At this point

$$R(m) = s_2 R(1)/s_1. \quad (11)$$

Using now s_2 instead of s_1 , we calculate $R(2)$ from (3) and compare it with $R(m)$ calculated from (11). If $R(2) = R(m)$, our assumption of higher derivatives being zero or negligible was justified. If the effect of higher derivatives is not negligible, the process can be repeated until minimum is reached.

If the observed F_0 are not on an absolute scale, they can be adjusted by multiplying them by a constant K , given by

$$\log K = -\frac{1}{N} \sum (\log F_0 - \log F_c). \quad (12)$$

This adjustment of the scale can be repeated after each approximation, as the changes of the co-ordinates may also affect the value of K .

We have successfully applied these methods to the three-dimensional refinement of parameters of a crystal of potassium caprate, a preliminary report of which was given by Vand, Lomer and Lang², and to the structure of lauric acid.

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Surface Resistance of Metal Films at a Frequency of 24,000 Mc/s.

THE reflexion, transmission and absorption coefficients (R , T , A) of a thin metal film can be expressed in terms of its surface resistance S , if the frequency is low enough for classical electromagnetic theory to apply. Then measurements of R , T , or A yield theoretical values of S which can be compared with the value (S_0) obtained from D.C. measurements on the film. Experiments of this type have been carried out¹⁻³ at infra-red wave-lengths (6–110 μ); but while a measure of agreement has been obtained, the anomalies suggest that dispersion occurs at these short wave-lengths. With the view of effecting a similar comparison between S and S_0 at centimetre wave-lengths, the theory has been investigated afresh⁴ to include the effect of multiple reflexions occurring in the film and its support, and has been extended to find the resonance condition for a cylindrical cavity resonator operating in the H_{01} mode, when it is loaded with a film of metal carried by a low-loss support travelling on the plunger. The theoretical value of the surface resistance is then given by the expression

$$S = \frac{120\pi\lambda_1}{\lambda \left[1 + \cot \frac{2\pi l'_1}{\lambda_1} \left\{ 2 \cot \frac{4\pi l_1}{\lambda_1} - \cot \frac{2\pi l'_1}{\lambda_1} \right\} \right]^{1/2}},$$

where λ is the wave-length in air, λ_1 that in the empty resonator, while l_1 and l'_1 are the resonant lengths of air space in front of the support in the presence and absence respectively of the film. In practice, λ is calculated from λ_1 and a resonator dimension, while l'_1 may either be measured directly, or calculated

from the thickness and permittivity of the film support.

Extensive measurements have been made at a frequency of 24,000 Mc/s. to test this relation and certain other theoretical predictions. For this purpose films of chromium, gold, aluminium, silver, copper and nickel of uniform thickness have been prepared by evaporation *in vacuo* on silica disks, some of which have been optically flat. Silica was chosen as the material for the film support because of its extremely small loss, and its permittivity at this frequency has been evaluated as 3.8 ± 0.001 . After measuring S , the value of S_0 has been determined in each case by evaporating thick silver contacts on to the film and measuring the resistance of a circular annulus by bridge and other methods. The film thicknesses investigated have lain in the range 5–300 Å.; for most metals this covers a range of values for S_0 lying between infinity and a few ohms/cm.².

Throughout this range the qualitative agreement between S and S_0 has been excellent. Thus if $S_0 = \infty$, the A.C. measurement always yields a value of $l_1 = l'_1$, so that $S = \infty$. Again, a low value of S_0 always corresponds to a low value of S , that is, $l_1 \sim \lambda_1/2$. Films with intermediate values of S give values of l_1 lying between these extreme limits, and the phase shift due to the film may be large. However, the high absorption of such films lowers the effective Q of the resonator, and the broadening in the response renders the precise determination of l_1 difficult. Nevertheless, the quantitative agreement between S and S_0 over the entire range of values is good. It is found that S is always less than S_0 , the ratio S_0/S generally lying between 1 and 2. A part of this small discrepancy can be attributed with certainty to the effect of the evaporated contacts on the film, since different contacts give slightly different values of S_0 . Aggregation in the film or surface oxidation occurring on exposure of the film to air would also contribute to the higher value of S_0 . Finally, the same agreement between S and S_0 has been found for films of metal contaminated with oxide, suggesting that the agreement is of a statistical nature.

Since any wave trapped in the resonator is partially reflected and transmitted by the film several times, the expression given for S represents a more stringent test of the theory than any of the expressions for R , T , A used in the infra-red, which depend on a single encounter between the wave and the film. The agreement obtained experimentally between S and S_0 must therefore be regarded as very satisfactory, indicating that the theory and underlying assumptions are valid and that no dispersion occurs in the metal at this frequency. The resonator method can thus be used to study other film properties connected with the electrical conductivity, for which purpose it has the advantage that no contacts to the film are required.

This work was partly carried out at the Clarendon Laboratory, Oxford; a fuller account will appear elsewhere.

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