High resolution X-ray diffractometry and reflectometry of semiconductor nano- and micro- structures based on x-ray refractive optics

Thesis abstract

Petr Ershov

The new generation of synchrotrons, together with refractive optics, has opened up ample opportunity for research in the field of micro-sized materials.

Apart from excellent microfocusing and imaging applications, one of the most notable and useful properties of compound refractive lenses (CRL) is its intrinsic ability to perform one- or two-dimensional Fourier transforms. In the case of hard X-rays, these properties have been demonstrated both theoretically and experimentally.

In spite of the progress made in X-ray refractive optics, many synchrotron facilities have been employing outdated methods and techniques incapable of using synchrotron radiation to its best advantage. It is noteworthy that today many high-resolution X-ray diffraction (HRXRD) and X-ray reflectivity (XRR) beamlines are based on the non-effective and complex conventional approaches.

This thesis discusses novel approaches to high-resolution X-ray diffractometry and reflectometry of semiconductor micro- and nano-structures based on CRL. The overall aim of this work is to modernize the existing HRXRD and XRR methods with the view of increasing the angular, space and time resolution for present-day synchrotron sources.

Other objectives of this thesis are as follows:

- To analyze conventional X-ray high-resolution methods of diffractometry and reflectometry.
- To design and implement an alternative X-ray optical scheme of HRXRD and XRR based on refractive X-ray lenses.
- To perform experiments and process data in order to generate the results demonstrating the advantages of new methods.

Ultimately, the two concepts as follows will be studied experimentally:

- X-ray Compound Refractive Lenses Fourier Transform (CRL FT) for HRXRD tasks.
- Hard X-ray Reflecto-Interferometer (HXRI) for X-ray Reflectometry tasks.

The new techniques were used to analyze micro-radian diffraction from Si–Ge nano-heterostructures representing two–dimensional lattice of nano-epitaxial germanium islands on a silicon pillars. It was estimated that CRL FT technique provide a resolution 10 times higher than that achieved with traditional HRXRD methods.

The Hard X-ray Reflecto-Interferometry based on a creating interferogramm by focusing on a film/membrane surface is proposed as a novel X-ray reflectivity method.
By new approach have been resolved thickness oscillation from Si3N4 membranes with thickness 200, 500 and 1000 nm. Also the degradation process of 100 nm PMMA film under X-ray exposure was studied.