ESRF

Experiment title:
Diffraction on single nano-fabricated electronic devices

Experiment number:
MI-582

Beamline:
ID22

Date of experiment:
from: 26/06/2002 to: 01/07/2002

Date of report:
February 28, 2003

Received at ESRF:

Shifts:
15

Local contact(s):
Michael Drakopoulos

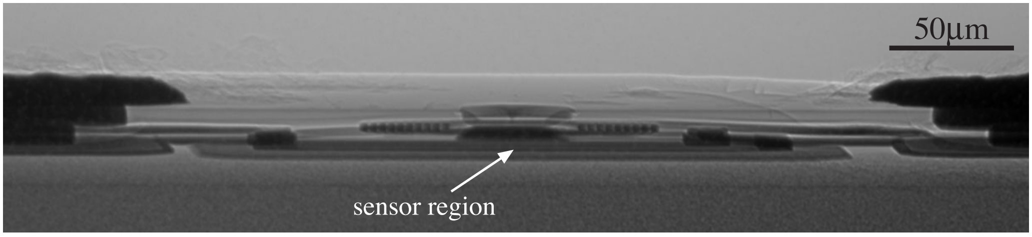
Names and affiliations of applicants (* indicates experimentalists):
Bruno Lengeler (RWTH), Michael Drakopoulos* (ESRF), Fatima Frehse* (RWTH), Thomas Kubicki (RWTH), Marion Kuhlmann* (RWTH), Olga Kurapova* (RWTH), Christoph Rau (ESRF), Christian Schroer* (RWTH), Christoph Schug* (IBM), Alexandre Simionovici (ESRF), Andrea Somogyi (ESRF)

Report:
The main goal of this experiment was to assess the feasibility of determining the crystalline structure of nano-structures of state-of-the-art nano-electronic devices. In collaboration with IBM (Mainz) this was done investigating the crystalline structure of the anti-ferromagnetic PtMn pinning layer of a GMR sensor used to read out a hard drive. This PtMn-layer is 300nm by 350nm by 15nm in size and pins the reference ferromagnetic layer in the sensor by exchange-bias. Two crystalline phases of PtMn are encountered in GMR sensor fabrication, the fct phase that is anti-ferromagnetic and the fcc phase that is not favorable to the performance of the finished device. A diffraction experiment on the device was supposed to determine the contribution of each of these phases to the PtMn-layer in a real device. Figures 2(a) and (b) show the reference diffraction patterns of PtMn films in the two different phases (thickness 15nm) deposited on a glass substrate.

To diffract from this exceedingly small device in its complicated environment, consisting of leads, shieldings, insulations, and other layers of the sensor, a small microbeam was pointed onto the region of interest. An x-ray energy of $E = 25$keV was chosen to easily penetrate the sensor head of almost 1mm thickness and to gather a large enough portion of reciprocal space in the field of view of a diffraction camera (Photonic Science).

The microbeam was produced using an Al parabolic compound refractive lens with $N = 250$ single lenses. Its lateral size was determined to 2.3μm (horiz. FWHM) and 0.8μm (vert. FWHM). To find the right position on the sample, a high resolution position sensitive detector (Princeton Instruments) was used to roughly align the sample in the microbeam. Fig. 1 shows a transmission microradiograph of the full device. The arrow points to the sensor region which is much smaller than a single pixel in this image. As the resolution of the camera is insufficient to fully align the device in the microbeam, an energy dispersive detector (SiLi) was used to make the fine alignment, scanning the local environment of the device and detecting the fluorescence radiation of the local structures. The well defined distribution of different elements in the vicinity of the device allows one to determine its exact position.

Figure 1: microradiograph of the read-write-head of an IBM hard-drive



A large series of diffraction patterns was recorded from the sample together with diffraction patterns from reference samples of the different components of the device. The diffraction patterns of the device could be fully interpreted in terms of its other components. No signature of the diffraction at PtMn was found. From the measured reference data we have estimated the signal strength and compared it to the measured data of the device. Comparison showed that the signal-to-background-ratio for this experiment was too low to detect the PtMn layer.

To improve the signal-to-background-ratio, a newly developed nanofocusing lens made of Si was used for the first time [1], generating a microbeam size below 200nm vertically and well below 1μm horizontally. The exact beam size could not be determined with the stages available. Thus, less of the surrounding of the device was illuminated and the signal-to-background-ratio was improved to a value of about 1.4, as compared to 0.3 for the microbeam produced with the Al lens. This was, however, insufficient to detect the PtMn diffraction pattern in any of the patterns recorded of different devices (e. g. Fig. 2(c)).

Figure 2(a): PtMn (fcc)

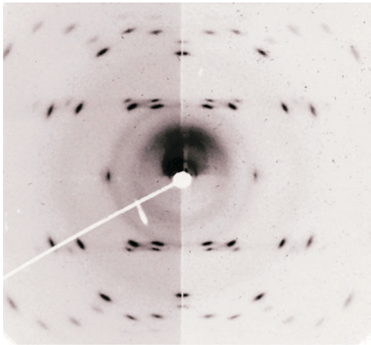


Figure 2(b): PtMn (fct)

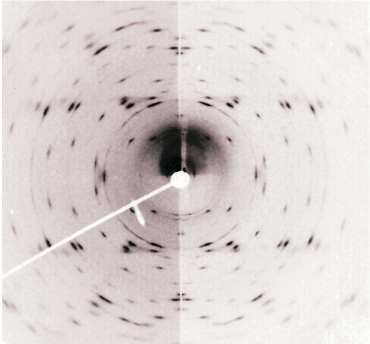
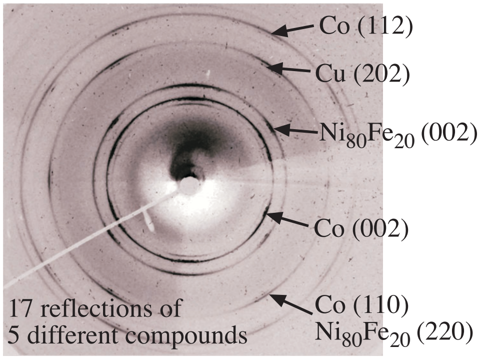


Figure 2(c): device



In this experiment, the signal-to-background-ratio for diffraction at this exceedingly small device embedded in its environment was only slightly too low. A smaller and brighter microbeam [1] and a diffraction camera with better signal-to-noise-ratio (e. g., MAR CCD) would make diffraction at a state-of-the-art nano-device possible, since the current result was not far from it. An experiment with improved optics and diffraction camera is planned.

[1] C. G. Schroer, M. Kuhlmann, U. T. Hunger, T. F. Günzler, O. Kurapova, S. Feste, F. Frehse, B. Lengeler, M. Drakopoulos, A. Somogyi, A. S. Simionovici, A. Snigirev, I. Snigireva, C. Schug, W. H. Schröder, *Appl. Phys. Lett.* **82** (9), 1485 (2003)