A TECHNIQUE FOR ACCURATE MEASUREMENT OF SURFACE ANGLES ON CRYSTAL SURFACES

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ABSTRACT

This paper describes a technique for accurate measurement of the angles on the surfaces of single crystals of ferroelectric substances. These angles are formed due to the change in level on the crystal surface caused by the presence of domains in the crystals.

INTRODUCTION

THE single crystals of ferroelectric substances (like $BaTiO_3$, $KNbO_3$, etc.), are characterized by the presence of domains in them. Due to these domains (and hence the domain walls) there is a change in level on the crystal surface, which causes the formation of surface angles[1]. The domains are very small in size but can be observed under ordinary microscopes. The angles that are formed are usually of the order of 60 minutes or less and the crystals themselves are very small (only a few millimetres in size) thus making it practically impossible to measure them using a spectrometer. A special technique of Multiple Beam Interferometry[2] is employed to measure these angles with accuracy.

TECHNIQUE

Tolansky's Multiple Beam Interferometric method consists of the production of multiple beam Fezeau fringes between two surfaces employing a succession of coherent beams. If the multiple beam interference pattern is formed between a flat glass plate and another nearly flat surface (though it may have a complex shape), the fringe pattern is effectively a contour map of the surface microtopography. The fringes are improved in quality if the two surfaces are coated uniformly with a thin reflecting film of silver (allowing about 10 to 15% transmission).

In order to study the microtopography of the surface of a crystal, it is suitably mounted on a glass plate with the help of some adhesive. The crystal and a flat glass plate are coated with silver using vacuum evaporation technique. The crystal plane is adjusted over the glass plate such that it forms an air wedge with the plane of the glass plate. The fringes are observed in reflected light using the green line of mercury (wavelength = 5461 Å).

TEST OF THE ACCURACY OF SURFACE ANGLE MEASUREMENTS USING THIS TECHNIQUE

In order to test the accuracy of the results of surface angle measurements by this technique, a preliminary experiment was carried out using Fresnel's biprism in the place of the crystal. The biprism angle was approximately 60 minutes. It was first coated with a thin reflecting film of silver and its angle was accurately determined using a spectrometer. (This could be easily done because the size of the biprism was sufficiently large and it could be easily mounted on the prism table of the spectrometer.) The reflections from the two surfaces forming the biprism angle were utilized for this purpose. Mean of a number of observations was taken and the result (66·0 minutes) was taken to be correct to an accuracy of half-a-minute.

The biprism was adjusted over the silvered glass plate such that the edge of the biprism touched the plate only at one point (Fig. 1, point E). The

