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ESRF

Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF.

Once completed, the report should be submitted electronically to the User Office via the User Portal:

https://wwws.esrf.fr/misapps/SMISWebClient/protected/welcome.do

Reports supporting requests for additional beam time

Reports can be submitted independently of new proposals – it is necessary simply to indicate the number of the report(s) supporting a new proposal on the proposal form.

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

Reports on experiments relating to long term projects

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

Published papers

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

Deadlines for submission of Experimental Reports

- 1st March for experiments carried out up until June of the previous year;
- 1st September for experiments carried out up until January of the same year.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report, in English.
- include the reference number of the proposal to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

ESRF	**Experiment title:** Structural characterization of topological insulators epitaxial layers	**Experiment number**: HE-3932
Beamline: BM-23	**Date of experiment**: from: 5.10.2012 to: 10. 10. 2012	**Date of report**: 21.2.2013 *Received at ESRF:*
Shifts: 15	**Local contact(s)**: Cornelius STROHM	

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Report:

The topological insulators are recently found family of materials. These materials have in bulk a band gap so that they behave like ordinary insulators or semiconductors, but they exhibit in addition a gapless surface or edge states that are topologically "protected" and immune to impurities or geom etrical perturbations (see the reviews [1,2]). Magnetic dopants in three dimensional (3D) topological insulators (TI) break the time reversal symmetry and result in the opening of a gap at the Dirac point which may lead to a number of striking topological phenomena [3]. We have studied Bi_2Se_3 and Bi_2Te_3 topological insulator epitaxial layers with manganese doping using EXAFS at Mn-K edge to determine Mn atom position in the TI crystal lattice.

The aim of the experiment was to determine the manganese position in the topological insulator Bi_2Te_3 and Bi_2Se_3 layers in the epitaxial layers of topological insulators and to correlate this information with the other x-

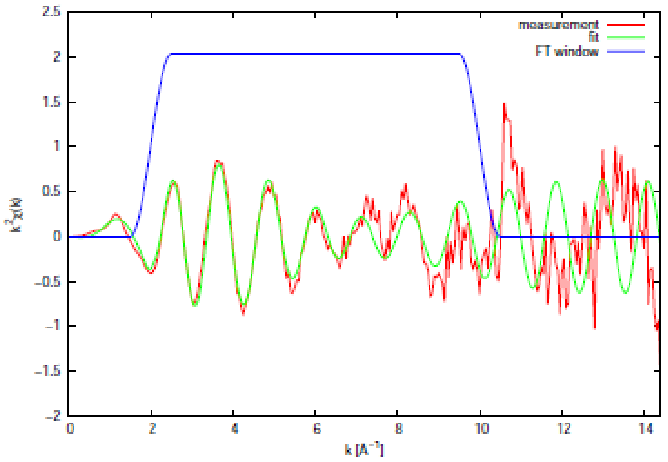

Fig. 1: Measured EXAFS spectrum and the best fit on the 500 nm thick $(Bi,Mn)_2Te_3$ layer grown on BaF_2 substrate. The nominal Mn concentration is 6 %.

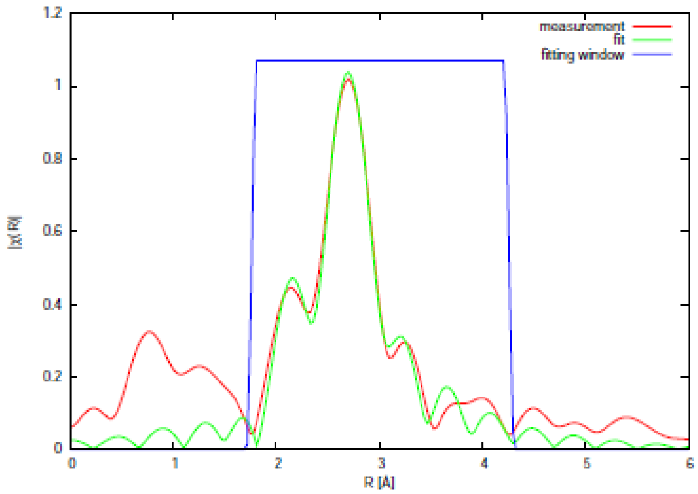

Fig. 2: Fourier transform to the real space coordinate of the measurement shown in Fig. 1.

ray diffraction study of the layer structure and subsequently wit the electronic structure studied using angle-resolved photo-electron spectroscopy measurement.

