LETTER OF INTENT

ISOLDE Secretariat
PH Department
CERN
CH-1211 Geneva 23

Dr. Kay Potzger
Forschungszentrum Dresden-Rossendorf
Bautzner Landstraße 400
01328 Dresden
k.potzger@fzd.de

CERN-INTC-2010-002 / INTC-I-084
06/01/2010

Dear Madame/Sir

I would like to express my intention to perform setup and initial experiments at the former ASPIC experiment at ISOLDE/CERN between 07/2010 and 06/2013. An usual application for beamtime at ISOLDE will be submitted later.

General goal

At the mass separator ISOLDE/CERN, basing on know-how from the ASPIC experiment, a novel in-situ ultra-high vacuum (UHV) chamber for multilayer growth and perturbed angular correlation spectroscopy (PACS) using radioactive probes will be set up within the project (ASPIC2). ASPIC2 will have the following scientific goals after setup:

(1) In-situ determination of the probe location during growth (diffusion, segregation).
(2) Depth resolved investigations of magnetic phenomena related to spin injection from a ferromagnetic into a non-ferromagnetic metal.
(3) Other goals related to the in-situ analysis of metallic or semiconducting multilayers on a local scale

The difference to the old ASPIC setup is the following: ASPIC2 will focus on doping of multilayer systems mainly by means of low-energy direct implantation. In contrast, ASPIC was a system for soft-landing indirect deposition of radioactive probes on ultra-clean metal surfaces, i.e. dedicated to surface physics. The latter required a complicated mechanics for the indirect deposition and very low residual pressure. In fact, the handling of ASPIC2 will allow other users to run the experiment without problems. The scientific possibilities of ASPIC2, i.e. atomically resolved research on multilayers, will also be attractive to a broader potential user community of applied researchers.

Detailed scientific and technical goals

ISOLDE as large scale facility is able to provide ultra-clean radioactive probes. Most of the experiments at ISOLDE are based on implantation of probe ions and ex-situ treatment/analysis. By contrast, ASPIC2 will allow in-situ investigations of multilayers during their preparation. Generally, the application of the in-situ technique will allow the introduction of the radioactive probes during the deposition process of the layers without breaking the vacuum as well as the applicability of short-living isotopes. ASPIC2 will also allow the change of investigated materials to various metals or semiconductors after each future measurement period so that it is interesting for a broad user community. The initial measurements after the setup will be performed by the group from the Forschungszentrum Dresden-Rossendorf and collaborators. They will focus on depth resolved investigation of spin currents injected from a ferromagnetic into a non-ferromagnetic layer. The spin-injection will be investigated by measuring the magnetic hyperfine field $B_{hf}(x)$ at a probe nucleus located in a defined depth of the non-magnetic metal. $B_{hf}(x)$ is directly proportional to the spin-splitting of the electronic s-states at the probe nucleus. Therefore the detailed setup-strategy of ASPIC2 mainly focuses on that topic. The thin film growth chamber thus will contain sources for magnetic and non-magnetic metals and analysis tools for the film characterization. The major analysis technique for ASPIC2 is perturbed angular correlation spectroscopy (PACS) which will be applied to the ASPIC2 system. By PACS, the electric quadrupole interaction tensor including the electric field gradient (EFG) and the asymmetry parameter, and the magnetic hyperfine field vector B_{hf} can be measured at the same time, giving combined information about local structural and magnetic properties. The detailed goals of the project are listed as follows:

(1) Development of an ultra-high-vacuum chamber for deposition of thin metallic films from an e-beam evaporator (growth chamber). Equipment with sources for other materials will be possible.
(2) Connection of the growth chamber to the modified implantation chamber from the old system ASPIC.
(3) Development of a sample manipulator for
    - Film deposition
    - PAC measurement at low temperatures
    - Masking the sample (shutter)
    - Electric contacting for generation and analysis of spin-polarized currents (Prober).
(4) Adapting the PAC measurement to the new UHV system.
(5) Test growth of metallic magnetic multilayers and introduction of the radioactive probes. Initially the system Co/Cu will be prepared.
(6) Measurement of the magnetic hyperfine field B_{hf} at the probe nuclei located in the Cu layer in the steady state of a flowing current.

