Automatic band detection in Kikuchi patterns using Hough transform

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ABSTRACT

The principles of obtaining Kikuchi band images (Kikuchi pattern) and methods of their analysis in order to determine local deformations for the studied crystals are considered. Digital pre-processing of Kikuchi images is performed, namely, noise is removed by bilateral filtering and their local contrast is increased. The image processing program is developed in Python. Contours on the image are selected using the Canny method. The band boundaries are first approximated by straight lines using the Hough method based on the image contours, and then the band boundaries are more accurately approximated by parabolas and hyperbolas. The Hough method selected only straight line segments that exceed a given length and the size of the gaps for which does not exceed a given one. The resulting bands were also selected by direction, which allows each band corresponding to a specific crystallographic direction to be separately investigated. The image was rotated by the bicubic interpolation method to the angle of inclination of the band, which simplifies further approximation of the band boundaries. For each point of the band boundary, the weight centre of the contours was calculated, and the obtained weight centres were approximated by a parabola using the least squares method. After that, the Kikuchi band boundary was approximated by a hyperbola, the parameters of which were obtained by the coordinate descent method by minimizing the mean square difference between the corresponding points of the parabola and hyperbola. A series of experimental images of Kikuchi bands obtained from synthesized diamond crystals was studied. For the studied images, the shape of the hyperbola describing the band boundary is close to a parabola in the vicinity of the vertex. The obtained hyperbolas provide a much more accurate description of the band boundaries compared to straight lines. Based on the analysis of the averaged profiles of Kikuchi bands, the deformations of the crystals, which are described by the relative change in their interplanar distances, were determined.

Keywords: Kikuchi pattern, Hough transform, digital image processing, hyperbole, synthesized diamonds.

1. INTRODUCTION

Analysis of backscattered electron diffraction images (Kikuchi pattern, Kikuchi band images) is a highly accurate and non-destructive method for determining local deformations for the studied crystals[1-3], in particular, synthesized diamond crystals[4]. Kikuchi images are formed in a scanning electron microscope as a result of registering electrons reflected (diffracted) from the studied crystal, which are focused on a local area of the sample. The reflected electrons fall on a phosphorescent screen, in which their energy is converted into electromagnetic radiation of the visible range. Registration of light rays that form the Kikuchi pattern is performed using photosensitive matrices (for example, a CCD matrix). In such an optical system, image blurring and its geometric distortions are minimized, similarly to other systems for optical diagnostics of objects[5-7].

Analysis of the shape of the intensity profiles of individual Kikuchi bands allows to determine not only the average local strains[8-9], but also strains for different crystallographic directions. However, experimental Kikuchi images are characterized by significant noise levels and inhomogeneous contrast, which reduces the accuracy of band detection. Manual detection of Kikuchi bands is laborious and has limited accuracy, and the use of the Hough method for automatic band detection allows us to accurately detect only clear bands.

Therefore, the paper proposes to perform digital pre-processing of Kikuchi images: noise removal by filtering and increasing their local contrast[10-11]. Noise removal was performed using a bilateral filter[12], which provides better preservation of the shape of the bands compared to the known Gaussian filter and median filter. A feature of the bilateral filter is the use of two Gaussian kernels, which perform image processing in the spatial domain and in the intensity domain. Promising means of reducing the noise level in the image are artificial neural networks (ANN), namely convolutional neural networks (CNN)[13], which implement deep learning methods. ANN provide high visual quality of images, but can lead to the appearance of artifacts. Therefore, bilateral filtering used for high-precision processing of Kikuchi images.

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