ESRF	**Experiment title:** Bulk strain analysis of multilayer structures with micrometer spatial resolution using dispersion compensating bent crystal optics.	**Experiment number:** MI-183
Beamline: ID15 A	**Date of experiment:** from: 4/6/97 to: 1 0/6/97	**Date of report:** 28/8/97
Shifts: 18	**Local contact(s):** V. Honkimaki	*Received at ESRF:* 2 9 AOUT 1997

Names and affiliations of applicants (* indicates experimentalists):

U. Lienert[1,2*], C. Schulze[3*], V. Honkimäki[1*], N. B. Thomsen[2,4*], S. Garbe[2*], H. F. Poulsen[2], A. Horsewell[2]

[1] ESRF
[2] Risø National Laboratory, Materials Department, DK-4000 Roskilde, Denmark
[3] Swiss Light Source Project, PSI, CH-5232 Villigen PSI, Switzerland
[4] Danfoss A/S, Denmark

Report:

Aim: The aim was to determine the strain gradient in layered, polycrystalline structures. Micro-focused, high energy synchrotron radiation (E = 90 keV) was utilized in transmission geometry. This allows, contrary to conventional techniques, a direct observation of depth dependent strain variations with high spatial resolution.

Optics: A linefocus was obtained by a bent Laue monochromator crystal, see fig. 1. Microfocusing was achieved by optimization of the asymmetry angle. In that case, the width of the Borrmann fan does not broaden the geometric focus. The off Rowland-circle geometry causes an energy gradient of $\Delta E/E = 1\%$ over the beam divergence.

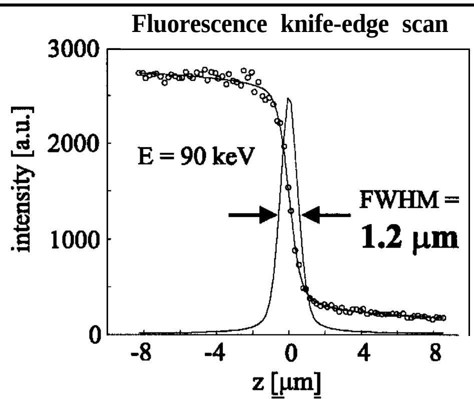

Fig. 1: Fluorescence knife-edge scan of the obtained linefocus. Shown are the experimental data and the corresponding focus profile. 0.5x0.5 mm^2 of beam were accepted resulting in a gain factor of 300. The efficiency is estimated to be 90%. The flux in the linefocus was about 4.3×10^9 ph/s/0. 1 A.

Experimental method: The samples were aligned with the interfaces parallel to the beam and then scanned in z-direction (growth-direction) across the beam. The scattering angles were monitored in axial and lateral direction. Cu/Ni multilayers and CrN and TiC coatings were measured. The layer spacing varied between 1 and 50 µm.

Strain profiles: Strain profiles were obtained from the center positions of the diffraction peaks by peak fitting. It was found that the peak center can be determined to about 1% of the peak width. Therefore, strain profiles can be extracted to an accuracy of 10^{-5} to 10^{-4} despite the broad diffraction peaks. Steep strain gradients in the Ni layers of a Cu/Ni multilayer sample were detected within a 10 µm wide region at the buried Cu-Ni interfaces, see fig. 2.

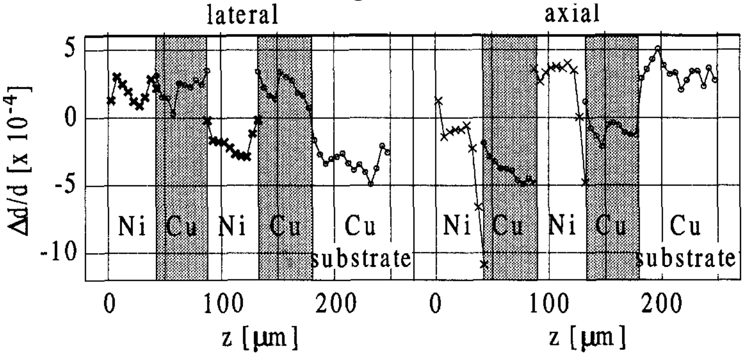

Fig. 2: Depth profile of [2 0 0] lattice plane spacing in a Cu/Ni multilayer sample.

Dispersion compensation: The use of synchrotron radiation provides in principle sufficient resolution to measure the intrinsic peak shape and extract information about dislocation densities etc.. In the present case this information is hidden by the divergence and energy bandwidth of the incident beam except if the dispersion of the investigated sample reflection is matched. The effect of the dispersion matching was clearly observed but the available beamtime did not allow for a peak shape analysis.

Conclusion: The bent Laue crystal proved to be a powerful tool to achieve microfocusing at high x-ray energies. The transmission geometry provided the expected direct and non-destructive measurement of strain gradients in layered polycrystalline samples, even at buried interfaces. This important information can not be obtained by other techniques.
Interesting improvements of the technique are the optimization of the Laue focusing to the diffraction limit (≈0.2 µm), the use of position sensitive detectors for faster data acquisition and quantitative peak shape analysis by application of dispersion compensation.

Publications:

U. Lienert, C. Schulze, V. Honkimäki, Th. Tschentscher, S. Garbe, 0. Hignette, A. Horsewell, M. Lingham, H. F. Poulsen, N. B. Thomsen, E. Ziegler, (1998). J. Synchrotron Rad., submitted

C. Schulze, U. Lienert, M. Hanfland, M. Lorenzen, F. Zontone, (1998). J. Synchrotron Rad., submitted