EUROPEAN SYNCHROTRON RADIATION FACILITY

INSTALLATION EUROPEENNE DE RAYONNEMENT SYNCHROTRON

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

Deadlines for submission of Experimental Reports

Experimental reports must be submitted within the period of 3 months after the end of the experiment.

Experiment Report supporting a new proposal ("relevant report")

If you are submitting a proposal for a new project, or to continue a project for which you have previously been allocated beam time, you must submit a report on each of your previous measurement(s):

- even on those carried out close to the proposal submission deadline (it can be a *"preliminary report"),*
- even for experiments whose scientific area is different form the scientific area of the new proposal,
- carried out on CRG beamlines.

You must then register the report(s) as "relevant report(s)" in the new application form for beam time.

Deadlines for submitting a report supporting a new proposal

- 1st March Proposal Round - **5th March**
- 10th September Proposal Round - **13th September**

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.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report in English.
- include the experiment number 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.

	Experiment title: Study of the interface quality in hybrid SuperconductorFerromagnetic heterostructures for spintronic applications	**Experiment number**: A25-2 986
Beamline: BM25	**Date of experiment**: from: 25/01/2022 to: 31/01/2022	**Date of report**: 10/03/2023
Shifts: 18	**Local contact(s)**: Juan Rubio Zuazo	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Irene Lucas del Pozo (proporser)

Pedro A. Algarabel (co-proposer)

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Report:

Hybrid structures formed by ferromagnetic (FM) and superconductor (SC) layers has recently attracted great interest from the scientific community. Recently, such combination of layers has been studied theoretically by several research groups. However, only a few experimentally attempts have been to date. Thermal injection of spin polarized currents into superconductors allows the spin current not to be suppressed being able to be propagated over long distances by the thermally excited quasiparticles. Hence, this unusual hybrid structures allows to explore new spin current driven effects that can be promising for new technological applications. Spin Seebeck Effect (SSE) is one of the most used techniques for spin injection in SC but is highly dependent on the interface quality between both layers, the FM and the SC layer. Due to this, controlling the characteristics of the interface becomes crucial to study the injection of spin currents into a superconductor layer.

During this experiment we have characterized these types of hybrid structures consisting in a layer of $YBa_2Cu_3O_7$ (YBCO) as superconductor material, and $Y_3Fe_5O_{12}$ (YIG) as ferrimagnetic material, deposited by pulsed laser deposition on MgO or $Gd_3Ga_5O_{12}$ (GGG) substrates. First, monolayers of YBCO on MgO substrate and YIG on GGG substrate were studied by *Grazing Incidence X-Ray Diffraction* (GIXRD). The YBCO//MgO monolayer were examined and, as it is shown in the figure 1, it has a pollycrystaline structure. However, the intense diffraction peaks present in the diffraction map show that its structure is partially oriented. On the other hand, YIG//GGG thin film present a *quasicrystalline* structure. The intense peak present in the figure 2 shows the high degree of orientation of the layer. However, it exists another localized diffraction peak which have lower intensity than the other one. For that, reason we can conclude that is almost completely monocrystalline. Furthermore, Laue oscillations are clearly visible in 1D diffractograms indicating a high degree of crystallinity.

