THE USE OF NEIGHBOURHOOD INTENSITY COMPARISONS, MORPHOLOGICAL GRADIENTS AND FOURIER ANALYSIS FOR AUTOMATED PRECIPITATE COUNTING & PENDELLÖSUNG FRINGE ANALYSIS IN X-RAY TOPOGRAPHY

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Crystal distortions modify the propagation of x-rays in single crystal materials, and x-ray topography can be used to record these modifications on a recording medium (e.g. film) thus providing images of the distributions and nature of defects, dislocations, strains, precipitates, etc. in semiconductors [1,2]. Analysis of the topographs is often difficult since many complicated features can appear in a single image. The topographs often present black or white areas wherein it is difficult to observe details. Small variations of contrast, which often need to be analysed can be rendered invisible. Furthermore, artefacts in the films must be removed. These could be due to unwanted phase contrast caused by imperfections in collimating slits [3] or could be real features in the topograph which overlay less visible features which need to be analysed [4]. This study examines the used of advanced image analysis techniques applied to a selection of x-ray topographs in section transmission mode: (i) the automated counting of oxygen-related precipitates, which also present many unwanted features including vertical streaking due to collimating slit phase contrast and strain features near the surface due to the presence of integrated circuit process strains and (ii) the enhancement of Pendellösung Fringes (PFs) for subsequent automated densitometric analysis of these, again in section topographs which also contain precipitate images and vertical and diagonal streaking due to materials processing and slit phase contrast. In the cases studied here, we examined 220 section transmission topographs of single crystal silicon, after a number of different IC processing steps (thermal annealing, overlayer deposition, doping, etc.)

For automated precipitate counting it was found that optimal precipitate identification is achieved using morphological image analysis [5] based on a 7x7 square structuring element together with a user-defined intensity difference variable. Overlapping precipitates are correctly separated using a morphological gradient, which was subtracted from the original image leaving small separated precipitate images. These were counted and subsequently grown by conditional dilation and removed from the image, leaving the remaining precipitates to be counted. The precipitates were correctly counted regardless of orientation, shape or size by a counting algorithm based on mathematical morphological methods.

For highlighting and analysing the PF images a different approach was used. Firstly, the brightness gradient is removed via morphological methods using either an 11x11 or a 21x21 structuring element, the choice of which is automated and depends on the input image size. The image is subsequently transformed into Fourier space and a strip pass filter is applied. An optimal strip pass filter of 5 pixel width produced best results. These removed any extraneous vertical or diagonal streaking in the topographs, as the PFs exist only in the horizontal plane of the original image. The user can subsequently perform a densitometric plot perpendicular to the PFs in order to compare experiment with theory, if required.

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