Relative X-Ray Reflectometry for Characterization of Nanostructures

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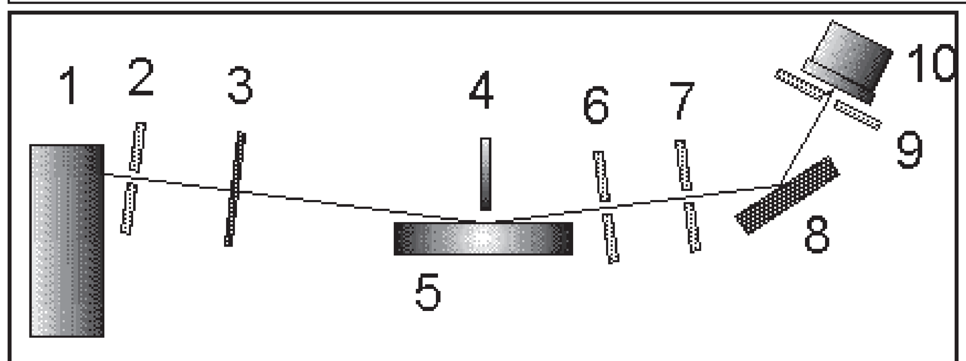
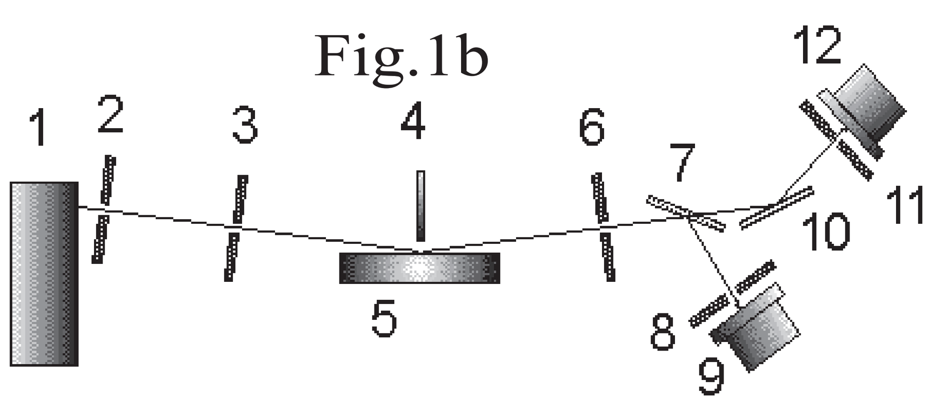


