EUROPEAN SYNCHROTRON RADIATION FACILITY

INSTALLATION EUROPEENNE DE RAYONNEMENT SYNCHROTRON

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

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.

<table>
<tr><td>ESRF</td><td>Experiment title:
RIXS perspective on the origin of the high-T_c plateau in trilayer cuprate $Bi_2Sr_2Ca_2Cu_3O_{10+\delta}$</td><td>Experiment number:
HC-4640</td></tr>
<tr><td>Beamline:
ID32</td><td>Date of experiment:
from: 10 November 2021 to: 16 November 2021</td><td rowspan="2">Date of report:

Received at ESRF:</td></tr>
<tr><td>Shifts:
18</td><td>Local contact(s):
Nicholas Brookes</td></tr>
<tr><td colspan="3">Names and affiliations of applicants (* indicates experimentalists):
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</table>

Report:

The motivation of our study is to find which electronic state is mostly related to the high-Tc plateau of tri-layer cuprates $Bi_2Sr_2Ca_2Cu_3O_{10+\delta}$ (Bi-2223), which represents a major mystery in this material. In a previous STM study, we found that the superconducting (SC) gap decreases monotonously with increasing doping, even though the Tc remains as high as 110 K [1,2]. This indictes that the SC gap is not the key factor of Tc in cuprates. Therefore, identifying the unchanged physical paramenter on the high-Tc plateau of Bi-2223 is desirable, which may provide fresh new insights on what determines Tc in cuprates.

During the beamtime, we have performed resonant inelastic X-ray scattering (RIXS) experiments at the Cu L_3-edge of Bi-2223. The energy resolution of our measurements is about 37 meV working at the high-throughput mode, which allows a quick acquisition of the RIXS spectra (each taken half an hour). Three overdoped Bi-2223 crystals were studied to investigate the possible charge density wave (CDW) or charge density fluctuation (CDF) state at different temperatures. Meanwhile, we obtained the inelastic phonon excitations taking advantage of the high energy resolution. All measurements conducted during this beamtime are new in the research field of tri-layer cuprates.

Because the c-axis lattice constant is very large (~37 A) in Bi-2223, we set the spectrometer at a geometry that ensures a constant L=3.5 to avoid any L-dependent behavior of CDW, CDF and phonon excitations. To enhance the charge signals, the polarization was set to vertical (i.e., σ-polarization), through which we have obtained high quality RIXS spectra along the Cu-O-Cu directions.