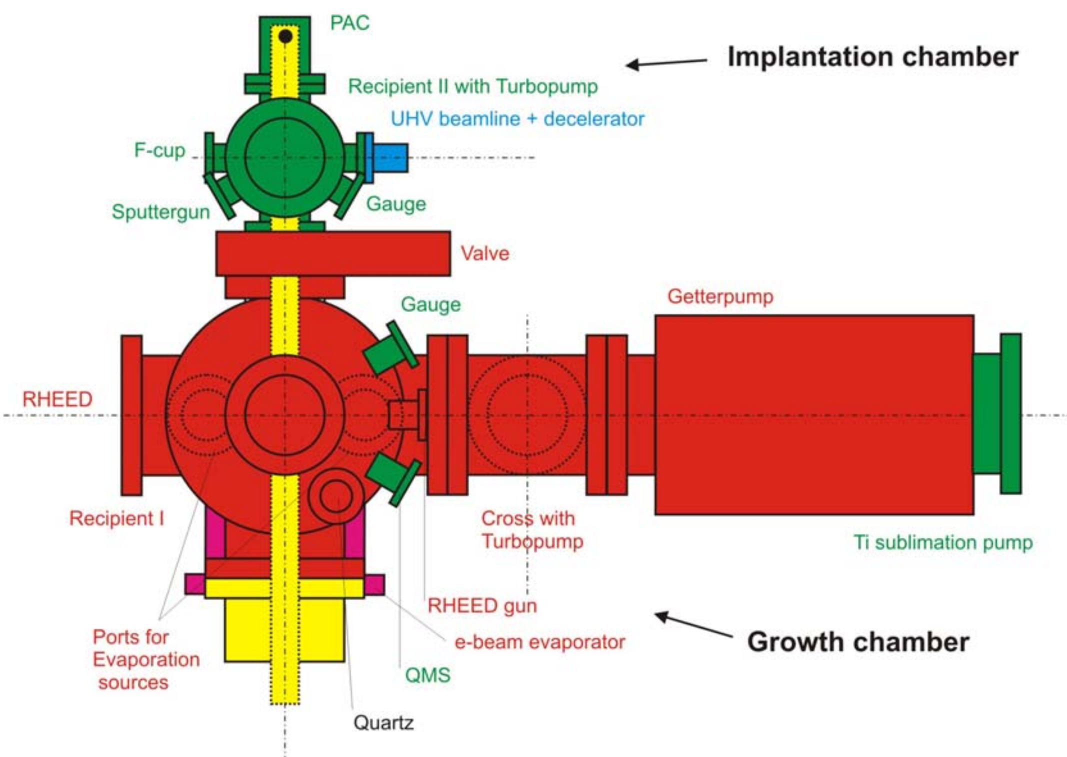

Fig. 1. schematic representation of ASPIC2. green: Present, can be used with small repair, yellow: Present, but changes needed, red: not present, must be purchased, blue: Expected to be provided from ISOLDE.

Technical resources

The work plan aims at the setup of the ASPIC2 experiment, initially solely for the scientific goals in spintronics as described above but with large possibilities for further modifications and upgrades. The layout for the new ASPIC2 chamber resulting is given in Fig. 1 (top view). For the realization of the experiment presented in Fig. 1, new equipment has to be installed. Besides that, parts of the old ASPIC setup will be used for ASPIC2[1] as shown in Fig. 1, and thus have to be transported to FZD. But since the major part of ASPIC2 has to be developed and set up afresh, the main part of the setup will take place at the FZD/Dresden. For development of the work plan on has to consider that parts of the old ASPIC installations, i.e. implantation chamber, PACS setup, UHV Beamline can be re-used. Moreover, the setup of the growth chamber corresponds to MBE systems well known to the project leader and the project executor from their time at ISOLDE, HMI Berlin, University of Kaiserslautern and FZD where they developed and worked with such systems. A new challenge is the development of a manipulator for a temperature of minimum below 10 K for PACS measurement and up to 1073 K during growth. At the same time, the manipulator will be equipped with a system for electrically point probing as well as a shutter for masking during growth. Therefore, a major time window will be foreseen for such development.The work-plan points are listed below in an approximate timely order.

1. Sighting the present status of the chamber ASPIC. Performing necessary repairs of the implantation chamber including its installations (green in Fig. 1): ISE 10 sputter gun (Omicron), Faraday cup (self made), vacuum gauge (Pfeiffer vacuum), Turbopump (Pfeiffer vacuum), load lock (self made), Beamline valve (VAT).
2. Sighting and repairing the UHV Beamline.
3. Detailed technical layout for the growth chamber of ASPIC2 (red in Fig. 1).
4. Detailed technical layout for the new manipulator (yellow in Fig. 1). While the outer mechanics is still present in ASPIC, the inner cryostat and heating position must be developed individually. The Cryostat should include a shutter as well as a prober.
5. Purchase of new equipment.
6. Assembly and test of the manipulator.
7. Assembly and test of the growth chamber (Co-Cu multilayer growth)
    a. Growth of thin multilayers Si/SiO2/Cr(10)/Co(6)/Cu(2.5)/Co(0.25)/Py(8)/Cu(40)/Cr(3) in CIP and two CPP[2] configurations
    b. Test of RHEED
    c. In-situ measurement of the GMR at temperatures down below 10 K
    d. Structural investigation by TEM and layer thickness determination
    e. Ex-situ characterization by GMR measurements (comparison) and Kerr effect
8. Final tests and installation of ASPIC2 at ISOLDE.
9. Beamline connection to ASPIC2.
10. Test experiments with Co-Cu multilayers at ISOLDE using the ^{111}In/^{111}Cd probe.
    a. Growth of a stack Si/SiO2/Cr(10)/Cu(40)/Cu(20) and implantation of ^{111}In/^{111}Cd probe atoms at 10 keV.
    b. Annealing experiments at different temperatures up to 1073 K and PACS investigation of lattice recovery and probe position.
    c. Covering by Cu(10…80)/Co(6)/Cu(40)
    d. Magnetizing Co top layer and application of different currents while measuring the hyperfine interaction.