Fig.1a

Fig.1b



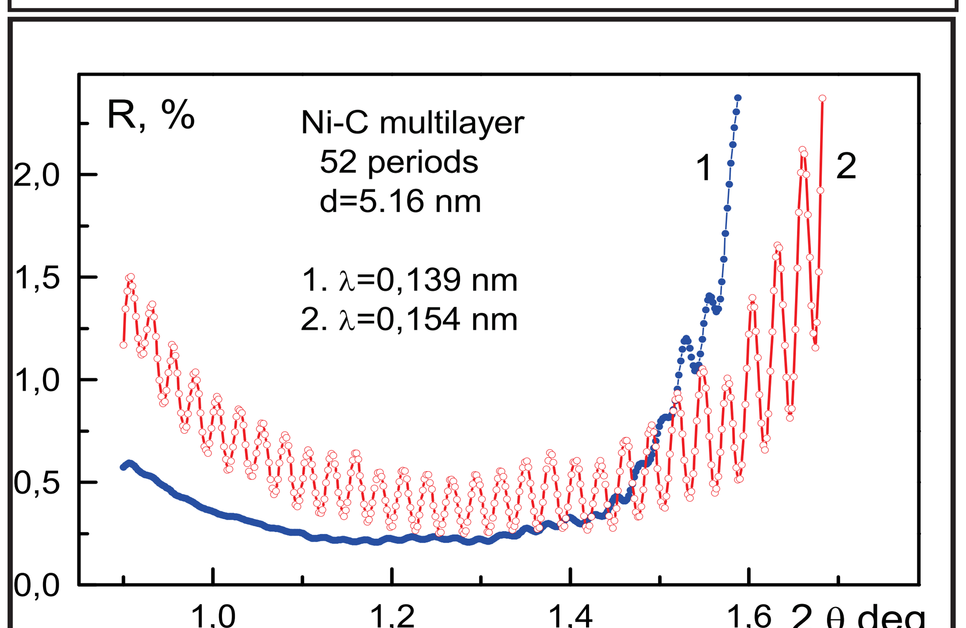


Fig. 2

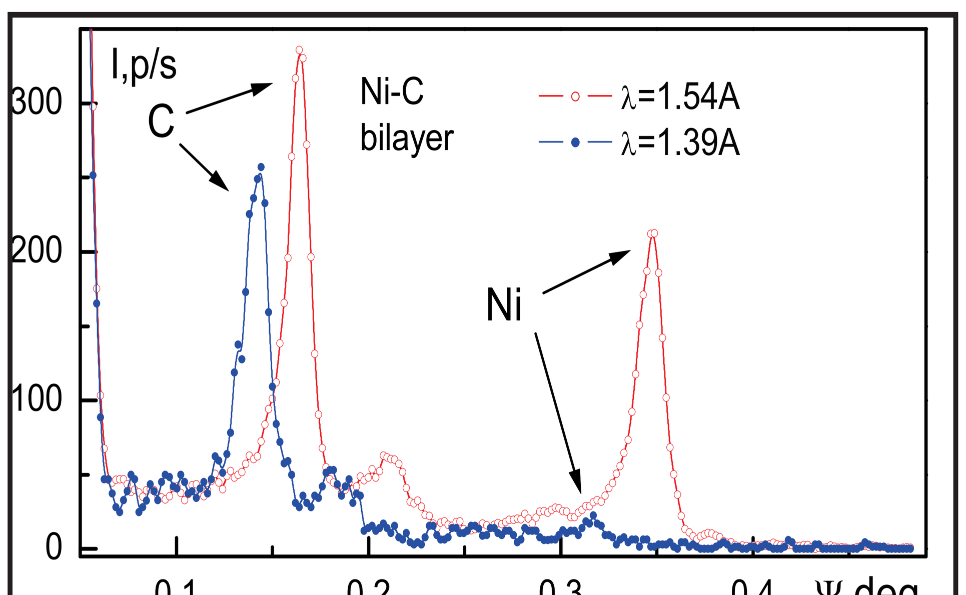


Fig. 3

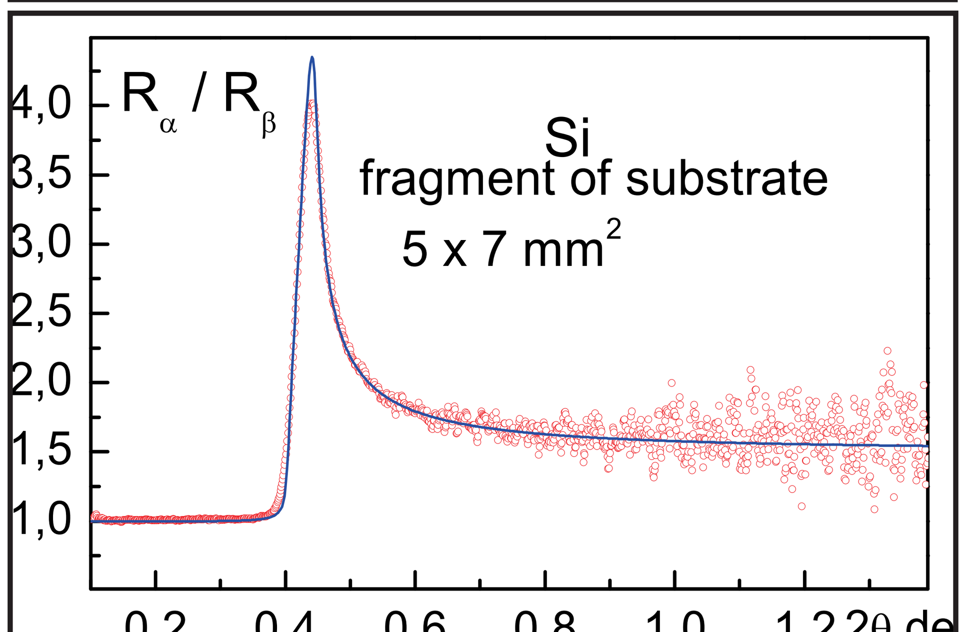


Fig. 4

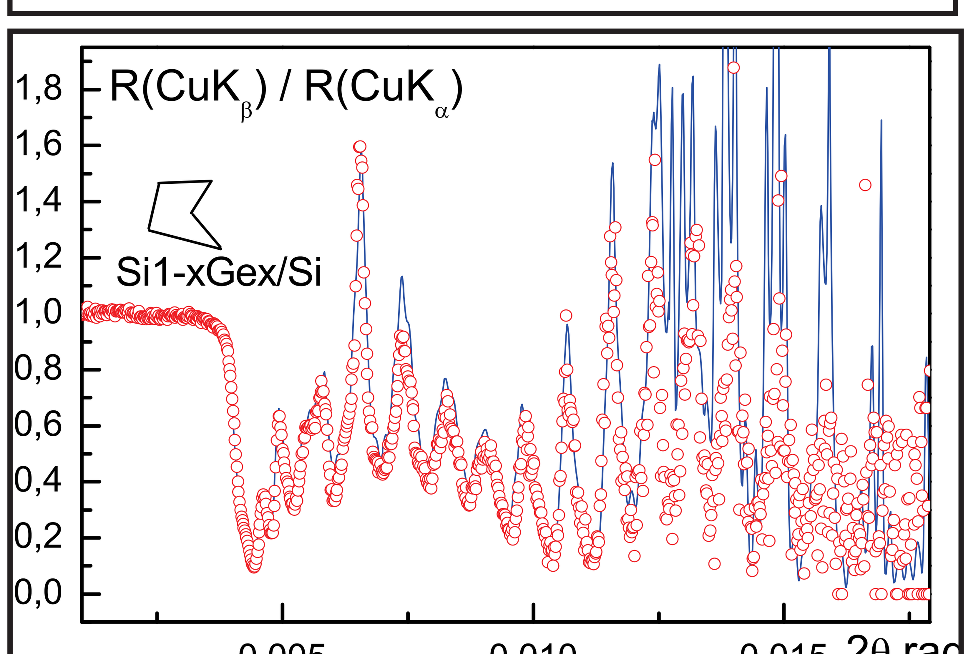


Fig. 5

TWO-WAVE X-RAY REFLECTOMETER

Making Rflectometry Versatile and Reliable

(USA Patent 6041098/RF Patent 2124481)

COMPARISON OF EXISTING SCHEMES

The essence of the *Two-Wave Reflectometer* (2-WXR) scheme can be easily understood from comparison between the presently available *Philips X'Pert Reflectivity Diffractometer and Bruker Reflectometer* (Fig. 1a) and 2-WXR (Fig. 1b).

Both devices employ polychromatic radiation for the sample irradiation and separate characteristic lines from the reflected beam by PG monochromators. However, the *Philips/Bruker systems* use only one characteristic line, but the 2-WXR detects simultaneously two. This is achieved thanks to semitransparent HOPG monochromators and the new patented X-ray arrangement.

NEW MEASUREMENT OPPORTUNITIES

1. Double volume of information
At equivalent geometry and sample irradiation conditions 2-WXR always gives twice as much information as conventional one (Fig 2).

2. Ratio reflectivity mode
Intensity values and its ratio are measured simultaneously for two spectral lines at every angle step. It provides a complete suppression of the X-ray source instability and illumination variations with angle.

3. Refractometry mode.
Direct determination of refractive index of surface layers by transmitting a probing beam through a sample edge. (Fig. 3).

