Testing the switching of polar structure of Magnetite by an ac electric field using time resolved diffraction

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We have performed a continuation of our first experiment at P09 [proposal- I-20120143], where we investigated polar structural switching of Magnetite by an applied ac electric field using time resolved diffraction technique. The 120K Verwey transition is Mgnetite is the classicle example of charge ordering (CO)[1]. Macroscopic indications of ferroelectricity in mganetite has been reported decades ago[2] and recently proposed as relaxor ferroelctric[3]. However, ferroelectricity implies also switchability by an electric field, and the macroscopic indications of this are unclear. Because of presence of residual conductivity in the ferroelctric phase the experiment needs to be time resolved [report-proposal-I-20120143]. Our aim of the experiment was to test the intrinsic ferroelectric behavior of magnetite by monitoring intensities of selected Bragg peaks under periodically applied external electric field by time resolved diffraction experiment. With the promising preliminary results obtained from our test experiment, we continued testing several reflections under the same conditions as mentioned in proposal I-20120536. However, during our test experiment we had faced major problem of heat-load on the sample developing from the switching current as well as from the voltage. With the satndard cryostat we could reach only ~11 K and the high temperature partially obscured the switching due to increased ohmic conductivity. To overcome this problem and to improve the result this time we used a cryostat with a lower base tempearture of 1.7 K employing Joule-Thomson cooling . However the decision to use this crystat turned out to be a mistake, because the thermal decoupling associted with the Joule-Thomson stage implied that the heat-load from the resisitive heating of the sample could not be overcome, and consequently the reachable temperatures were even higher than in the test experiment. Despite repeated trials on several reflections, with the hope of reproducing the effect observed in the test experiment, we were unable reproduce the results and the result one of those reflections (-1, 1, 9) is shown in the figure (a). Eventually we found out that main reason for not observing the switching effect was a partial short through a defect (crack in the crystal) which was confirmed by resistance measurement, showed ~3kΩ. Given that the temperature and the heat load turned out once again to be a major detriment for next time, we plan to use a flow cryostat and at the time sudy a thin film rather than a thick crystal, so that much lower voltage can be used.

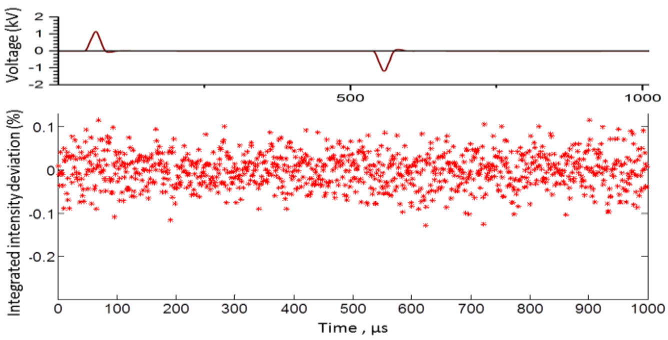

Figure: The intensity of the Bragg reflection (-1 -1 9) and the upper panel shows the applied periodic high voltage (1.2 kV) at energy 8.5 keV.

References

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