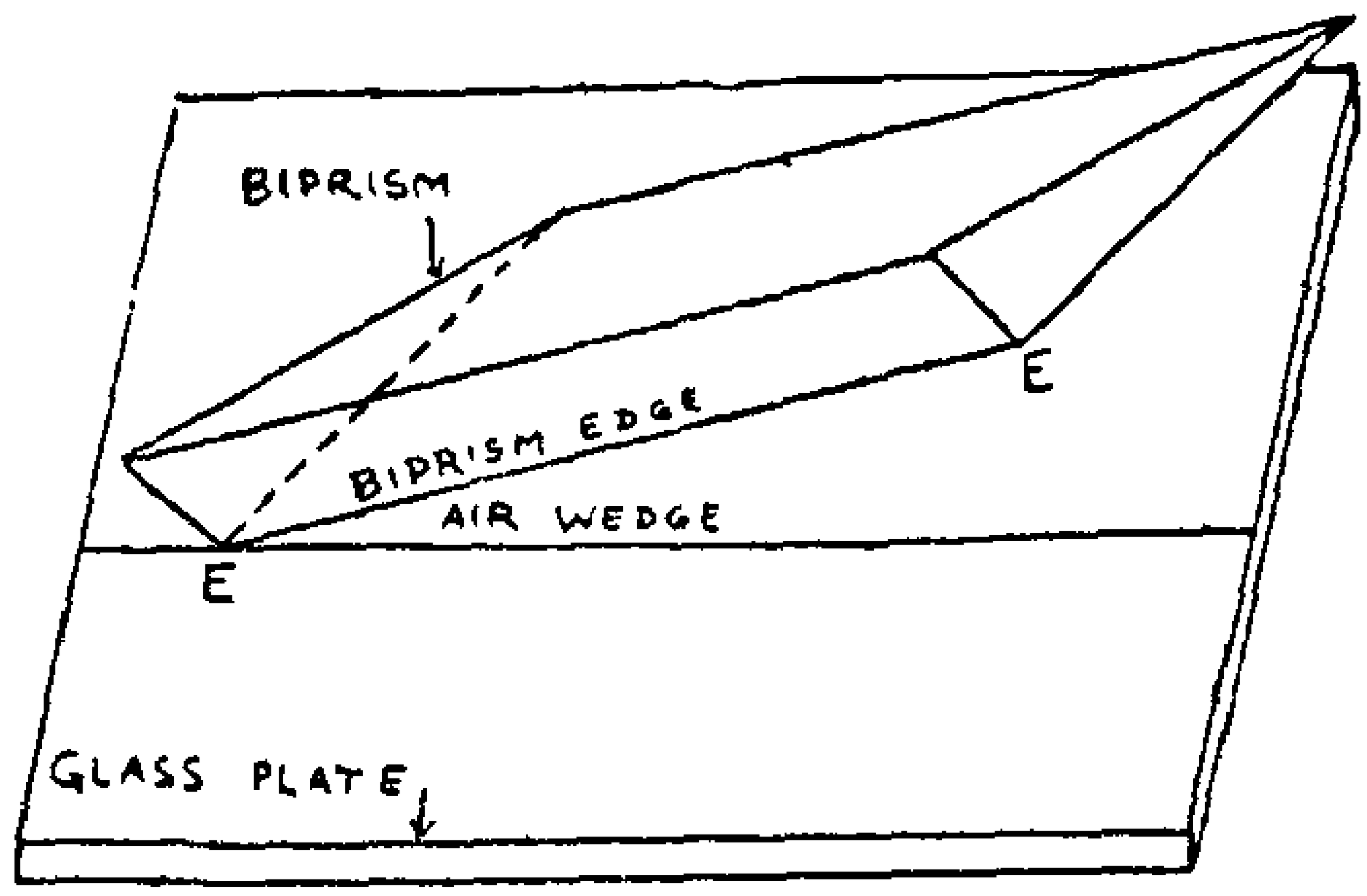

FIG. 1. The arrangement of the biprism over the optical flat to obtain the multiple beam interferometric fringes.

inclinations of the two planes of the biprism were adjusted to be nearly equal on the glass plate. With such an arrangement the interference fringes obtained were as shown in Fig. 2.

If the biprism edge EE′ is parallel to the optical flat, an expected fringe system is a set of equidistant parallel fringes on both sides of the line EE′.

Figure 3 shows a Multiple Beam Interferogram where the biprism has been adjusted with its edge EE′ parallel to the optical flat. Here it is seen that the fringes near the edge EE′ of the biprism are not equidistant, indicating the rounding off of the edge. Hence while making the measurements for the distance between the fringes, the fringes situated sufficiently away from the edge EE′ were used.

