Coherent X-ray Diffraction on Nano-size Objects

I.A. Vartanyants[1], I.K. Robinson[2]

[1]HASYLAB at DESY, Notkestr. 85, D-22607 Hamburg Germany;
[2]Department of Physics, University of Illinois, 1110 W. Green St., Urbana IL 61801, USA

Coherent x-ray diffraction (CXD) is a new experimental method for studying perfect and imperfect crystals. The method has become available by the recent development of high-brilliance third generation sources of synchrotron radiation (ESRF, APS, SPRING-8). The beams coherence volume being of the order of few microns can entirely enclose a nano-size object. Instead of incoherent averaging, a coherent sum of amplitudes produces a coherent diffraction pattern originating from the real space arrangement of the sample. If high-quality x-ray lenses were available as they are for electrons, such diffraction patterns could be transformed to magnified images directly. However such x-ray microscopes still suffer a lot from optics aberration and resolution is often limited to the pixel size of the CCD.

In this talk we will show how the objective lens of the microscope can be replaced by a special iterative phase reconstruction procedure that inverts intensity measurements of the CXD pattern to real space image. The method is based on the fact that the diffraction pattern can be oversampled relative to its spatial Nyquist frequency so that the Fourier transform can be overdetermined in spite of missing phase information. In principle this method does not have any limitations on the available resolution.

Several applications of the method will be given in the talk. It will be shown how 3D images of the interiors of Au nanocrystals that show 50 nm wide bands of contrast with {111} orientation can be obtained applying this technique [1]. The size of the objects can be further reduced to the size of the quantum dots samples if repetitive motive in the form of 2D crystal is used. It will be demonstrated that in the case of coherent illumination of these samples the correct shape and orientation of individual island can be obtained. In the case of partially coherent illumination the correct shape of the particle can be obtained only when the coherence of the incoming beam is reduced to match the size of the island [2]. In the last example experimental results of CXD scattering on the sample of specially fabricated GeSi islands of nanometer size and in a regular array embedded to Si substrate will be shown [3]. Two geometries of scattering that is grazing incidence diffraction (GID) and grazing incidence small angle x-ray scattering (GISAXS) were used. Applying a microfocuse coherent beam on our sample give rise to coherent diffraction pattern with Bragg spots and broad diffuse maxima in GID geometry. The GISAXS pattern has a typical shape resulting from the periodic array of identical islands. This diffraction pattern was used to reconstruct the average shape of the islands using a model independent phase retrieval algorithms.

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