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PIXE-KOSSEL IN A GAAS MONOCRYSTAL

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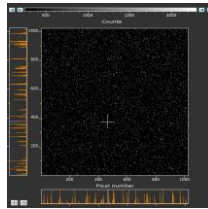
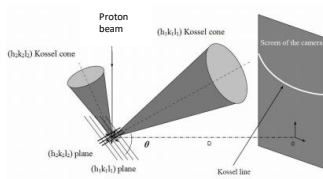
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ABSTRACT

A new methodology was developed to analyse thin films at the nanoscale by combining Kossel diffraction with particle-induced X-ray emission (PIXE). This technique is related to the standing wave method and has already been applied to the study of periodic nanoscale multilayers [1, 2]. The Kossel diffraction of a GaAs single crystal, generated during irradiation with a 1.5 MeV proton beam, is presented. The intensities of the characteristic K emissions of Ga and As of GaAs can be measured as a function of the detection angle with a CCD camera (Andor IKON-M), making it possible to obtain Kossel curves without the use of high precision goniometric systems. An oscillation of intensity is observed when the detection angle varies around the Bragg angle, defined by the energy of the X-ray emission and by the lattice distance of the plane which will diffract. The CCD camera allows the selection of x-ray energy at any angle within a given angular range and the entire experimental setup is fixed.

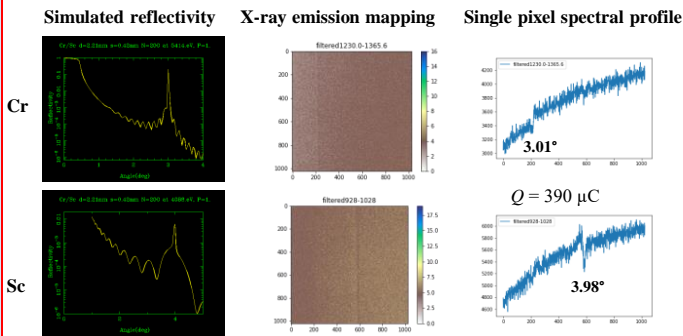
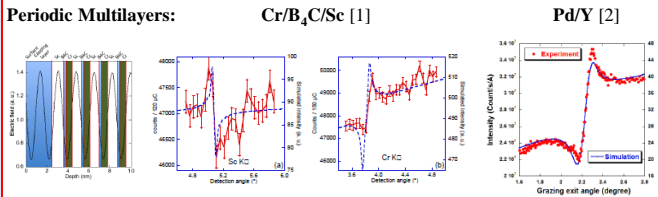
INTRODUCTION

The interaction of the incident protons with the sample produces X-rays which can have a constructive interference when conditions satisfy Bragg's Law ($n\lambda = 2d \sin\theta$). The Bragg-diffracted X-rays will result in the emission of Kossel cones, which will then be intercepted through the CDD screen (13 μm resolution).



Under Bragg conditions, a standing wave having the inter-planar distance period develops and shifts perpendicular to the layers as the angle changes. The variation in the detection angle causes a shift in the nodes of the electric field emitted by the crystal.

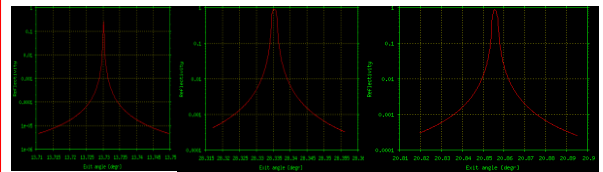
Periodic Multilayers:



Other applications: X-ray planar waveguides of Pt/Fe/Pt and Ta/Cr/Pt [3].

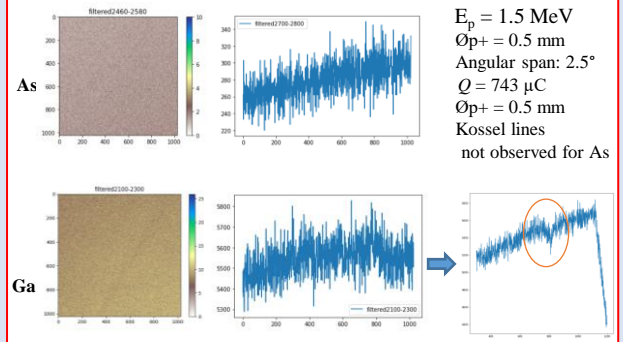
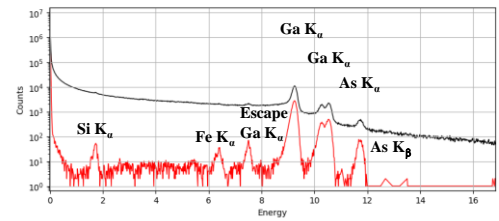
RESULTS

Calculations with dynamical theory of diffraction show that the GaAs structures should be very narrow but perhaps observable at various planes.



Ga planes (002) (004) (133)

PIXE spectra of GaAs



A Kossel curve was observed for Ga (111)?

CONCLUSIONS

The image acquisition of Kossel lines from multi-layered CrSc and Pd/Y structures was successfully done with a CDD camera and a 4x4 binning. Single crystal GaAs structures require a single pixel readout mode (1x1) of the CDD camera to increase the camera spatial resolution, resulting in a deterioration of the signal to noise ratio and in increased camera readout times. An angular resolution of $\sim 0.01^\circ$ and of $\sim 0.0025^\circ$ can be achieved with a bin size of 4x4 and 1x1 respectively. A higher angular resolution can be achieved at a higher distance between the sample and camera, but at the cost of a lower X-ray yield due to the lower solid angle. The Kossel lines are more complicated to measure in single crystals as these require high proton charges and long beamtime exposures that can damage the crystalline lattice. Further experiments are foreseen to identify angularly resolved Kossel lines from Ga and As.

REFERENCES

- [1] *Kossel interferences of proton-induced x-ray emission lines in periodic multilayers*. M. Wu (吴梅忆), K. Le Guen, Jean-Michel André, V. Ilakovac, I. Vickridge, D. Schmaus, E. Briand, S. Steydli, C. Burcklen, F. Bridou, E. Meltchakov, S. de Rossi, F. Delmotte, P. Jonnard. Nucl. Instr. And Meth B. 386 pp 39-43 (2016).
- [2] *Kossel diffraction observed with X-ray color camera during PIXE of nano-scale periodic multilayer*. M. Wu, K. Le Guen, Jean-Michel André, P. Jonnard, I. Vickridge, D. Schmaus, E. Briand, P. Walter, Q. Huang, Z. Wang., Nucl. Instr. And Meth. B 450 pp 252-256 (2019).
- [3] *Kossel interferences of proton-induced X-ray emission lines to study thin film waveguides*, J. P. Zhang, C. Pendenque, K. Le Guen, R. Delaunay, I. Vickridge, D. Schmaus, Q.G. Fu, P. Jonnard, Nucl. Instr. And Meth B. 452, pp 12-20 (2019).

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