Comment on "Standing Spin Waves in Ferromagnetic Thin Films"

Abstract—**Hartwell recently discussed ferromagnetic film spin wave pinning referenced to a surface anomaly model. This model does predict the proper spectrum in some cases, particularly those where the substrate is scratched deliberately or the films are oxidized. For some films it is believed that a better model involves a gradient in the saturation magnetization caused by a compositional change of the alloy through the film thickness, previously described by Penn and West.**

In the abstract of the above paper[1] Hartwell states that the saturation magnetization M_s is taken as a constant for his theoretical considerations. The pinning mechanism is assumed to be surface located. Later, to explain some experimental spectra, he allows a change of M_s near the surface "to a gentle upward slope in M_s as the surface is approached from the interior of the film," similar to the assumption of Portis.[2] Whether the pinning is caused by a surface effect or a change in M_s through the film depends strongly on the method of deposition and subsequent treatment such as etches, anneals, abrasion, and oxidation. Films evaporated from an alloy melt by a tungsten boat under typical laboratory conditions have been shown[3] to have a change in alloy composition linearly through the film thickness of the order of 4 percent to 7 percent per 1000 Å. The fact that the vapor pressure of Fe is lower than Ni results in the substrate side of the film being rich in Fe. A linear change in composition through the film results in a relatively linear change of M_s, decreasing from substrate to surface. Schlömann[4] has shown that a linear change in M_s of the order of 5 percent is sufficient to cause spin pinning. A 5-percent change in M_s is caused by a change in alloy composition of only 1 percent.

Manuscript received March 22, 1968.

[1] J. W. Hartwell, *Proc. IEEE*, vol. 56, pp. 23–31, January 1968.

[2] A. M. Portis, "Low-lying spin wave modes in ferromagnetic films," *Appl. Phys. Lett.*, vol. 2, pp. 69–71, February 15, 1963.

[3] T. C. Penn and F. G. West, "Magnetostriction and compositional gradients in boat-evaporated permalloy films," *J. Appl. Phys.*, vol. 38, pp. 2060–2064, April 1967.

[4] E. Schlömann, "Theory of spin-wave resonance in thin films," *J. Appl. Phys.*, vol. 36, pp. 1193–1194, March 1965.

Films having little compositional gradient may be prepared by evaporation from a large melt with the aid of a shutter mechanism, by sputtering, by dual source control, and by true flash evaporation[5] where small granules of the alloy are dropped on a hot surface well above the melting point of the alloy.

The results that Hartwell reported which could not be properly interpreted by surface pinning[6] are fairly typical for films not deliberately (or inadvertently) surface contaminated. A compositional gradient causing a change in M_s through the film might explain this discrepancy.

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[5] L. Harris and B. M. Siegel, "A method for the evaporation of alloys," *J. Appl. Phys.*, vol. 19, pp. 739–741, August 1948.

[6] M. Nisenoff and R. W. Terhune, "Experimental studies of standing spin-wave modes in ferromagnetic films," *J. Appl. Phys.*, vol. 35, pp. 806–807, March 1964.

Correction to "Modifications of the Methods of Horner and Bairstow"[1]

In equations (8), (9), (10), (11a), and (11b), the symbol R should have been interchanged with the symbol S, and likewise the symbol R' with the symbol S'.

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[1] K. H. Haase, *Proc. IEEE (Letters)*, vol. 56, p. 345, March 1968.

Standard Frequency and Time Notices

Notice of No Adjustments in Phases of Seconds Pulses from NBS Radio Station WWVB and No Adjustment in Phases of Time Pulses from NBS Radio Stations WWV and WWVH on July 1, 1968.

In accordance with National Bureau of Standards policy of giving monthly notices regarding changes of phases in seconds pulses, notice is hereby given that there were no adjustments in the phase of seconds pulses emitted from radio station WWVB, Fort Collins, Colo., on July 1, 1968. The carrier frequency of WWVB is 60 kHz and is broadcast without offset. These emissions are made following the stepped atomic time (SAT) system as coordinated by the Bureau International de l'Heure (BIH).

Notice is also hereby given that there were no adjustments in the phases of time pulses emitted from radio stations WWV, Fort Collins, Colo., and WWVH, Maui, Hawaii, on July 1, 1968. These pulses occur at intervals which are longer than one second by 300 parts in 10^{10}. This is due to the offset presently maintained in the carrier frequencies of these stations following the universal time (UTC) system as coordinated by the BIH.

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Monthly Fractional Frequency and Time Offsets and Deviations for NBS Radio Stations WWV, WWVH, WWVL, and WWVB

Because of wide interest in accurate values presently available as a result of improved monitoring and control techniques, the National Bureau of Standards Time and Frequency Division furnishes each month frequency and time correction data relating to its broadcasts from radio stations WWV, WWVH, WWVL, and WWVB. The first of these notices exhibited data beginning January 1, 1965, and was published in the PROCEEDINGS in the April, 1965, issue.

Frequency: The frequencies of WWV, Fort Collins, Colo., WWVH, Maui, Hawaii, and WWVL, Fort Collins, Colo., were offset from their nominal values by -150 parts in 10^{10} during 1965, by -300 parts in 10^{10} in 1966 and 1967, and will remain offset by the latter amount in 1968. Determination of the offset to be used each year is coordinated by the Bureau International de l'Heure (BIH). The frequency of WWVB, Fort Collins, Colo., is not offset.

The frequencies of WWV and WWVH are kept constant at their intended values, within less than 2 parts in 10^{11} and 1 part in 10^{10}, respec-