Polarization analysis in Resonant X-ray Bragg Diffraction by Hematite at the Fe K-edge.

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Abstract:

Bragg diffraction of x-rays close to an absorption edge unveils a rich variety of phenomena, which arise from complex electronic structures. Particularly important is the study of dipolar and quadrupolar resonance events. They give us information on the presence not only of charge, orbital, magnetic ordering, but also more exotic ones such as toroidal moment or presence of orbital currents. The use of circularly polarized light can help to distinguish the different events that are encountered when performing such experiments. Study of well-known material as hematite is of vital importance in order to test models that can be subsequently applied to more complex materials such as multiferroic materials.

Motivation:

Hematite (α-Fe₂O₃) has corundum structure and presents an antiferromagnetic behavior below the Néel Temperature, T_N=950K. Its magnetic structure can be described as a weak ferromagnetism at room temperature and as a fully compensating, collinear antiferromagnetism below the Morin Temperature, T_M = 260 K [1].

Finkelstein et al. [2], were the first to perform resonant Bragg diffraction experiments in hematite, near the Fe K-absorption edge. They observed a six-fold azimuthal modulation of the diffracted intensity at (0,0,3)_H as a function of the azimuthal angle. As electric dipole-dipole (E1-E1) transitions were not observed, the observed intensities were attributed to E2-E2 (parity-even) and, or E1-E2 (parity-odd). Recently, magnetic and non-magnetic x-ray diffraction were studied near Fe K-edge of hematite at room temperature and 150 K, and compared to limited, symmetry-based calculations [3]. Reflections (0,0,3)_H and (0,0,9)_H show a resonant peak in the pre-edge energy region, with measured intensities not fully explained by simple calculations.

Experimental details:

We performed a detailed investigation of the (0,0,3)_H and (0,0,9)_H reflections above and below T_M in the vicinity of the Fe K-edge, 7.1115 keV as proposed in Ref. [4]. The polarization of the incident X-rays was changed from linear to circular by use of phase plate retarders.

Results:

In Figure 1 we show energy scan at fixed wave vector at the (0,0,9)_H reflection in hematite, similar as the one reported by Finkelstein et al. [3]. Polarization analysis suggests that most of the resonant contribution is in the σ₁π channel. In Figure 2 (left) we show the azimuthal angle scan of the (0,0,9)_H reflection. It is possible to describe the observed modulation with the model presented by Lovesey et al. [4].
The expressions for a circular polarized primary beam were present in the work of Lovesey et al. [4] showing a different dependence in the intensity on the azimuthal angle, $\psi$, for the different Events. In the case of E2-E2 is related to $\sin(6\psi)$ and for the E1-E2 event depend with $\sin(3\psi)$. Notably, induced intensity from the parity-odd, E1-E2, event is a product of a magneto-electric octupole and a polar quadrupole, a measure of local chirality, which has not been directly observed with any material, to the best of our knowledge. In the case of an E2-E2 event, induced intensity is a product of an octupole and a hexadecapole. As it is shown in Figure 2 (Right) the dependence seems to be a tree-fold. From this we can expect that the E1-E2 will be the event with more weight in this case.

Conclusion and Future Work:

For the moment we have information gathered at the forbidden reflections $(0,0,3)_{h}$ and $(0,0,9)_{h}$ above and below the Morin temperature, for both with and without circular polarized analysis. As it is briefly discussed in the previous item, the two events that may be responsible from this behaviour, E1-E2 and E2-E2, seems to govern depending on the temperature. For accomplishing the goal of understanding the relation between the different events, E1-E2 and E2-E2, present in this kind of analysis additional beamtime will be requested.

References