Two sample series were grown using molecular beam epitaxy on the cleaved BaF_2 (111) substrates by JKU Linz. The thickness of the layers was 300 nm to 500 nm. The first sample series consisted of manganese doped Bi2Te3 TI layers and the other were manganese doped Bi2Se3 TI layers. The nominal Mn concentration of the layers was varied from 2 % up to 13 % for both sample series. The measurement was performed at the Mn-K edge (6.54 keV) for the angle of incidence of 2.5 deg and Mn fluorescence signal was detected.

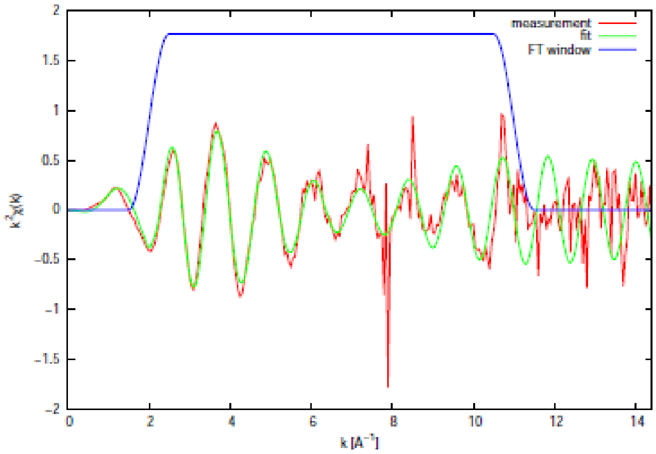

Fig. 3: Measured EXAFS spectrum and the best fit on the 500 nm thick $(Bi,Mn)_2Te_3$ layer grown on BaF_2 substrate. The nominal Mn concentration is 13 %.

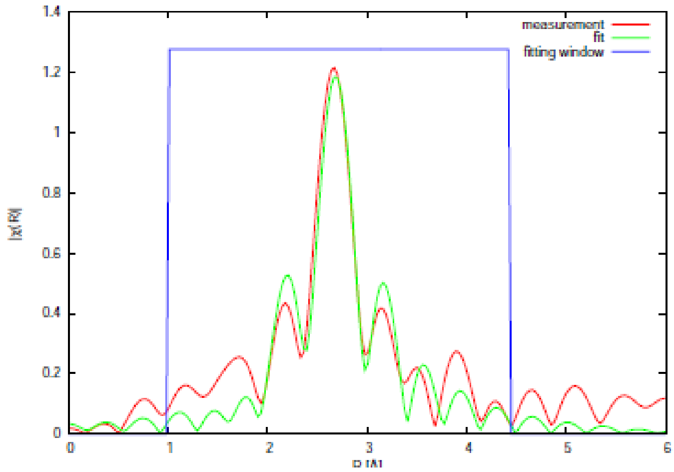

Fig. 4: Fourier transform to the real space coordinate of the measurement shown in Fig. 3.

The resulting collected spectra for (Bi,Mn)2Te samples with nominal Mn concentration of 6% and 13% are shown in Figs. 1 and 3, respectively. The collected spectra were analyzed using standard FEFF software. The best correspondence was achieved for the Mn in the interstitial position between two tellurium planes (so-called Van-der-Waals gap). The best fit are shown along with the measured spectra in Figs 1-4.

The resulting distances of the nearest-neighbor atoms are presented in table 1.

Sample	nominal Mn concentration	Mn-Te distance [Å]	Mn-Bi distance [Å]
2823	6 %	2.916 ± 0.008	3.04 ± 0.02
2822	9 %	2.918 ± 0.008	3.03 ± 0.02
2826	13 %	2.91 ± 0.01	3.06 ± 0.03
Nominal distance in undistorted lattice		2.885	3.050

The EXAFS data measured on $(Bi,Mn)_2Se_3$ show more complicated behavior and their interpretation is still in progress.

References

[1] X. L. Qi and S. C. Zhang, Physics Today **63**, 33 (2010).
[2] M. Z. Hasan and C. L. Kane, Rev. Mod. Phys. **82**, 3045 (2010).
[3] X. L. Qi and S. C. Zhang, Rev. Mod. Phys. **83**, 1057 (2011).