[1] ASPIC was installed at ISOLDE at the beginning of the 1990 ies. The installations thus have around 15 years of age. Most of the installations are not working anymore. For the new setup ASPIC2 only a few parts can be re-used (Fig. 1).

[2] CPP = current perpendicular to plane

e. Alternative experiment using the soft landing system.
f. Data processing
g. Initial scientific studies on the system Cu/Co, depending on the results from a-f

For the different points, the following time-plan is allocated:

Point	Time window	Location	Milestone
1	1.7. 2010 - 31.12. 2010	FZD/CERN	-
2	1.7. 2010 - 31.12. 2010	CERN	-
3	1.7. 2010 - 31.12. 2010	FZD	-
4	1.7. 2010 - 31.12. 2010	FZD	-
5	Till 31.03. 2011	FZD	M1
6	1.1. 2011 – 30.07. 2012	FZD	-
7	1.1. 2011 – 30.07. 2012	FZD	-
8	1.8. 2012 - 30.09. 2012	FZD/CERN	M2
9	1.8. 2012 - 30.09. 2012	FZD/CERN	-
10	1.10. 2012 – 30.6. 2013	FZD/CERN	-
	Till 31.02. 2012	FZD/CERN	M3

Milestones

Milestone M1: This milestone is located at the end of all technical planning. At that point, i.e. before the start of ordering and major assembly, still changes in the concept are possible.
Milestone M2: At his milestone, all the tests at the FZD will be done. Without applying radioactive probe atoms, the growth conditions for the first system, i.e. Cu/Co multilayers will be tested. Moreover, the cooling capability of the manipulator/cryostat will be tested as well as the function of the prober. ASPIC2 will be installed at ISOLDE.
Milestone M3: At this milestone, the setup including all sub-systems (implantation chamber, growth chamber, beamline, PAC setup should run).

Special request from ISOLDE

2010: Access to ISOLDE Hall and to ASPIC experiment. Support in dismounting parts of the old ASPIC setup and shipment to Dresden (crane). Check of the UHV beamline and support with small repair.
2011: No requests
2012: Access to ISOLDE Hall and to ASPIC experiment. Support in mounting the new ASPIC2 setup and disposal of old ASPIC parts. Connection to the UHV beamline and support with offline and stable beam test experiments. Supply of 60 keV and 10 keV stable ions. Supply of $^{111}In/^{111}Cd$ and $^{111m}Cd/^{111}Cd$ radioactive beams for tests.
2013: Support for initial scientific experiments depending on the results from the tests. Hopefully, a conventional beamtime allocation will be granted by then.

Team

The personnel for the realization of the project will consist of the following people:

- **Project leader:** Dr. K. Potzger, FZ Dresden Rossendorf **(FZD funded)**
- **Technical/scientific project executor:** Dr. M.O. Liedke, junior researcher, FZ Dresden-Rossendorf, **(BMBF funded, present application)**
- **TEM[3] support:** Dr. A. Mücklich, Dresden Rossendorf **(FZD funded)**
- **ISOLDE/CERN local support:** Dr. K. Johnston, ISOLDE, CERN **(BMBF funded)**

[3] TEM = transmission electron microscope

Collaboration

Applications from the following Institutions will be submitted for the current funding project: Universität des Saarlandes, Forschungszentrum Dresden-Rossendorf (FZD), Universität Göttingen. There is a strong overlap of the FZD application with the other two applications within the program „Investigations of condensed matter at large scale facilities“:

- „Ausbau und Unterhalt der Einrichtungen an ISOLDE/CERN“, Prof. Th. Wichert, Universität des Saarlandes, Saarbrücken
- „Weiterentwicklung der digitalen γγ-Winkelkorrelations-Spektroskopie und Niederenergie-Implantation von Radionukliden“, Prof. Dr. H. C. Hofsäss, Georg-August-Universität Göttingen

and with the running project

- BMBF-Verbundprojekt: Multifunktionale Speicherkonzepte, Teilprojekt B: Next Generation MRAM, FKZ: 13N10144, Prof. J. Fassbender, FZ Dresden-Rossendorf, Dresden

Groups from outside FZD which already expressed their interest to work with ASPIC2 are:

1. Magnetic multilayers (initial measurements, collaboration with the FZD group)
   - University of Aveiro, - CICECO (Prof. Vitor Amaral)
   - University of Lisboa - CFNUL (Prof. Armandina Lima Lopes)
   - University of Porto - IFIMUP (Prof. João Pedro Araújo)
2. Other materials
   - Prof. C. Ronning, University of Jena
   - Dr. R. Vianden, University of Bonn