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Incoherent processing of transmission images of thin films obtained in electron microscope*

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The aim of this work is the processing of transmission images obtained in electron microscope, especially images of very thin films. In order to avoid the coherent noises we used a partially coherent setup with a Hg bulk lamp as a light source in the optical processing system. Fourier holograms have been used as a spatial filter for image deblurring while absorbing masks for contour enhancement. This resulted in significant suppression of noises in the processed images.

1. Introduction

Transmission images of thin films recorded in electron microscope are of low contrast. The crystal grains are small and thin, less than 100 μ. The grain borders affect insignificantly the electron beam. Such images are hard to analysis.

The aim of this paper is to improve the images by using optical means.

2. Transmission images

A simple but powerfull method for contrast enhancement is a proper screening of the zeroth spatial frequency of Fourier spectrum of the object. In a coherent system this technique works very effectively but unavoided coherent noises spoil the results. In order to overcome these difficulties we used a quasi-coherent source for improving the images.

The optical setup is a conventional two-lens arrangement. A Hg low pressure bulk is the light source. Its spatial coherence is increased by using a pinhole of diameter of 0.3 mm, placed at the focal point in the two-lens illuminator. The ultraviolet radiation is absorbed by a 50 mm long glass rod, the yellow illumination is not recorded by the photographical plates. We availed only the green line for the images processing.

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A black spot of transmittance shown in Fig. 1, placed in the centre of the Fourier plane of the system, plays the role of a high pass filter. Generally, the transmission plot of the filter used must be matched with the object to be improved.

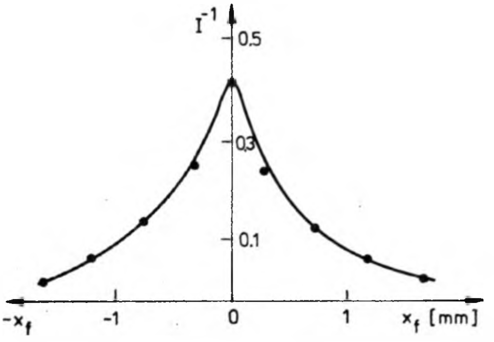


Fig. 1. Transmission I plot of the screening spatial filter

In a coherent system, the light field behind the filter is

$$U(\vec{x}_f) = \tilde{S}_0(\vec{x}_f)[\Lambda(\vec{x}_f)^{-1}], \qquad x_f = (x_f, y_f)$$

where: $\tilde{S}_0$ is the Fourier spectrum of the input image S_0, Λ^{-1} figures the filter transmittance. In the imaging plane we have

$$S_i(\vec{x}) = S_0(\vec{x}) * [\mathrm{sinc}^2(\vec{x})]^{-1}, \qquad x = (x, y).$$

The resulting image is deprived of light transmitted through the input image without diffraction, so the contours are enhanced.

What are the disadvantages of the coherent systems? The filter causes the appearance of satellite lines accompanying each contour in the processed image, and the reflections in the optical setup give coherent noise of high contrast.

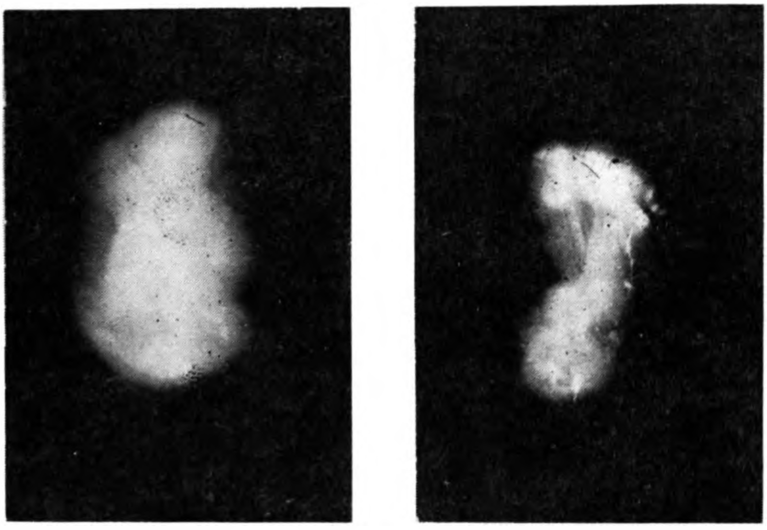
A partially coherent illumination can produce better images. The filter operates in the central part of the focal plane which corresponds to zeroth spatial frequencies mainly, while the higher spatial frequencies overlapping one another are transmitted.