NEW SCOPE OF APPLICATIONS

The above-mentioned 2-WXR features offer new opportunities in investigation methods and allow controlling samples that have been considered earlier as unacceptable for X-ray optical analysis.

- ***Small samples***
- ***Irregular form samples***
- ***Locally processed samples***
- ***Deeply buried or capsulated layers***
- ***Curved samples***

CONCLUSION

Presented results clearly demonstrate that ***the Two-Wave Reflectometer*** and relevant measurement techniques offer a powerful tool for diagnostics of surfaces and thin film structures with ***unmatched versatility, reliability, and information volume.***

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Figures

Fig.1 a, b – X-ray schemes of the **X'Pert Reflectivity Diffractometer** from Philips Analytical X-Ray BV and **Two-Wave Reflectometer** respectively.

Fig. 2. Reflectivity curves from Ni-C multilayer on the Si substrate between 1st Bragg maximum and the critical angle of total external reflection for CuK_α and CuK_β lines (period d=5.16 nm, number of periods N=52).

Fig. 3. Refracted intensity vs. deviation angle (refractogram) for a C - Ni bilayer on Si substrate (C - 36 nm, Ni - 115 nm).

Fig. 4. Angle dependence of the reflectivity ratio $R(CuK_\alpha) / R(CuK_\beta)$ for a Si wafer fragment (5 x 7 mm²).

Fig. 5. Angle dependence of the reflectivity ratio $R(CuK_\alpha) / R(CuK_\beta)$ for an irregular form fragment of epitaxial $Si_{1-x}Ge_x$/Si structure (S≈10 mm²): dots - experiment, solid curve - calculations.

