EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Letter of Intent to the ISOLDE and Neutron Time-of-Flight Committee

Emission Mössbauer spectroscopy using ^{57}Co to study magnetism in C-implanted ZnO

K. Bharuth-Ram[1], H. Masenda[2], M. Moodley[3], D. Naidoo[2], H. P. Gunnlaugsson[4], T. B. Doyle[5], C. Ronning[6] and P. Schaaf[7]

[1]Durban University of Technology, South Africa, [2]University of the Witwatersrand, South Africa, [3]University of KwaZulu-Natal, South Africa, [4]University of Iceland, Iceland, [5]iThemba LABS, South Africa, [6]Friedrich-Schiller University Jena, Germany, [7]Technisch Universität-Ilmenau, Germany.

Spokespersons:	K. Bharuth-Ram (kbr@tlabs.ac.za)
	H. Masenda (Hilary.Masenda@wits.ac.za)
Local contact:	Karl Johnston (Karl.Johnston@cern.ch)

Abstract

We plan to conduct ^{57}Fe-Mössbauer spectroscopy (MS) investigations on carbon (C)-implanted ZnO, with the ^{57}Fe state populated via the long-lived precursor isotope ^{57}Co. These measurements will supplement and extend the on-line emission MS measurements which we have completed and in which the ^{57}Fe probe was populated in the β-decay of implanted radioactive precursor ^{57}Mn.

This LOI presents our proposed intention to implant ^{57}Co in single crystal and thin film ZnO samples pre-implanted with different concentration of C ions.

The implanted samples, after due clearance by the Radiation Protection Division, will be transferred to our home laboratories for emission Mössbauer Spectroscopy, magnetization and several other related analyses.

Science case:

Our LOI springs from two main considerations. Firstly, our recent emission Mössbauer Spectroscopy (eMS) studies on ZnO implanted with C ions to concentrations of 4.0, 1.0 and 0.4 at. % show quite interesting results (not yet published, manuscript in preparation). The C-implanted ZnO samples show no magnetic structure for the 4 and 1 at. % C incorporated samples, but strong magnetic structure is observed in the eMS measurements on the 0.4 at. % C implanted sample. Temperature dependent studies show the spin-lattice relaxation time to be longer than observed for virgin ZnO[1].

Secondly, a recent study of the magnetic properties of ZnO thin films implanted with different concentrations of C ions indicates that the site occupancy depends on the C concentration [2]. First principles calculations based on density functional theory shows appreciable magnetic moments only when the C atom occupies either the substitutional O site or the interstitial site [2].

Proposal:
We propose to do systematic investigations on the magnetic properties of ZnO samples, single crystal and PLD deposited thin films, implanted with C ions to concentrations in the range 0.1 to 1.0 at.%. Our primary investigative tool will be emission Mössbauer spectroscopy (eMS) following the implantation of the long-lived precursor isotope ^{57}Co into the C-implanted samples. eMS measurements will be conducted as functions of C concentration and temperature (down to 20-40 K). Complementary characterization techniques include magnetization measurements (VSM at iThemba LABS, SQUID at the University of Johannesburg), X-ray absorption near edge analysis, Atomic Force Microscopy (AFM) and RBS analysis.

Expected outcome:
A clearer understanding of the mechanisms that induce ferromagnetic ordering in the different C concentration regimes as well as of the factors that inhibit magnetic ordering.

Samples:
A total of 10 samples will be studied, comprising 5 ZnO single crystal samples and 5 PLD deposited thin ZnO films, implanted respectively with 1.0, 0.8, 0.6, 0.4 and 0.2% C.

Implantation requirements:
^{57}Co yields of ~5×10^{7} ions per μC of beam current has been produced at ISOLDE in 2010 with ZrO_2 targets and the VADIS ion source. Yields with the RILIS ion source are expected to be almost 2 times higher.

For the collection of data with sufficient statistics, approx. 4×10^{12} ^{57}Co ions per sample are required. Allowing for storage and Radiation Safety tests at ISOLDE before transfer of samples to home institutes may necessitate increasing the implanted concentration to 6×10^{12} ^{57}Co ions per sample.

We would request 6 samples to be implanted in 2018 and a further 4 samples in 2019.
Further request for implantations in 2020 will be dictated by the results achieved.

In addition, these experiments would require the presence of support from CERN's RP services during working hours.

References
[1] T.E. Mølholt et al., *Phys. Scr.* **T148** (2012) 014006
[2] K. Saravanan et al., *Phys. Che. Chem. Phys.* **19** (2017) 13316