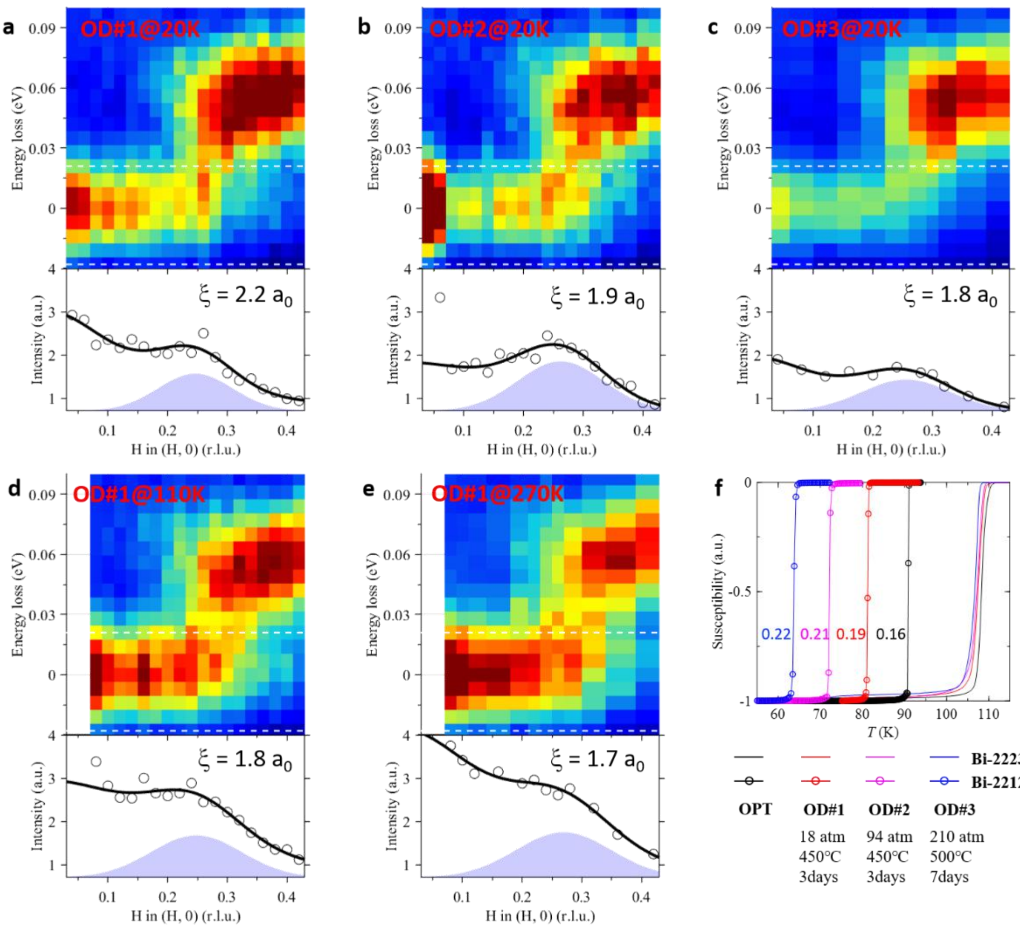

Figure 1 shows part of our high-quality RIXS data after the self-absorption correction process. Before the RIXS experiments, we have obtained the overdoped Bi-2223 crystals (see Fig. 1f) through high-pressure oxygen annealings [2], which was carried out together with double-layer Bi-2212. It can be seen that the Tc of Bi-2223 is indeed kept at 110 K, in contrast to Bi-2212. Figures 1a-1c display the energy-momentum RIXS intensity maps with increasing doping from the OD#1 to OD#3 samples. An apprent feature of the data is that the CDW signal is particularly weak, in consistent with the expectation that CDW disappears at the overdoped regime. The quasi-elastic region ([-30 meV, 20 meV]) are integrated to obtain the intensity profile (black circles) with the fiited curves superimposed (black curve). The intensity peak (blue shaded) is very broad that has a characteristic correlation length ξ of only ~2 a_0, half of the charge density modulation period (~4 a_0 from Q~0.25 r.l.u.), reminicent of the CDF feature reported in YBCO cuprates [3]. Moreover, such broad CDF feature is temperature-independent by comparing the 20 K data (Fig. 1a) with that at 110 K (Fig. 1d) and 270 K (Fig. 1e).

Therefore, we have identified the existence of CDF in the Bi-2223 cuprates for the first time. Interestingly, the CDF is doping-independent which may serve as a possible explanation of the high-Tc plateau. We will further analyze our data to have a more conpenhensive understanding, e.g., taking account of the phonon intensity, which is doping dependent (see Fig. 1a-1c).

References:

[1] Zou, et al., Effect of Structural Supermodulation on Superconductivity in Trilayer Cuprate $Bi_2Sr_2Ca_2Cu_3O_{10+\delta}$. Phys. Rev. Lett. 124, 047003 (2020).

[2] Hao, et al., Anomalous Doping Evolution of Superconductivity and Quasiparticle Interference in $Bi_2Sr_2Ca_2Cu_3O_{10+\delta}$ Trilayer Cuprates. Phys. Rev. Lett. 125, 237005 (2020).

[3] Arpaia, et al., Dynamical charge density fluctuations pervading the phase diagram of a Cu-based high-Tc superconductor. Science 365, 906 (2019).