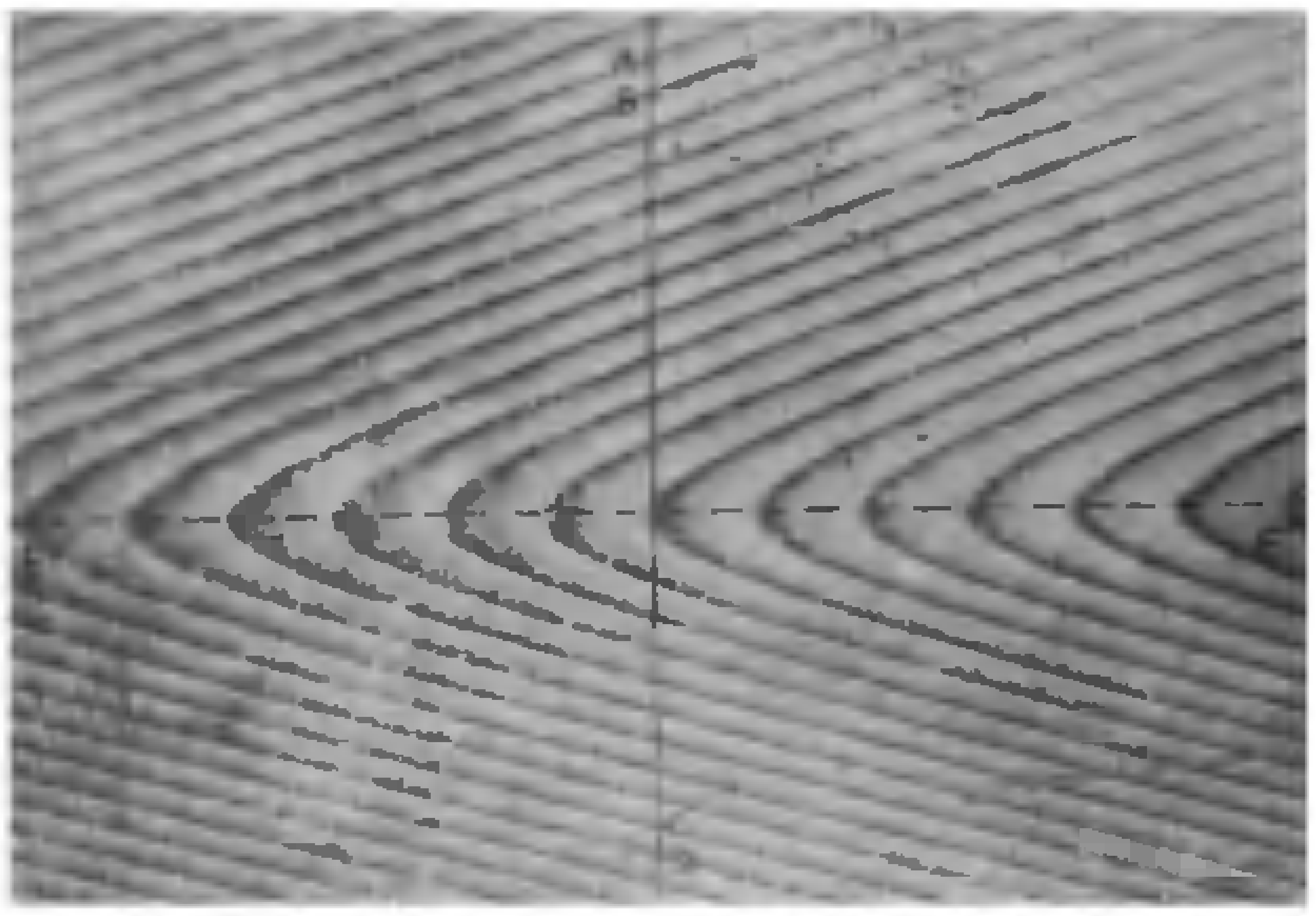

FIG. 2. Multiple Beam Interferometric fringes obtained by the arrangement of Fig. 1 (Magnification 110 ×).