Let us consider a semi-coherent illumination as being the sum of coherent and incoherent ones [1]. Now, the resultant image is

$$|S_i(\vec{x})|^2 = |S_0(\vec{x})|^2 + |S_0(\vec{x}) * \mathrm{sinc}^{-2}(\vec{x})|^2.$$

The modulating term is here overlaid with the undisturbed incoherent image and constitutes its alteration only. The improved image and the original image are confronted in Fig. 2.

Similar results can be obtained by using a computer-aided image processing [2], but in our opinion optical technique is simpler. Like in all integral processes the filter must be always fitted to the object.



a b

Fig. 2. Image of thin borazon film recorded in electron microscope: **a** — before processing, **b** — after processing

3. Diffraction patterns

We have tried to employ the partially coherent illumination for sharpening the blurred diffraction images obtained in the electron microscope. However, the blur of the diffraction lines has an analytical sense and the plot of the diffraction stripe is of value for the evaluation of the crystalline state of the film. But a sharpening of the line can be helpful for its exact positioning.

Since the object we tried to sharpen was almost undiscernible we decided to use the deblurring technique of STROKE [3]. The deblurring filter has been manufactured in a coherent system for recording Fourier holograms. A pinhole placed at the input plane serves as the image of the impulse response. The diameter of the pinhole must be found experimentally. Several filters (Fourier holograms) have been made with the use of reference beams of various intensities. Depending on these intensities the obtained filters differ in the transmittance at their central parts. Two different plots of the filter transmissions are shown in Fig. 3. They screen the zeroth spatial frequency in a different degree.

The spatial filters are next used in a two-lens deblurring system with incoherent illumination. The diffraction image recorded in electron microscope is placed at the input and the filter is carefully inserted in the focal plane of the first lens. The deblurred image can be found in the side diffracted conjugated beam at a distance which depends on the filter used.