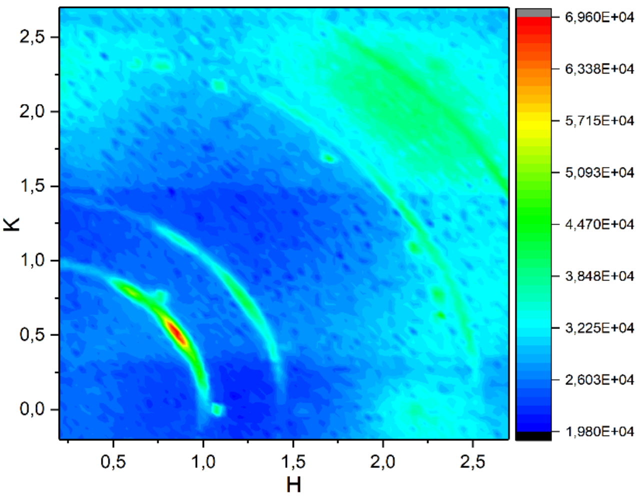

Figure 1. Diffraction map of MgO/YBCO

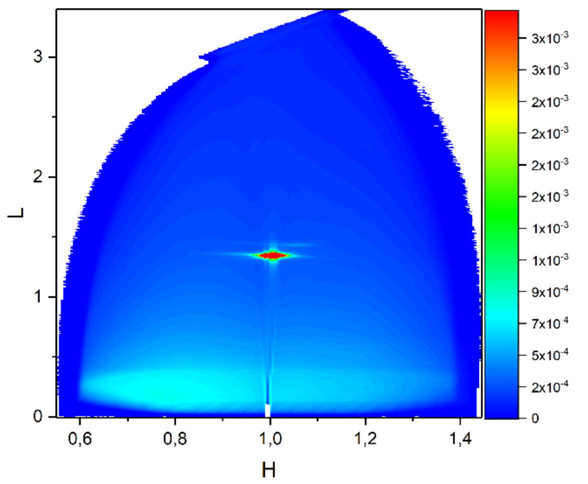

Figure 2. Diffraction map of GGG/YIG

Once the characterization of the monolayers were made, we started to study the hybrid structures. Structures consisting in GGG//YIG/YBCO were examined by XRD. In this case, not only the peaks corresponding to the monolayer of YIG/GGG are visible, but a plycrystalline material is also present which correspond to YBCO. This is shown in figure 3 and figure 4. Structures formed by MgO//YBCO/YIG were also studied with GIXRD concluding that YIG is deposited in a polycrystalline way on the superconductor layer. Furthermore, degree of crystallinity grows while thick of YIG layer also grows.

XPS studies of these hybrid materials were impossible to make due to experimental issues.

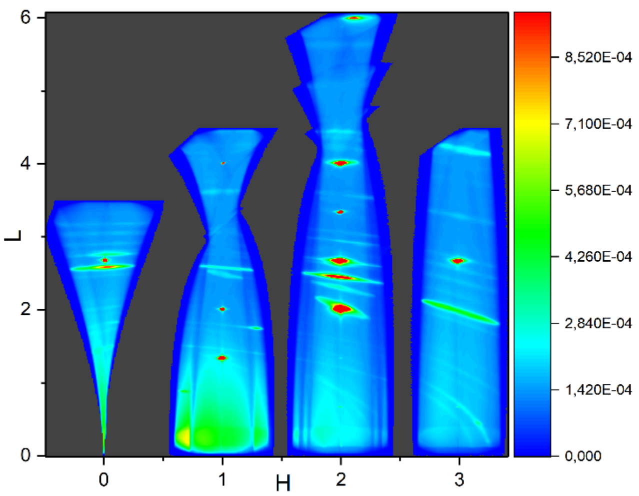

Figure 3. Diffraction map of GGG/YIG/YBCO

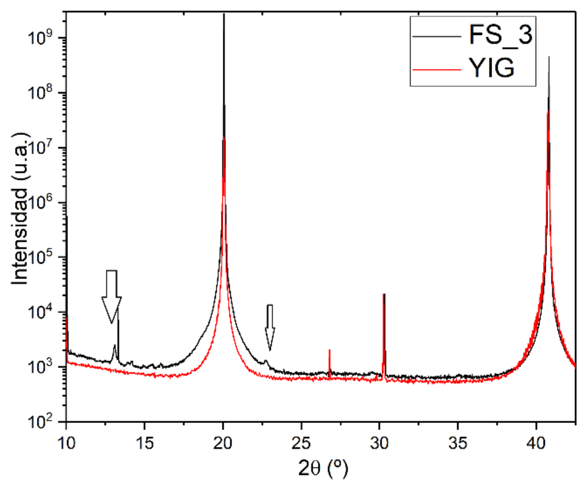

Figure 4. Comparation of XRD patterns of GGG//YIG and GGG//YIG/YBCO