



University
of Victoria

Graduate Studies

Notice of the Final Oral Examination
for the Degree of Doctor of Philosophy

of

MANA NOROUZPOUR

MSc (Science and Research University of Tehran, 2007)

BSc (University of Tehran, 2004)

**“The Development of Self-Interference of Split HOLZ (SIS-HOLZ) Lines
for Measuring Z-Dependent Atomic Displacement in Crystals”**

Department of Mechanical Engineering

Wednesday, April 12, 2017

1:00 P.M.

Engineering Office Wing

Room 230

Supervisory Committee:

Dr. Rodney Herring, Department of Mechanical Engineering, University of Victoria (Supervisor)

Dr. Brian Lent, Department of Mechanical Engineering, UVic (Member)

Dr. Thomas Tiedje, Department of Electrical and Computer Engineering, UVic (Outside Member)

Dr. Matthew G. Moffitt, Department of Chemistry, UVic (Outside Member)

External Examiner:

Dr. Michael Robertson, Department of Physics, Acadia University

Chair of Oral Examination:

Dr. Timothy Iles, Department of Pacific and Asian Studies, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

Measuring atomic displacement inside crystals has been an important field of interest for decades especially in semiconductor industry for its effect on the electron/hole mobility through the material. There are three different image based, diffraction based, and electron holography based techniques using transmission electron microscope (TEM). These methods enable measuring atomic displacement inside specimen. However, among all TEM techniques offering nano-scale resolution measurements, convergent beam electron diffraction (CBED) patterns show the highest sensitivity to the atomic displacement. Higher order Laue zone (HOLZ) lines split by small variations of lattice constant allowing the atomic displacement measurement through the crystal. However it is a cumbersome measurement and it can only reveal the atomic displacement in two dimensions. Therefore, the atomic displacement information at each depth through the specimen thickness is still missing. This information can be obtained by recovering the phase information across the split HOLZ line. The phase profile across the split HOLZ line can be retrieved by the electron interferometry method. The phase of the diffracted beam is the required information to reconstruct the atomic displacement profile through the specimen thickness.

In this work, we first propose a novel technique of self-interference of split HOLZ line based on the diffracted beam interferometry which recovers the phase information across the split HOLZ line. The experimental details of the technique have been examined to report the parameters in order to implement the method. Regarding the novelty of the technique and the lack of the of a reference phase profile to discuss the results, phase profile simulation was a main contribution. For simulating the phase profile across the split HOLZ line the Howie-Whelan formula supporting the kinematical theory of diffraction is used. Accordingly, the analytical approach to simulate the phase profiles across the split HOLZ line for three various suggested atomic displacements are studied. Also, the effect of some parameters such as the atomic displacement amplitude, the specimen thickness, and the \mathbf{g} reflection is investigated on the phase profile. This study leads to an equation used for fitting the experimental results with the simulated phase profile.

Consequently, self-interference of split HOLZ line (SIS-HOLZ) is studied as a method of reconstructing the phase profile across the split HOLZ line which carries the information of atomic displacement through the specimen thickness.

Eventually, this work has been the winner of two awards:

1- The student poster award in the physical science session of the electron microscopy annual conference, Microscopy and Microanalysis (M&M) 2015. It was held in Portland-Oregon- USA.

2- The student poster award in the Pacific Centre for Advanced Materials and Microstructures (PCAMM) 2016. It was held in UBC- Vancouver-Canada.