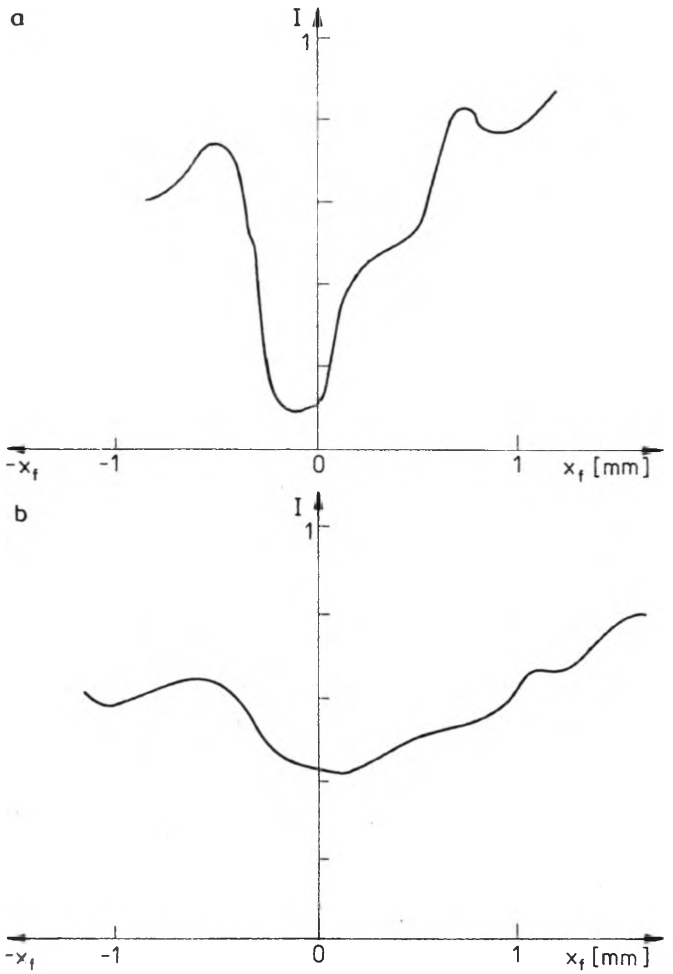


Fig. 3. Plot of the transmission I of the deblurring spatial filter: **a** – screening the central part, **b** – transmitting the central part of the Fourier image

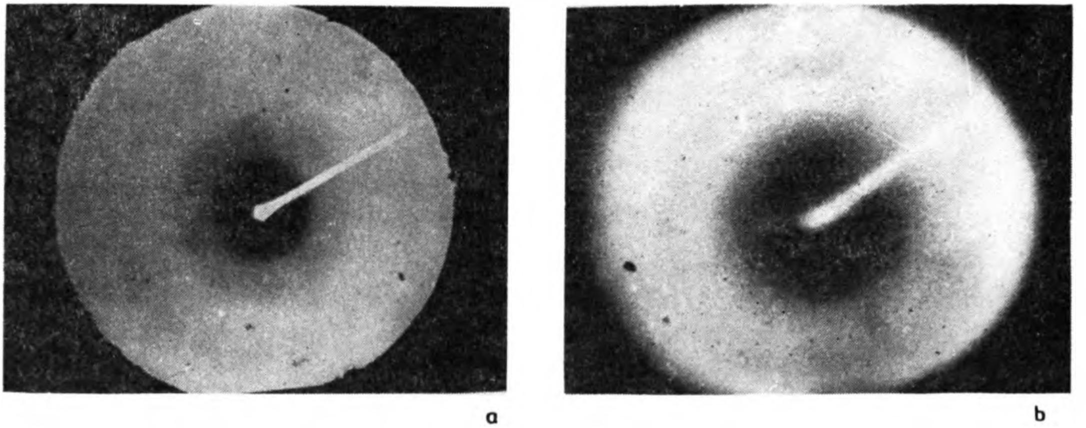


Fig. 4. Diffraction pattern of a thin diamond film: **a** – before processing, **b** – after processing. The low line is enhanced, the sharp lines become smeared

We have obtained best results with the filter, realized from an impulse response imitating a pinhole of diameter 1.8 mm. It transmits spatial frequency band from 1.5×10^3 l/mm to 13×10^3 l/mm and was recorded on Agfa Gevaert 10E75 plates.

The images of the input object and the deblurred image are compared in Fig. 4.

4. Conclusion

The advantage of incoherent illumination is the absence of noises. The disadvantage is a linear blurr caused by the dispersion of Hg line due to diffraction by the Fourier hologram.

Acknowledgement — The processed images were thin films of borazon and diamond obtained with pulse plasma in the Laboratory of Materials Science, the Warsaw Technical University, Poland.

References

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Некогерентная обработка изображений

Изображения, обработанные в когерентных системах обработки сигналов, часто искажены некогерентными шумами. В настоящей работе мы использовали некогерентную оптическую систему обработки. Пространственными фильтрами, использованными в работе, были непрозрачные маски и голограммы Фурье, как используемые в когерентных системах. На выходе нашей некогерентной системы мы получили преобразованные образцы с пониженным шумом. Некогерентная обработка применена для образцов, полученных в электронном микроскопе.