Acta Cryst. (1968). A**24**, 614

An Application of Holography in Reflexion Microscopy

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(*Received* 2 *October* 1967)

A method for reflexion microscopic holography is given. The hologram is obtained of the real image formed by the objective and viewed with the ocular of a normal microscope. The method is suitable for inspecting crystal surfaces and reflecting surfaces in general.

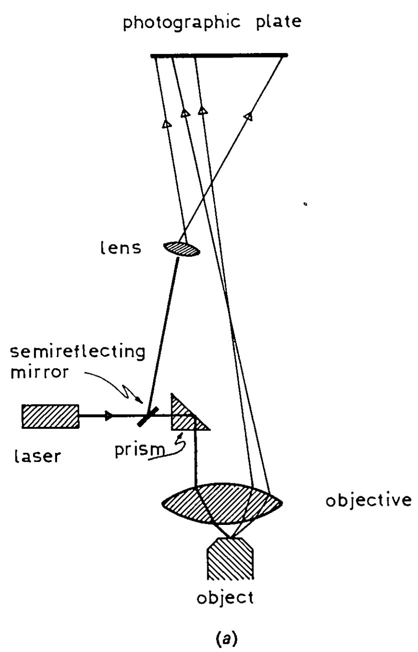
Some new holographic techniques have been applied in transmission microscopy during the last two years (Van Ligten & Osterberg, 1966; Ellis, 1966; Van Ligten, 1967). We have studied a holographic method for reflection microscopy.

Experimental method

The work was carried out in two main steps. Firstly we made a hologram of the real image given by the objective of a microscope. A schematic drawing is seen in Fig. 1(*a*). An objective Leitz Opakilluminator (used with the total reflecting prism) receives the laser beam directly and sends the light reflected from the object on a photographic plate. Through a semireflecting mirror, under a suitable angle, a fraction of the laser beam, which acts as reference beam, is sent through a diffusing lens to the same photographic plate.

In the second step we observed the hologram through a common eyepiece of a microscope. It is necessary to observe the real image of the hologram. A schematic drawing is given in Fig. 1(*b*).

The reflecting object used was the diamond twin studied by Bedarida & Komatsu (1966) and Bedarida (1967) by interferometry and phase contrast microscopy. The objective used on the Leitz Opakilluminator was a 10×, 0·3 N.A. A continuous wave He–Ne laser, 0·5 milliwatt at 6328 Å, was used. The reference beam was at about 15° to the axis of the objective. The photographic plate was a Kodak 649F placed normally to



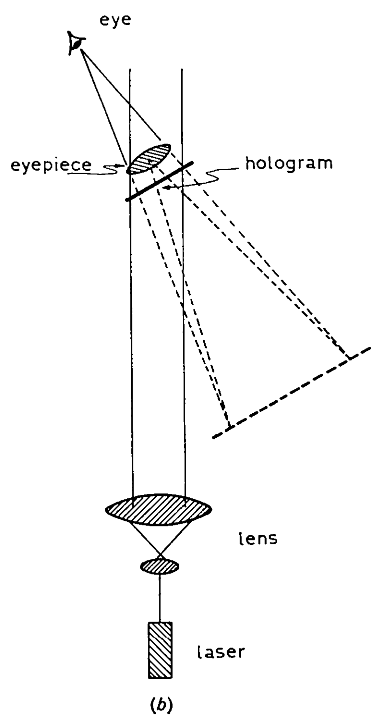


Fig. 1. (*a*) Schematic drawing of the apparatus used to obtain the hologram. (*b*) Schematic drawing of the reconstruction of the image through the eyepiece.

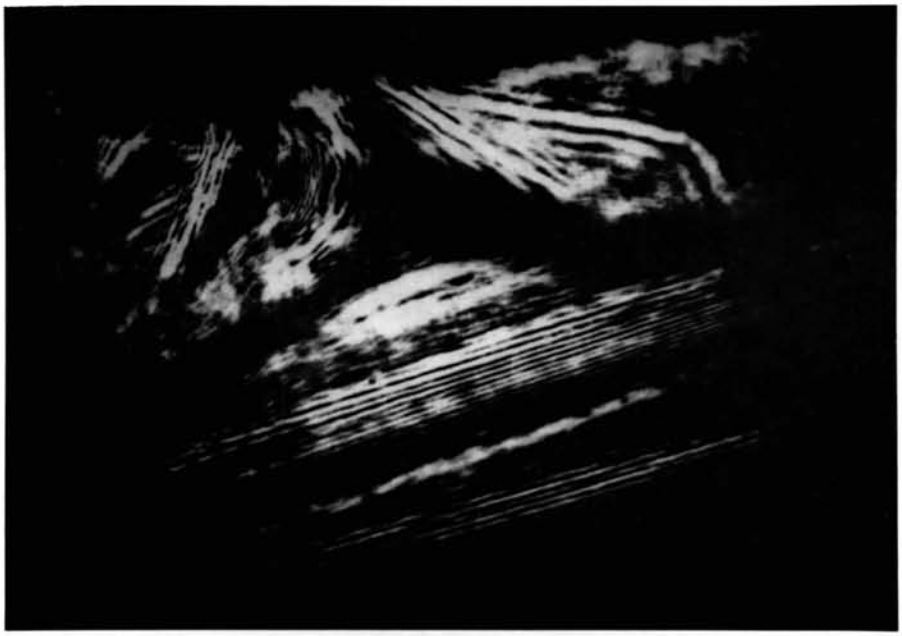


Fig. 2. Enlargement of the hologram. The enlargement relative to the real hologram is × 10.

