Measurement of Easy Direction Dispersion in Magnetic Thin Films

Clow[1] has described a method for the measurement of the dispersion of the easy direction of magnetization in a single nickel–iron thin film. In this method "a field pulse H_A, greater than the anisotropy field H_K, was applied along the average difficult direction, and during the latter part of this pulse a small pulse H_D was applied along the average easy direction. The flux change parallel to the easy axis, due to the application of H_A, was measured with a single pick-up loop, and the minimum value of H_D giving full output was taken to be proportional to the maximum value of β (the angular dispersion of the anisotropy axis). In practice, the approach to full output was too gradual for accurate measurement of this minimum value, and a level of H_D, H'_D say, giving 80 per cent full output, was used. An angle β′ given by $\sin\beta' = H'_D/H_K$ therefore gives the maximum dispersion in anisotropy over some 80 per cent of the film. Hence, 20 per cent of the film has hard directions at angles to the mean greater than β′, and 80 per cent at angles less than β′".

In fact, the relation $H'_D = H_K \sin\beta'$ will only give the dispersion of easy direction if it is assumed first that there is no dispersion of H_K in the film, and secondly that no co-operative phenomena occur during the relaxation of the film into domains. Chu *et al.*[2] have shown by microprobe analysis that a variation of 3 per cent in nickel content can exist between neighbouring regions of the film. Smith[3] has shown that this variation could produce a variation of 40 per cent in the magnitude of H_K, and a direct method for measuring the dispersion of H_K in a single film has been described by Hearn[4]. It is therefore unlikely that the method described would give a direct measurement of the dispersion of easy direction within the film. In fact what has been measured is the dispersion of a composite film parameter $H_K \sin\beta'$.

We would like to suggest a more satisfactory method of measuring the easy direction dispersion which is not directly influenced by the dispersion of H_K. The film is mounted on a rotatable platform such that a large pulse field may be applied in the plane of the film in any orientation. The change in the component of flux at right angles to the original pulse is detected by means of a sense coil. If the film is oriented so that the drive pulse is in the mean hard direction, no output is observed from the sense coil. If the film is rotated the output rises to a maximum and then decreases on further rotation. This maximum occurs when the hard direction makes an angle β with the direction of the pulse field, where β is the maximum dispersion of the anisotropy axis (neglecting the small reduction in output due to the rotation of the film relative to the sense coil). Since the approach to this maximum is gradual, we may define an angle β′ at which the output rises to 80 per cent of the maximum. This value may be taken as a measure of the dispersion of easy direction in the film. The output observed is proportional to the net flux change in the sense coil; thus, at the angle β′, 90 per cent of the film (not 80 per cent[1]) has become magnetized in one preferred direction on removal of the pulse field.

Neglecting co-operative effects, the measurement is independent of any dispersion of H_K. The value of β′ obtained is therefore a good measure of the dispersion of easy direction within the film.

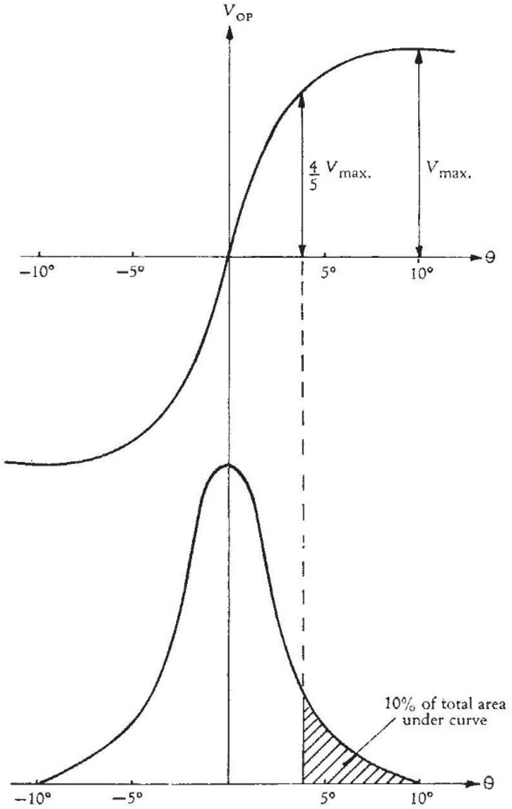

Fig. 1. Above, output from sense coil as a function of the angle of rotation; below, distribution of easy direction in an 80/20 nickel–iron film

The measurement described may be extended to produce a first-order plot of the distribution of easy direction within a film. The output V_{OP} obtained from the sense coil can be plotted against θ, the angle between the pulse field and the mean hard direction, as shown in Fig. 1 (above). The increment of output δV_{OP} in any small interval of angle δβ is determined by the proportion of the film having an easy direction with the interval $\theta \rightarrow \theta + \delta\theta$. Thus distribution of easy direction is given by $\frac{dV_{OP}}{d\theta}$, the the slope of the graph of V_{OP} against θ. By plotting the slope of this graph as a function of θ, the distribution of easy direction within a film may be obtained. Fig. 1 (below) shows the distribution obtained using an orthodox 1000 Å. 80/20 nickel–iron film.

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[2] Chu, W. W. L., *J. App. Phys.*, **30**, No. 4, 272*S* (1959).
[3] Smith, D. O., *J. App. Phys.*, **32**, 70*S* (1961).
[4] Hearn, B. R., *Proc. Symp. Elec. and Magnetic Prop. Thin Metallic Layers, Leuven* (Sept. 1961).

With reference to the foregoing communication by Peacock and Winsor, I agree that my measurements of the angle β′ gives values which depend on the dispersion of the magnitude of the anisotropy field H_K. Further, the method of measurement described in their communication would generally be considered to be more accurate than mine.