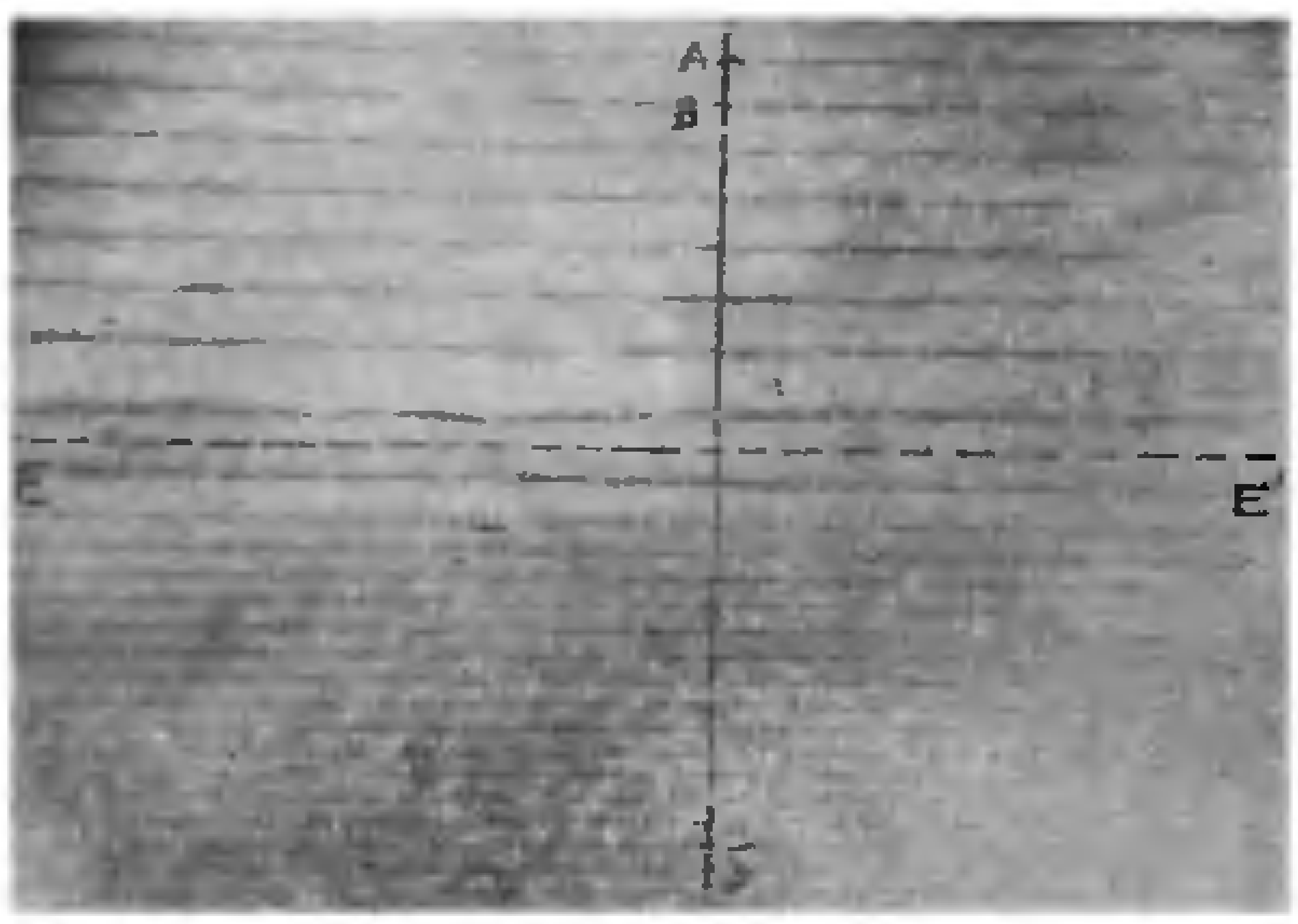

FIG. 3. Multiple Beam Interferometric fringes obtained when the edge EE′ of the biprism is parallel to the optical flat (Magnification 115 ×).

The biprism angle was calculated from the interferograms of Figs. 2 and 3 using the formula given by Tolansky[2]:

$$\theta = \frac{M\lambda}{2}\left(\frac{1}{AB} + \frac{1}{CD}\right) \text{ radians}$$

where M is the total magnification (this quantity should be accurately found out because the measurements are done on enlarged photographs).

AB and CD are the distances as shown in Figs. 2 and 3. (In practice, the distance between a number of fringes is found out and then it is averaged, in order to minimise the error in the measurements.)

λ is the wavelength of the light used.

The value of the biprism angle thus calculated was found to be 66·2 minutes. The spectrometer also gave very nearly the same result thus confirming the accuracy in the use of Multiple Beam Interferometry for such work.

SURFACE ANGLES DUE TO DOMAINS IN $KNbO_3$ SINGLE CRYSTALS

Figure 4 shows the micrograph of the surface of a silvered $KNbO_3$ single crystal in reflected light. Figure 5 is the corresponding interferogram over the same surface. The micrograph of Fig. 4

