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Departure from the independent electron behavior in itinerant magnets

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Report:

Departure from the independent electron behavior in itinerant magnets

Metallic iron is generally assumed to be a prototype of a system whose valence electrons are nearly independent. We report on a novel way to determine the spin polarization of the core hole by using Auger decay spectroscopy with light circularly polarized perpendicular to the magnetization direction. This method does not suffer from the inherently low count rates associated with spin detection. It demonstrates the existence of strong $3d$ electron correlation even in itinerant materials and the breakdown of the one-electron approach.

In x-ray photoemission an electron is excited from a core level into a continuum state far above the Fermi level. The remaining core hole is polarized by its interaction with the magnetically aligned valence band orbital and spin moments [1]. As indicated by magnetic circular dichroism measurements in photoemission **[2]** the $2p_{3/2}$ level contains more majority than minority spin. In a one-electron model the net spin polarization of the core hole should be zero.

We use the Auger decay to quantify the spin polarization of the core hole. In the $L_3M_{2,3}M_{2,3}$ Auger process, $2p^63d^n \rightarrow 2p^53d^n\varepsilon \rightarrow 2p^63p^4\varepsilon\varepsilon'$, the intermediate $2p$ core hole state, created after photoelectron emission, decays by Coulomb interaction into a two-hole final state $3p^4$ under emission of an Auger electron ε' into the continuum. Since the magnetic $3d$ *is* a spectator shell for an Auger final state with two core holes, the integrated dichroism signal, which measures the difference between the number of holes created with left and right circularly polarized light, should be zero. We have

shown previously that in the case of resonant photoemission spin conservation in the initial x-ray absorption process where a $2p$ electron is excited into an empty $3d$ state causes an alignment of the intermediate $2p$ core hole. This results in a non-zero dichroism signal in the geometry employed in our experiments. [3] For the Auger process, however, this mechanism will not be present and dichroism should be zero.

The Auger spectra measured at a photon energy of 900 eV are shown in Fig. 1. Similar to the $2p$ photoemission spectrum, the $L_3M_{23}M_{23}$ Auger spectrum has high-spin states at the low binding energy side and low-spin states at the high binding energy side. For the magnetic dichroism we find a value of 0.06 ± 0.02 with respect to the background-corrected peak intensity with unpolarized light. From this we estimate using Eq. (6) in Ref. [4] that the spin polarization of the core hole is equal to O. 19+0.06. The identical spectral lineshapes of the dichroism in the Auger (solid symbols) and resonant photoemission (solid line) spectra in Fig. lb indicate a similar origin, viz. the orientation of the intermediate $2p$ core hole. The non-zero dichroism in the Auger decay for Fe shows the existence of a strong mechanism which aligns the core hole and valence spins. We can presently only speculate about its origin but the absence of this effect in Ni [3] seems to indicate a connection with the (delocalized nature of the spin-polarized valence electrons.

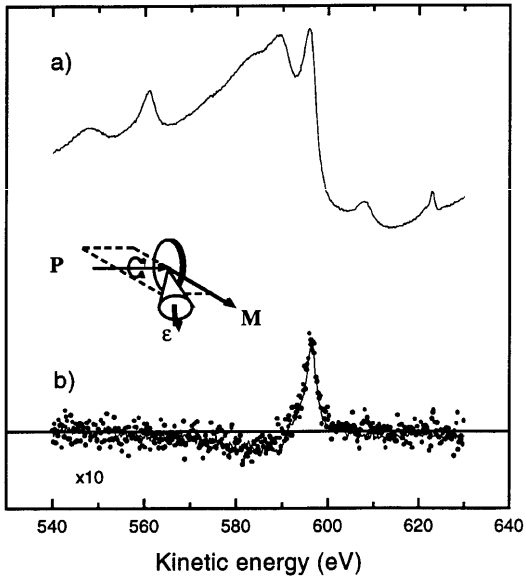

FIG. 1 The Fe $L_3M_{23}M_{23}$ Auger spectrum of Fe/Cu(110)' measured at a photon energy of 900 eV. (a) Sum of the spectra obtained with left and right circular polarization perpendicular to the magnetization direction; (b) difference spectrum of the Auger (solid symbols) and the resealed resonant $2p\,3p\,3p$ photoemission (solid line) spectra.
Inset – Experimental geometry: **P is** the helicity vector of the incident circularly polarized light, **M** is the sample magnetization direction and **ε** gives the cone in which the emitted electrons are

Spin-dependent properties can be obtained in spin-integrated measurements because of the spin-orbit coupling of the $2p$ core hole. The detection of core hole polarization in both resonant photoemission and Auger decay using circularly polarized x-rays adds considerably to the possibility to study the magnetic properties of materials. The localized and element specific nature of these probes enables their use to investigate surface and interface magnetism in solids, thin films and nanostructures.

REFERENCES

1. G. van der Laan, Phys. Rev. B 51, 240-249 (1995).
2. C.M. Schneider, D. Venus, and J. Kirschner, Phys. Rev. B 45,5041-5044 (1992).
3. B.T. Thole, H.A. Dürr, and G. van der Laan, Phys. Rev. Lett. 74, 2371-2374 (1995).
4. G. van der Laan, H.A. Dürr, and M. Surman, J. Electron Spectrosc. Relat. Phenomen. 78, 213-216 (1996).