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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:** Study of the unusual structure of thin films of uranium on tungsten	**Experiment number**: 28-01-1014
Beamline: BM28	**Date of experiment**: from: 07 May 2013 to: 13 May 2013	**Date of report**: 20th October 2013
Shifts: 18	**Local contact(s)**: Didier Wermeille	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Dr. Ross Springell* University of Bristol

Dr. Sean Langridge

Dr. Roger Ward

Prof. Gerard Lander*

Report:

Experiments were conducted on a ~ 2000 Å thin film of orthorhombic uranium (α–U) grown on a W buffer placed on a sapphire substrate. Earlier work had established the epitaxial relationship of such a film [1] with the buffer and substrate, and the relationships given in that paper were observed in the present experiment. The film has the *c*-axis along the film growth direction, and *a* and *b* of the orthorhombic uranium in the plane of the film. There are two domains of epitaxial uranium, with equal populations.

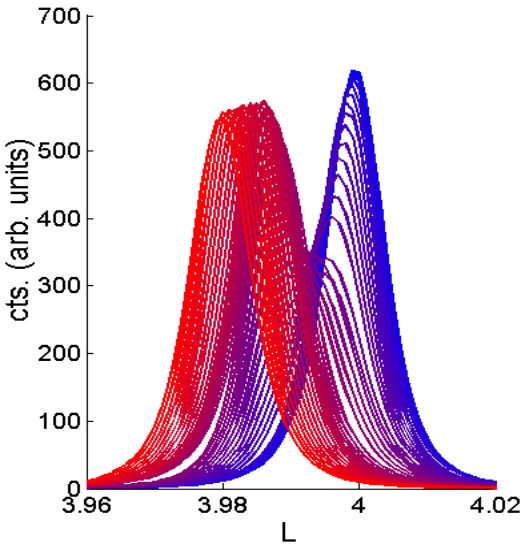

Fig. 1 – Temperature dependence of the (004) alpha-U reflection from 20 K (blue line) to 200 K (red line) in steps of 5 K.

On cooling we measured a dramatic change in the lattice parameters. The *c*-axis of the film contracts, whereas both *a* and *b* expand, by 7 and 4.6 x 10^{-3} in relative units, respectively, when cooling from 120 – 50 K. Measuring the (004) reflection of the film as a function of temperature gives a spectacular pattern when reflections at different temperatures are superposed – see Fig. 1. The result is an overall expansion of volume when cooling through this temperature range. The changes are not abrupt – they occur uniformly over this large temperature range.

α–U is known to exhibit a charge-density wave (CDW) at 43 K [2], and we have already observed this state (also below ~ 50 K) in a series of epitaxial films grown on Nb buffers (on sapphire). Such films have the α–U growth axis as [110], and the CDW formation closely resembles the CDW found in the bulk [3].

The situation in the α–U/W films is quite different from that observed in either the bulk [2] or α–U/Nb films [3]. At ~ 160 K we observe the simple periodic doubling of the *a*-axis that occurs because the soft optic phonon Σ_4 is unstable if the unit cell is expanded, and especially if the *a*-axis is lengthened [4], which happens in this case because of the interaction with the substrate. For example, the (1.5 0 3) reflection first appears at ~150 K and then increases in intensity so that it becomes almost 5% of the strong charge reflection (2 0 2) at T = 10 K. This signifies a sinusoidal periodic lattice distortion (compatible with the Σ_4 phonon) doubling the *a*-axis with a displacement of the U atoms by ~0.06 Å from their equilibrium position. Around 45 K, the other components of the CDW [2] appear, but they are much weaker than found previously.

It has been shown recently [5] that the electron-phonon coupling plays the major role in driving both the CDW and superconductivity in α–U. The present experiments with thin films show that the strain induced by different substrates can drastically modify the low-temperature behavior of this element. These observations, together with the presence of *hcp*–U if U is deposited on a hexagonal template [3], show the extreme malleability of the element uranium.

References:

[1] R. C. C. Ward *et al*., J. Phys. Cond. Matter **20**, 135003 (2008)
[2] G. H. Lander *et al.*, Adv. in Physics **43**, 1 (1994)
[3] R. Springell *et al.*, Phys. Rev. B **78**, 193403 (2008)
[4] J. Bouchet, Phys. Rev. B **77**, 024113 (2008)
[5] S. Raymond *et al.*, Phys. Rev. Lett. **107**, 136401 (2011)