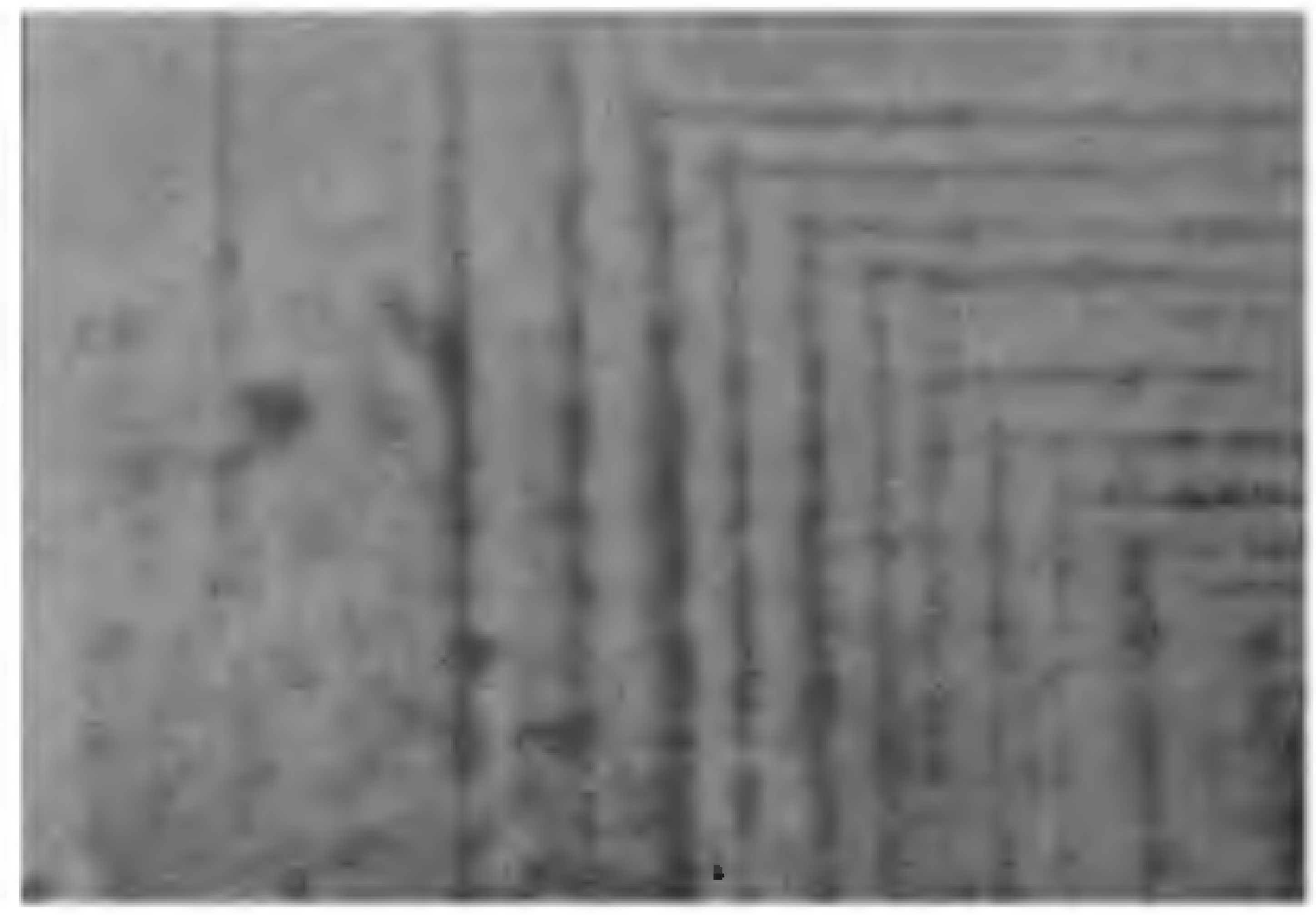

FIG. 4. Micrograph over the surface of the $KNbO_3$ single crystal (Magnification 135 ×).

reveals a large number of domain walls and the fringes in the corresponding interferogram of Fig. 5

