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## Report:

In this continuing experiment, on magnetic scattering of transition metal oxides, K-edge resonant x-ray magnetic scattering (RXMS) experiments have been carried out on the antiferromagnet NiO to study its electronic and magnetic properties. Two resonant enhancements of the magnetically scattered intensity were observed. Using polarization analysis of the scattered beam we were able to distinguish between a quadrupolar transition (1s-3d) and a dipolar transition (1s-4p), which gives information about the spin polarization in those bands. Furthermore the azimuthal dependence of the intensity has been studied in detail.

The experiment has been carried out at energies in the range of 8.30 keV - 8.40 keV, which contains the Ni K-edge (8.33 keV). All measurements were done at room temperature at which NiO is in an antiferromagnet state of type II ($T_N$ = 523 K). The magnetic moments are ferromagnetically aligned in the (111) planes and antiferromagnetically aligned in between two (111) planes. The NiO single crystal, with a (111) surface, was mounted on the four circle diffractometer with the (111) direction in the scattering plane. The crystal was mounted on a special rotation stage, allowing azimuthal scans around the propagation vector and which also gives access to larger angles in θ, and thus more magnetic Bragg peaks. Special care had been taken in optimizing the incident beam size in order to get rid of contributions from different grains of the crystal.

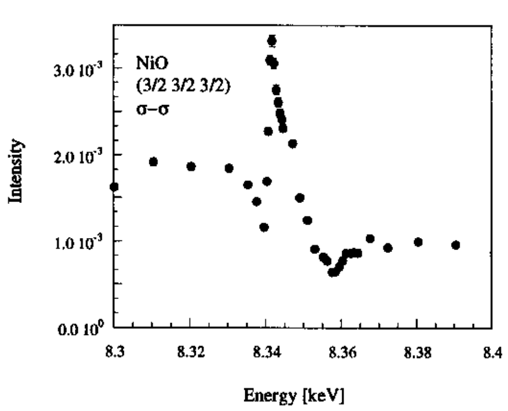
Three magnetic reflections have been studied in detail: the (1/2 1/2 1/2), (3/2 3/2 3/2) and (5/2 5/2 5/2) Bragg reflection. On every reflection the magnetic intensity has been measured as a function of photon energy and for various azimuthal positions. Polarization analysis, using a PG (006) analyzer crystal has been performed for all positions and energies. As absorption gets important above the edge, all intensities have been corrected using Fluorescence measurements.

In a simple picture resonant magnetic X-ray scattering is interpreted in terms of electronic multipole transitions leading an electron from a core hole to a state above the Fermi level. Strong enhancements are expected when the transition probabilities exhibit an asymmetry due to spin-orbit coupling and spin polarization of the intermediate states. In the case of the K-edge two resonant channels are expected. The first one leads a 1s electron via weak quadrupolar transition to the highly polarised 3d states. A net orbital moment in the ground state is also needed in order to observe this quadrupolar transition. The second resonant channel brings the 1s electron via dipolar transition to the 4p level, which is only weakly spin polarized and exhibits smaller spin-orbit coupling.

During this experiment for the first time both resonances have been observed, whereas in former studies only the quadrupolar transition has been evidenced. The figures show the integrated magnetic intensity of the magnetic Bragg reflection (3/2 3/2 3/2) as a function of energy in the two polarization channels $\sigma\sigma$ and $\sigma\pi$. The first resonance at 8.344 keV is present in both channels, which is typical for quadrupolar transitions. The presence of this resonance confirms our previous measurement of the existence of orbital moment in NiO, using non resonant magnetic x-ray scattering. The second one at higher energy corresponds to the dipolar transition. Here the enhancement of the intensity can only be observed in the rotated $\sigma\pi$ channel. The azimuthal dependence of the magnetically scattered intensities are necessary, as the intensity measured is a sum of the 3 different magnetic domains (threefold symmetry of the (111) direction) and the relative direction of the magnetic moments compared to the direction of incoming and outgoing beam play an important role in the amplitude of the enhancement. It is interesting to mention that in the $\sigma\pi$ channel we observed in the vicinity of the quadrupolar resonance a $2\pi/3$ modulation whereas a $\pi$ modulation would be expected in the existing models. This might be due to the fact that the existing model, based on an atomic picture, does not take into account the crystal local symmetry.

These results have to be put on a quantitative basis, including a more complete theoretical approach than already given by existing models. Works on different oxides, like MnO and CoO, are already in progress and interesting properties of their resonant behavior are expected.

These first results have been presented by the authors in the ESRF highlights 1997/1998.



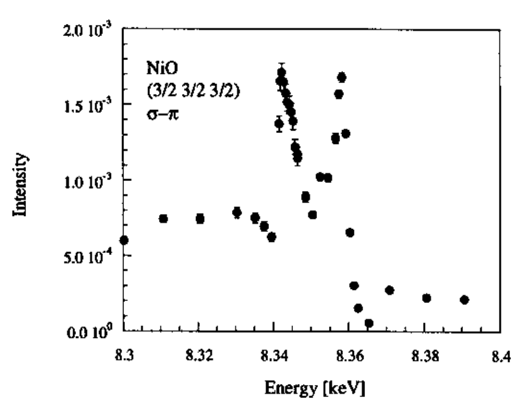




Figure: On the left the energy dependence of the resonant magnetic scattering intensity at the K-edge of Ni in the $\sigma\sigma$ channel, and on the right in the $\sigma\pi$ channel.