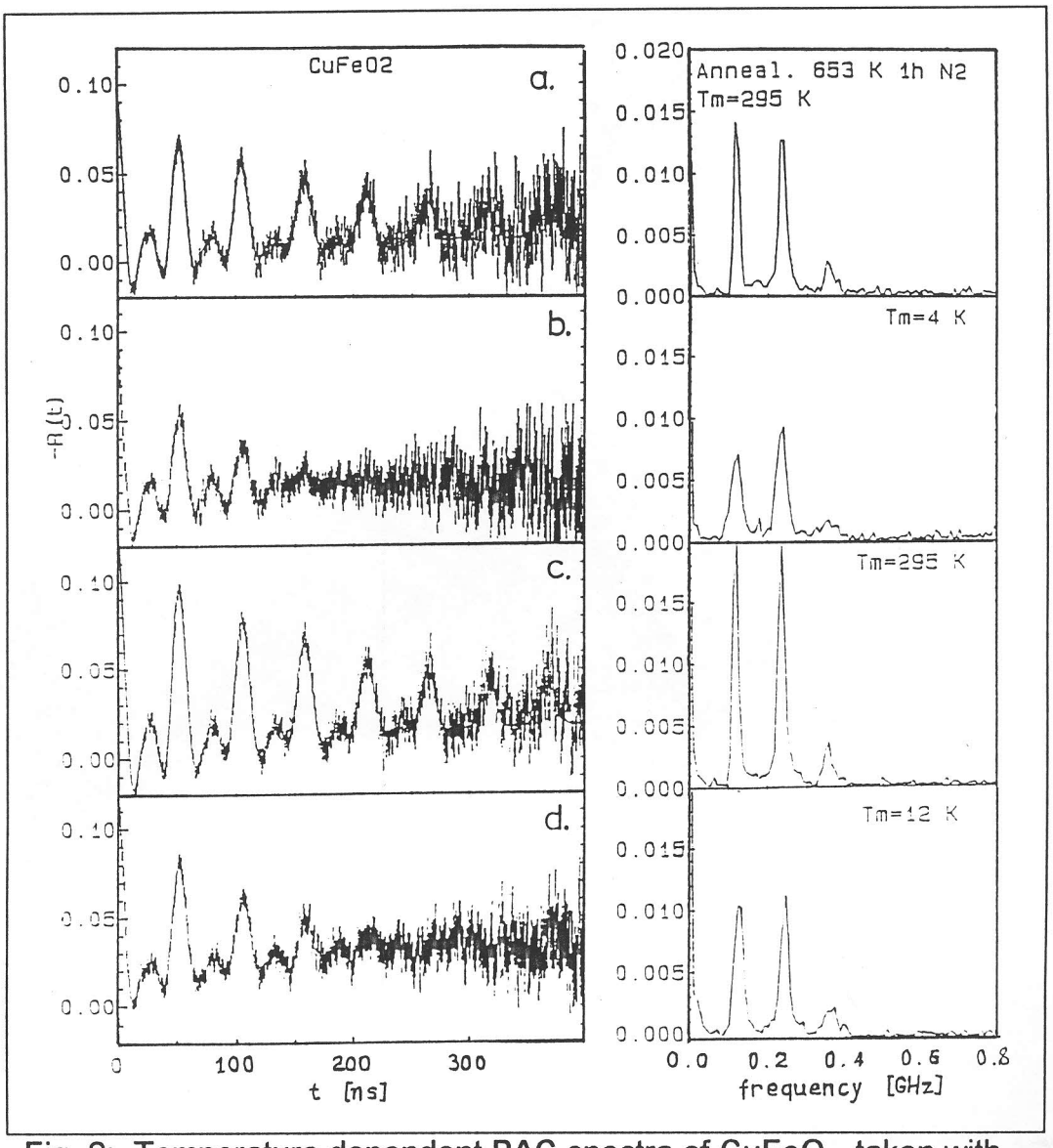

Fig. 2: Temperature dependent PAC spectra of $CuFeO_2$, taken with with BaF_2 - (a,b) or with NaI-detectors (C,d). For b) the sample was suspended in liquid He.

The antiferromagnetic compounds $CuFeO_2$, $CuCrO_2$ and $AgCrO_2$ were studied below their respective Néel temperatures (T_N =11 - 25 K [13,14,15]). Due to their crystal structure (planes of magnetic ions with a triangular lattice) the spins are highly fru-

strated at these temperatures [13]. For $CuFeO_2$ only a slight damping of the R(t)-function was observed below the Néel temperature (see Fig. 2b) which is the result of combined interaction of the structural EFG and a weak magnetic field of $B_{hf} \leq 0.3T$. On the other hand, with Mössbauer spectroscopy (MS) a strong magnetic field of 51.7T [2] has been observed at 4.2 K, typical for Fe^{3+} ions. In Fig. 3 we try to explain this surprising result: MS experiments do not influence the frustrated spin system (left part of Fig. 3), but with ^{111}In (dotted) in the center of the hexagon the six next

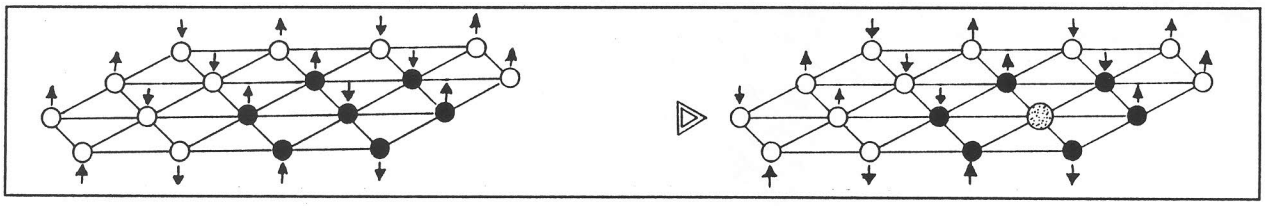

Fig. 3: Spin frustration in a triangular lattice and its local cancelling by the ^{111}In probe

Fe-neighbours can establish the AF-order, simply by a spin-flip in the marked row of Fe-atoms, unhindered by the frustrated rest of the 2-dim triangular lattice. Consequently the local MHF for the PAC probe vanishes. The small observed field of 0.3 T may have its origin in the same plane or, even more interesting , it may be the interaction with neighbour-planes which up to the present has only be observed in metallic multilayers. A similar behaviour was found for $AgCrO_2$ and $CuCrO_2$. Here the MHF is also very small, but clearly larger than in $CuFeO_2$. These two Delafossites show a difference to $CuFeO_2$ in the AF spin-structure of the parallel planes. This may be a hint for interplanar magnetic interaction. The triangular AF`s promise new interesting PAC experiments, either in the comparison with MS experiments or in comparison with cubic AF`s. The present study already proves the mainly local sensitivity of the PAC also for MHF`s, similar to the well known case of EFG`s.

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