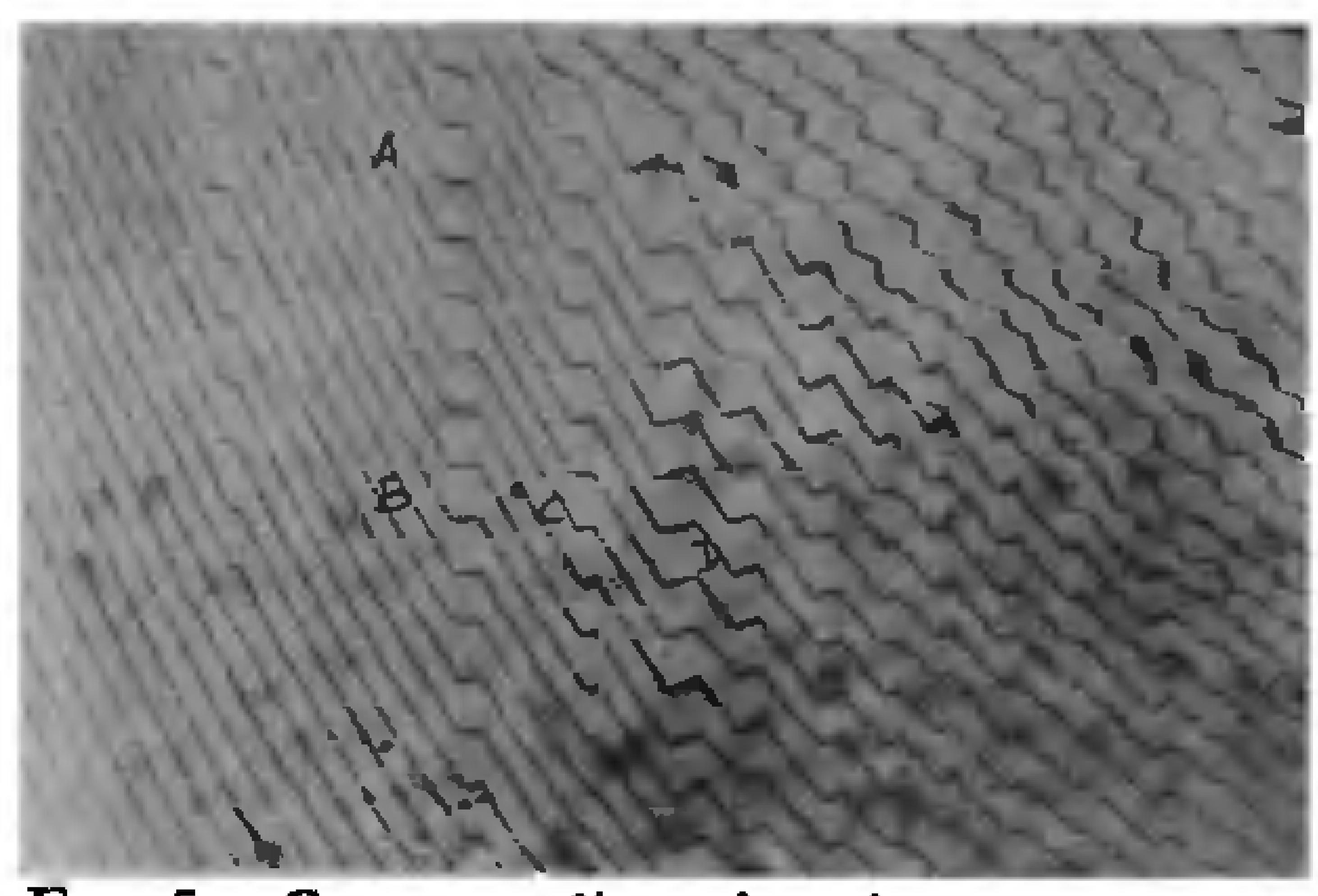

FIG. 5. Corresponding interferogram over the same surface of $KNbO_3$ single crystal (Magnification 135 ×).

show that there is a definite change in level at each of the domain wall. If the crystal surface were a perfect plane, the interferogram would have shown straight parallel fringes.

The surface angles have been measured at the places marked A, B, C, and D and the values calculated using the formulae of Tolansky[2] are 56·5, 56·6, 56·8, and 57·2 minutes respectively. These values show a close agreement with the theoretical value of 57 minutes, the angle at which the planes across 60° domain walls in $KNbO_3$ single crystals are inclined.

1. Bhide, V. G. and Bapat, N. J., *Physica*, 1961, 27, 531.
2. Tolansky, S., *Multiple Beam Interferometry of Surfaces and Films*, Clarendon Press, Oxford, England, 1948.