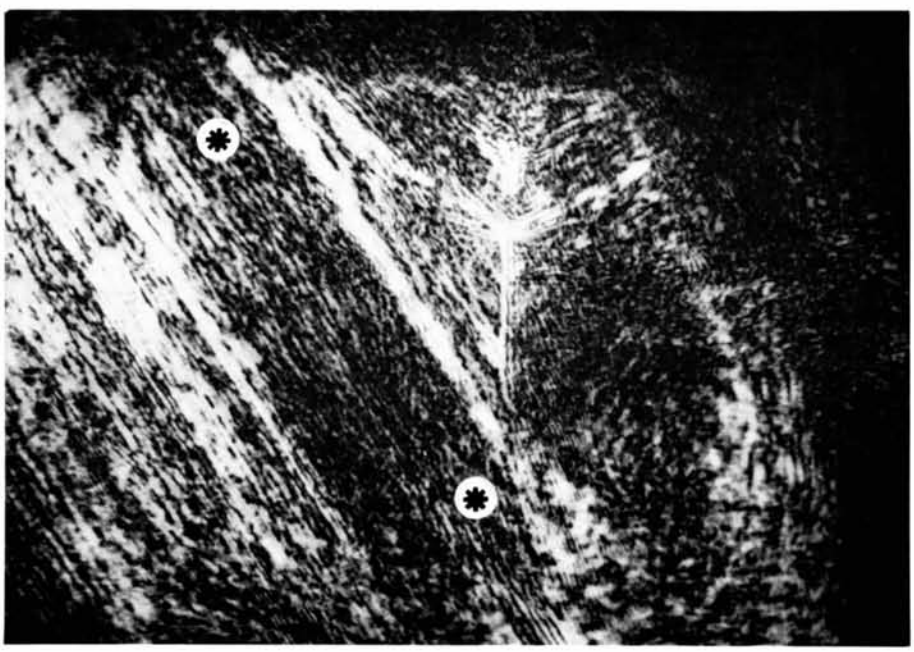


Fig. 3. Photograph of the image of a trigon, reconstructed from Fig. 2 through the eyepiece (× 150).

Fig. 4. Same subject as Fig. 3; image reconstructed through the eyepiece from a hologram with reference beam stronger than Fig. 2 and a slightly different inclination to the axis of the objective (× 150).

Fig. 5. Reconstructed image of part of the date on a 50 lire coin (× 120).

the axis of the objective, at a distance of about 10 cm from the object. The exposure was about 8 seconds. The image reconstruction was obtained through an eyepiece 10×, 0·4 N.A. The ratio between the intensities of the two beams does not seem to be critical but there are some differences in the details using the reference beam stronger or weaker than the reflected beam. The reference beam was constant in intensity and the relative intensities were varied by rotating a polaroid on the beam entering the Opakilluminator.

An enlargement of the hologram is shown in Fig. 2. A photograph of the image reconstructed from Fig. 2 through the eyepiece is shown in Fig. 3. The actual enlargement of the apparatus with the lenses used is 100×. On the photograph the total enlargement is about 150×. The subject is a point-bottomed trigon. Also in Fig. 2 it is possible to recognize broadly the shape of the trigon since the reference beam was weaker than the light reflected from the diamond. Fig. 4 is the same trigon reconstructed from another hologram, whose reference beam was stronger and with an inclination slightly different to the axis of the objective.

We have applied this method also to the inspection of metallic surfaces. Fig. 5 is the microscopic reconstructed image by holography of a part of the number 7 of the date 1967 in relief on an Italian 50 lire coin; the actual enlargement on the photograph is in this case 120×.

By this method some microscopical details may be enhanced in respect to the classical optical methods. If the slope of the surface labelled with two asterisks in Fig. 3 is examined by phase contrast microscopy and interferometry, its stepped nature can be detected, but hardly any information is obtained regarding the fine irregularities of the edges of the steps and they seem to be almost rectilinear. By the method of reconstructing the image one can detect in addition that in the area with the asterisks the edges are a little waved. The wall of the trigon is also waved, as one can see in the region marked with an arrow in the reconstructed image of Fig. 4, and the edges of the trigon are represented by broken lines since they are stepped. The results are satisfying even at this early stage of the work and we think it is possible to improve the method.

We both wish to thank Professor Malvano and Professor Sanero for their interest in this work.

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Acta Cryst. (1968). A**24**, 615

The Debye–Waller Factor for Small Cubes and Thin Films

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(*Received* 4 *March* 1968)

The dependence of the Debye–Waller factor on the size of cubes and plates is calculated by assuming the Debye theory, but using the frequency distribution which incorporates a term that is proportional to the surface area. The ratio of B for small particles to B for large particles is less than 0·01 for cubes with 10^9 atoms or more and for plates which are more than 330 atoms thick. The inclusion or exclusion of the zero point energy terms has a large influence on the size correction which has to be applied to small particles and thin films.

Introduction

Comparison of the Debye–Waller factors for small and large crystallites can give some information about the specific surface vibrations in small particles. However, before this can be obtained it is necessary to apply a size correction to the frequency distribution for volume vibrations. This correction is calculated here for small crystallites and thin films belonging to the cubic system, using the Debye theory. Although the Debye theory of lattice vibrations is a simplification which is justifiable at low temperatures, experimental results are often expressed in terms of this theory because it leads to one single parameter, the Debye temperature, which is 'characteristic' of every material.

Bolt (1939), Maa (1939) and Roe (1941) were first to show that the correct counting of the vibrational frequencies introduces surface and edge terms in the frequency distribution for a Debye solid. Later Montroll (1950) estimated that the size effect in specific heat measurements would become noticeable for non-metallic powders and thin films at 1 °K. Recently Marshall