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Attenuation and indirect excitation effects in x-ray fluorescence holography

D. T. Dul*, K. M. Dąbrowski and P. Korecki

Institute of Physics, Jagiellonian University, Reymonta 4, 30-059 Kraków, Poland

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*e-mail: dawid.tadeusz.dul@uj.edu.pl

Many physical properties of materials are determined by local atomic structure. A variety of imaging techniques have been developed over the years to gain local structure information. Among them is x-ray fluorescence holography (XFH) which gives direct access to the intensity and phase of the scattered radiation enabling full three dimensional imaging of atomic structure. The holographic pattern can be viewed as a small, direction dependent oscillatory part of the x-ray absorption coefficient and originates from the interference of an incident photon wave with waves scattered from atoms inside the sample. The holographic signal for a given element is probed by measuring characteristic fluorescence radiation. On the one hand the usage of x-rays and fluorescence allows studies of bulk materials, avoids strong multiple scattering and provides element sensitivity. On the other hand it might introduce parasitic effects such as indirect excitation (IE) and beam attenuation (BA).

In this work we discuss BA and IE effects in XFH and their influence on element sensitivity and local structure imaging. Beam attenuation simply refers to the decrease of the beam's intensity as it penetrates through the sample. Indirect excitation occurs when fluorescence from one kind of atoms can excite other types of atoms introducing secondary x-ray fluorescence. Both processes influence the number of measured fluorescence photons and therefore the measured holograms. Although IE can be avoided with an appropriate adjustment of the incident beam energy it limits the number of samples which can be analysed with XFH especially in the multi-energy variant of XFH.

We argue that in the presence of BA and IE the experimentally measured hologram should be regarded as a weighted sum of holograms from all the elements from which the sample is composed rather than as a single element hologram. In other words, that element sensitivity with respect to the central absorbing atom is reduced. As a consequence artifacts might arise in the reconstruction images. As an example, Figure 1 presents a multi-energy holographic reconstruction from simulated gallium holograms for GaAs. In the presence of BA and IE additional maxima appear apart from the ones which can be attributed to As atoms. These additional maxima cannot be attributed to remnants of twin images.

A model which takes BA and IE effects into account and which allows to correct for them is proposed [1]. The construction of the model is based on quantitative methods of x-ray spectrometry and holds for samples of arbitrary thickness. We consider both the monochromatic as well as the polychromatic case of XFH [2].

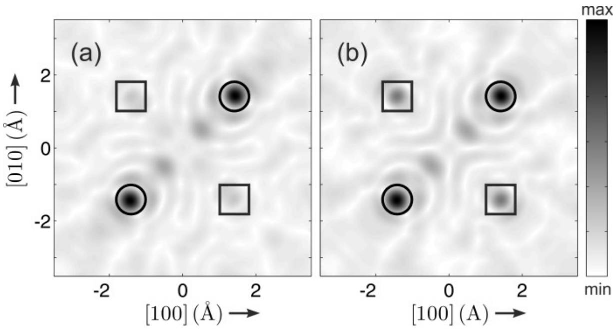

Figure 1. Multi-energy holographic reconstruction in the (004) plane from gallium holograms simulated for GaAs without (a) and with (b) BA and IE effects. Fifteen holograms have been used for the reconstruction with energies ranging from 12 keV to 19 keV with a step of 0.5 keV. The sample thickness was set to 30 μm. Black circles mark the expected positions of As atoms. Black squares mark positions where artefacts arise due to BA and IE.

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[2] K. M. Dąbrowski, D. T. Dul, T. P. Roszczynialski, P. Korecki, *Physical Review B* **87** (2013) 064111.