Fig 6. Angle dependencies of the modified reflectivity ratio [R(β)-r(β)] / [R(α)-r(α)] for the ion-implanted diamond plate depicted in the upper right corner. R and r are respectively coefficients of reflection from an ion-implanted area and pure diamond; 1 - experiment, 2 - calculated.

Fig. 7. Refracted intensity vs. deviation angle from multilayer heterostructure Ge_xSi_{1-x}/Si grown by MBE for CuK_α and CuK_β lines.

Fig. 8a and 8b. Angle diagrams and corresponding PSD functions of the standard Si wafer for CuK_α and CuK_β lines characterizing surface roughness and radius of curvature).

Fig. 9a and 9b. Angle dependencies of reflectivity for CuK and CuK lines for the diamond-like C film (54 nm) on Si substrate and corresponding a reflectivity ratio $R(CuK_\alpha) / R(CuK_\beta)$.

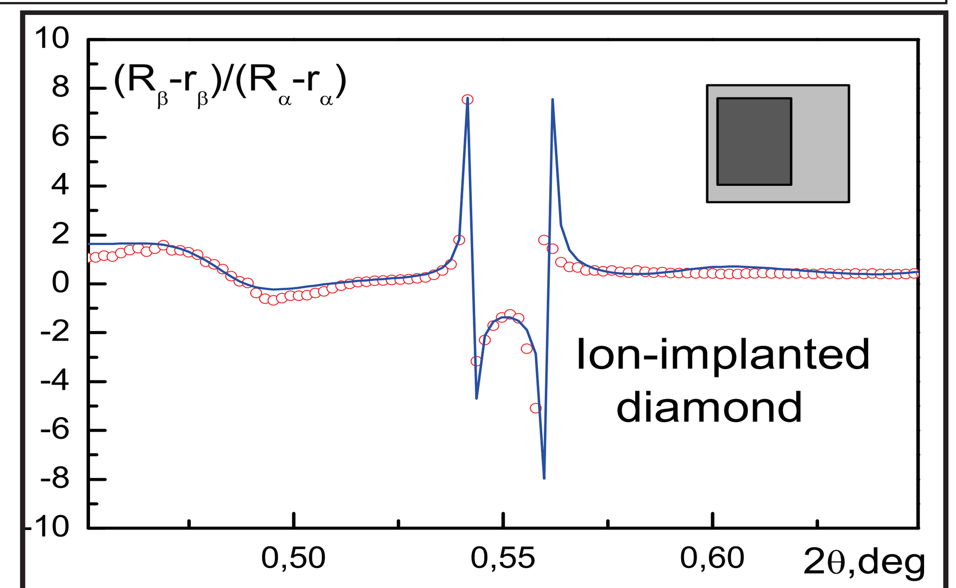

Fig. 6

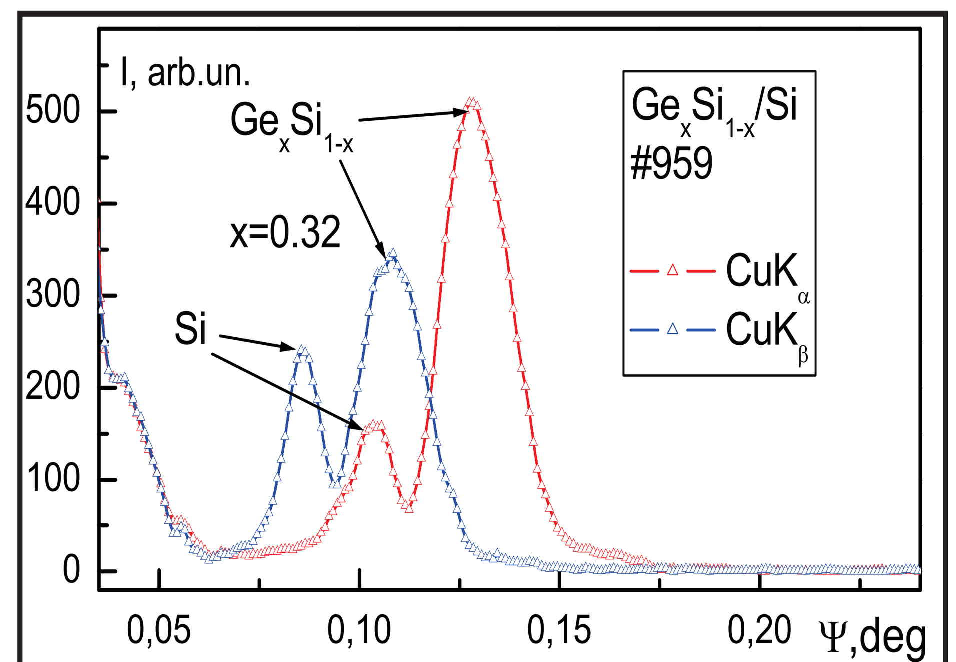

Fig. 7

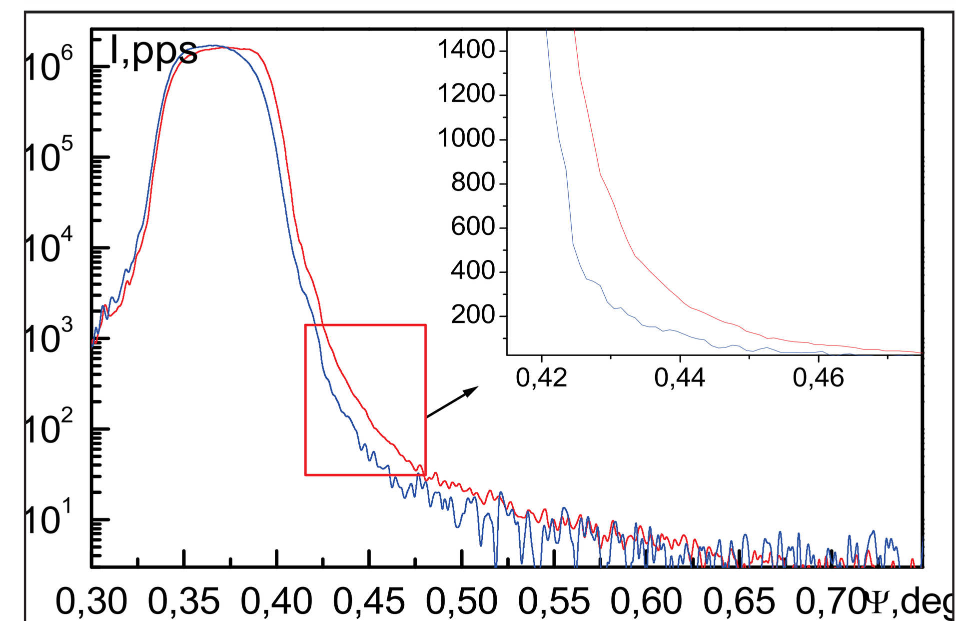

Fig. 8a

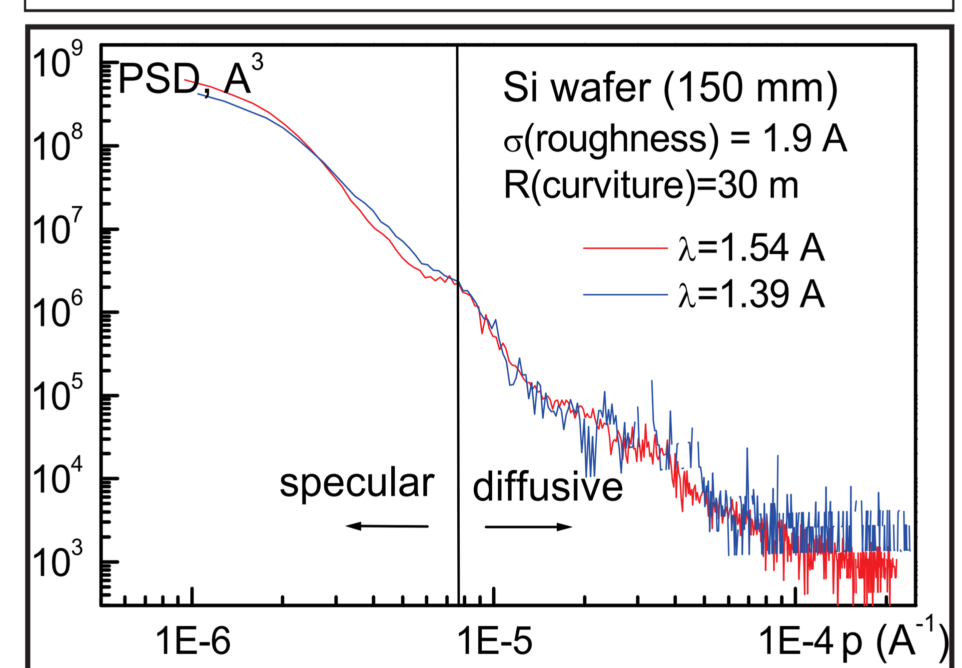

Fig. 8b