| ESRF | **Experiment title:** **magnetic ordering of a cobalt nanodots network** | **Experiment number:** |
|---|---|---|
| **Beamline:** | **Date of experiment:** from: 16/04/03 to: 21/04/03 | **Date of report:** 25/04/03 |
| **Shifts:** | **Local contact(s):** P. Bencok | *Received at ESRF:* |


**Names and affiliations of applicants** (* indicates experimentalists):

S. Rousset, V. Repain, S. Rohart,
*Groupe de Physique des Solides, 4 pl de Jussieu 75 251 Paris cedex 05 (France)*
T. Cren
*Institut de Physique des Nanostructures, EPFL, CH-1015 Lausanne (Switzerland)*
P. Bencok,
*ESRF, BP220 38042 Grenoble (France)*
P. Ohresser,
*LURE, Université Paris Sud 91898 Orsay (France)*
F. Scheurer
*IPCMS, 23 rue du Loess 67034 Strasbourg (France)*
(all experimentalists)


**Report:**

The aim of this project was to analyse by resonant soft-X ray diffraction the magnetic order in a magnetic dot lattice of several nanometers periodicity. A magnetic square dot lattice with perpendicular magnetic anisotropy may show antiferromagnetic coupling, due to the dipolar coupling between adjacent dots. An antiferromagnetic order will produce a doubling of the real space periodicity, giving rise to half-integer order peaks in the reciprocal lattice.

The first question concerned the possibility of observing classical diffraction effects of the regular dot arrangement in this periodicity range. It has indeed been shown by Grazing Incidence Small Angle Scattering that such a regular arrangement of dots leads to a super crystallographic cell, giving rise to diffraction structures at very small angles when using a hard X-ray beam [1]. However, direct diffraction of such a nanometer periodicity lattice has never been tested yet. This implies to use soft X-ray beams, below the keV range.

The second question concerned the magnetic superstructure. The above dot lattice is superparamagnetic with a blocking temperature around 60 K. Not much is known experimentaly about such lattices, but an antiferromagnetic order might be expected, provided the dipolar coupling is strong enough. The aim here was to seek for such an antiferromagnetic superstructure.

This experiment was performed on the ID08 beamline with the new in situ X-ray diffractometer and is one of the very first experiments on this apparatus.

For the experiment we used a vicinal Au(11 12 12) surface which is nano-structured in two directions, due to the combination of the gold reconstruction and the steps. As the intersection of the gold reconstruction and the step edge acts as a favoured nucleation center for cobalt adatoms, Co deposition can lead to the formation of a regular array (6nm x 7nm) of two monolayer Co nano-dots with a high degree of order (fig. 1). The array is achevied with several cycles of 0.3 ML Co deposition at 130 K followed by annealing at 350 K. The final sample is covered by 1 ML of cobalt. The array displays a narrow size distribution [2] centered

around 20 nm². The clusters are nearly round and the distance between two dots is as small as possible, particularly in the direction orthogonal to the steps (1.2 ML of Co corresponds to the coalescence of the dots in this direction).
The surface was then covered by several monolayers (7-8 ML) of Au to protect the dots from oxidation.

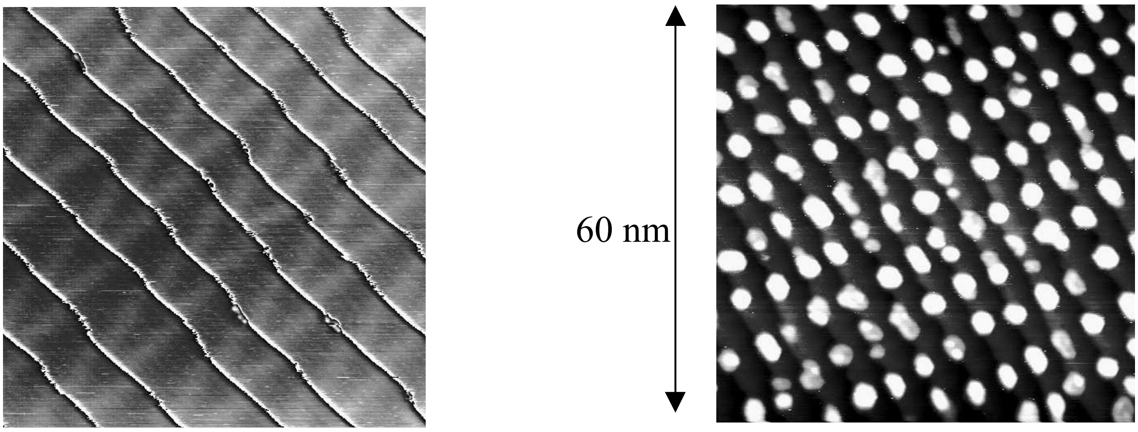


*Fig. 1 : a- Clean Au(11 12 12) surface. b- 0.5 ML Co on Au(11 12 12) at 130 K followed by an annealing at room temperature.*

We show that the regular Co dots arrangement gives rise to clear diffraction features, provided the energy is set close to the absorption edge of Co. Figure 2 shows for example a scan along the (h 0) reciprocal direction, taken parallel to the step edges, for an energy of 778 eV at the Co $L_3$ edge, and for an energy of 780 eV, slightly above the edge. The incidence angle is 10°, and the steps are parallel to the incident beam. The detector was just scanned with one angular rotation, giving a so-called h-scan. One can see that there is nearly no diffracted intensity for off-resonance energy conditions. From this scan one can deduce a dot lattice constant of 6.9 nm in this direction. Similarly, in the (0 k) direction, perpendicular to the step edges, one measures a spacing of 5.3 nm (the sample was 90 degree rotated and the detector was scanned as previously). We also checked that it was possible to measure peaks in off-normal conditions for the detector, although the intersection of the reciprocal lattice rods with the Ewald sphere is less favorable.

Cooling down to a temperature estimated to be slightly above 100 K led to no evidence of any magnetic superstructure. From earlier diffraction experiments on domain patterns on FePd multilayers [3] we estimated that the magnetic contrast should be sufficient to observe potential magnetic satellite peaks. The absence of half-order peaks means probably that the magnetic correlation length is too small at this temperature. On another hand, it is not obvious that a long-range antiferromagnetic order can be obtained spontaneously upon cooling, but future improvement of the cooling stage should allow investigating this question.

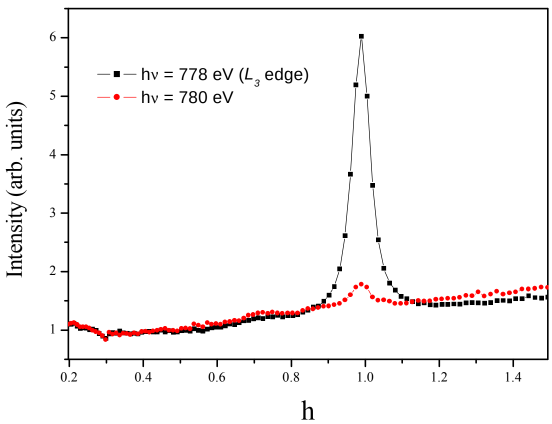


*Fig. 2*

[1] O. Fruchart *et al.,* J. Cryst. Growth 237, 2034 (2002)
[2] V. Repain *et al.,* Europhys. Lett 58, 730 (2002)
[3] H. Dürr *et al.*, Science, 284, 2166 (1999)