The contribution of phonon scattering to HREM

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Introduction

It has been suggested that phonon scattering may make a significant contribution to lattice images and thus may be the cause of the experimentally measured low contrast, often known as the Stobbs factor.

Here we use energy filtered electron holography to measure the proportion of phonon scattering and its effect on lattice fringe contrast in high-resolution images of ZnO.

The lattice image reconstructed from the hologram fringes, the skeleton, is formed by interference with a reference wave and thus contains only elastic scattering.

The normal lattice image, the centreband, formed by filtering out the hologram fringes, contains both elastic and phonon scattering. The holograms are energy filtered to ensure that the centreband contains no inelastic scattering.

Measuring phonon scattering using holography

One number of a tedious series of energy filtered electron holograms of a ZnO crystal used for an [200] zone axis. The inset enlargement shows the holographic interference fringes and the (200) and (000) lattice fringes of ZnO.32

Figure 1: The hologram with the “centreband” and “skeleton” marked. The two circles show the size of the apertures used when reconstructing the lattice images.

Stages involved in the determination of mean intensity and lattice fringe amplitude profiles from holograms:

1. (a) and (c) Recorded and developed of the hologram (waveform positive).

2. (b) Amplitude and phase of the hologram computed from the developed.

3. (d) Lattice image reconstructed from the wavelet after the elasticity of the hologram component wave has been subtracted.

4. (e) Lattice image calculated from the squares of the amplitude image reconstructed from the wavelet from the developed.

5. (f) Mean intensity of the lattice image, calculated by applying a mask to the (200) fringe by e, for all images. The mean intensity is shown in the 0-200 range in f. The yellow solid line shows the initial intensity repeated at the end of the series and the unfiltered image taken at the start of the series.

6. (g) Lattice fringes skeleton (elastic only) and elastic plus phonon at three different thicknesses.

Lattice fringe amplitudes

Mean image intensity

Elastic + phonon (centreband)

mean = 0

white = 1.5

Elastic only (centreband)

black = 0

white = 1.5

Phonon only (centreband - skeleton)

black = -0.3

white = 0.4

Line profile through centre of image

Mean intensity of the centreband images, skeleton images and an unfiltered image plotted as a function of distance from the specimen edge the centreband images (solid line) and skeleton images (dotted line) for all three thicknesses.

The mean intensity intensity shows that in the lattice image phonon scattering increases with increasing specimen thickness.

Conclusion

For a sample whose thickness is typical of that used in HREM, phonon scattering contributes about 10% of the intensity in an energy filtered image.

Phonon scattering reduces the lattice fringe contrast to about 70%, corresponding to a Stobbs factor of 1.4.

This is not sufficient to account for the observed lack of contrast in experimental lattice images, typically a factor of 2 to 3, especially in thin regions.

Phonon scattering combined with disorder from amorphous surface layers may be enough to account for the Stobbs factor.

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