Thickness Measurements of Thin Films

I READ with interest the description by Gunn and Scott[1] of their method of measuring the thickness of thin films. I have been using the same method for some time, but have found necessary a number of modifications and precautions which it may be helpful to record.

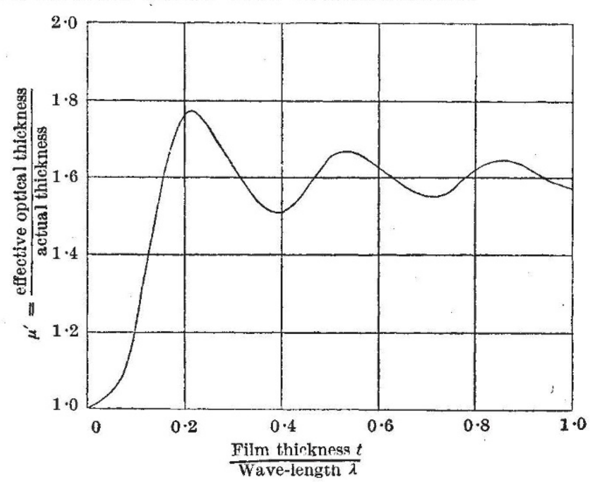
Gunn and Scott use multiple-beam wedge interference with monochromatic light between a reference surface and a slide on which the film is deposited. Silver is evaporated over the slide and the film, and at a film border the step corresponding to the film thickness gives rise to a displacement of the interference fringes. The method suffers from the slight disadvantage that in measuring the fringes with the travelling microscope a certain area of the slide is covered, and, therefore, if accurate figures are to be obtained the film must be uniform in thickness and the slide plane over this area. These requirements can be avoided if white light is used and the fringe system observed by means of a spectrometer. Other advantages, such as improved sharpness, of these 'fringes of equal chromatic order' are treated in detail by S. Tolansky[2] in another connexion.

The technique is to project an image of a line of the interference surfaces on to the slit of a spectrometer, the line crossing a film border. In this way the thickness at a single point of the film border is determined.

Inaccuracies in both methods arise due to the imperfect reflectivity of silver at visible wave-lengths. This causes the phase change upon reflexion to differ appreciably from 180°, and the equation governing interference must be written (normal incidence)

$$n\lambda = 2\mu t + 2\delta,$$

where δ takes account of the phase change. If a relative fringe displacement is to correspond to a change in optical thickness only, then δ must be constant. However, δ depends on the substance in front of the silver and, for semi-opaque silvering, also on the substance backing the silver. Therefore, in the case of interference with transmitted light an error will certainly be introduced due to the change in refractive index at the film border of the substance backing the silver; unless, indeed, the film under consideration has the same index as the glass supporting slide. Thus accurate measurement of film thickness is made possible only by having opaque silvering over glass and film, and using interference in reflexion rather than in transmission.



In measuring the optical thickness μt by depositing the film over the silvered glass slide, a similar error is introduced, of the order of 20 per cent in μ for a film 400 A. thick.

Another phenomenon in the measurement of refractive index is that the effective optical thickness, as determined by the interference method, is not μt for films less than about one wave-length thick but follows the curve shown, in which the effective refractive index $\mu' = \dfrac{\text{effective optical thickness}}{\text{actual thickness } t}$ is plotted against $\dfrac{\text{thickness } t}{\text{wave-length } \lambda}$ for a true refractive index of 1·6.

This curve has been deduced theoretically by the application of Maxwell's equations, but has also been verified by experiment.

It is seen that, owing to this effect and to the phase change on reflexion, large errors can be introduced in measurements on very thin films.

I am greatly indebted to K. Donaldson, a member of Dr. Tolansky's team at the University of Manchester, for introducing me to the technique and difficulties of multiple-beam interferometry.

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[1] Gunn, A. F., and Scott, R. A., *Nature*, **158**, 621 (1946).

[2] Tolansky, S., *J. Sci. Instr.*, **22**, 161 (1945).

Choice of a 'Reality Index' for Suspected Cyclic Variations

THERE are natural phenomena which, without being purely periodical in character, show cyclic variations with maxima of different height, minima of different depth and varying intervals between consecutive maxima or minima. While in many cases the cyclic variations are so strongly marked that there can be no doubt as to their reality, in other cases it might be difficult to decide whether the variations appearing in a series of observed quantities are of real significance or not. In the latter cases it would be advantageous if we could find a 'reality index' which would indicate the degree of reality of suspected cyclic variations in a similar manner as, for example, in the calculus of correlation the correlation coefficient expresses the degree of relationship between two sets of observed quantities.

In an earlier communication[1], I reported on a function which could be used as criterion for the reality of cyclic variations. This function is really the probability that the number of extrema actually found is less than the number which would be expected if the terms of the series were distributed at random. This criterion, however, has the following disadvantage: it holds good only for long cycles, but not for short ones. If, for example, in a sufficiently long series of observed numbers large numbers always alternate with small ones, the existence of a short-cycle variation is very probable. Thus the reality index should, in this case, have a value near 1; the above function, however, is zero in this case.

A more suitable reality index can be found by making use of an interesting investigation by W. O. Kermack and A. G. McKendrick[2]. These authors pointed out that, in an infinitely long series of