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LOW FREQUENCY CREEP IN CoNiFe FILMS

by

David S. Bartran, Henry C. Bourne, Jr., L. George Chow

Abstract

This paper presents the results of an investigation of domain wall motion excited by slow rise-time, bipolar, hard-axis pulses in vacuum deposited CoNiFe films 1500Å - 2000Å thick. Surprisingly, the results are consistent with those of comparable NiFe films in spite of large differences in film properties. The present low-frequency creep data together with previously published results in this and other laboratories can be accounted for by a model which requires that the wall structure change usually associated with low-frequency creep be predominately a gyromagnetic process. The correctness of this model is reinforced by the observation that the wall coercive force, the planar wall mobility and the occurrence of an abrupt wall structure change are the only properties closely correlated to the creep displacement characteristics of a planar wall in low dispersion films.

Introduction

In a previous paper [1] dealing with this phenomenon in NiFe films of similar thickness, it is shown that for a given hard-axis field magnitude ($\sim .6H_k$), the creep displacement is initially linear in the amount of easy-axis bias in excess of the value necessary to cause net motion. As the amount of easy-axis bias field approaches the conventional wall motion threshold, the creep displacement increases at a much faster rate. Eventually this threshold is exceeded and continuous wall motion takes place. It is also found that for hard-axis fields in the range

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$0.4 \leq H_h/H_k \leq 0.8$, the conventional wall motion threshold and the creep motion threshold are well separated, the creep motion is very consistent, not random, and the amount of easy-axis bias necessary for the onset of creep motion, $(H_e)_{crit}$, is very nearly independent of the hard-axis field amplitude. These features are also characteristic of the data published by other investigators using similar applied fields[2-6].

In order to extend the range of available wall coercive force for continuing creep studies, nonmagnetostrictive uniaxial CoNiFe films are made. Using published melt compositions and substrate temperatures [7], the film properties are remarkably predictable.

Experimental Results

The threshold curves for a typical CoNiFe sample are shown in Fig. 1, and the creep displacement curves for several samples including some NiFe films from a previous study are shown in Fig. 2. This data is obtained using previously discussed experimental techniques [1]. The individual displacement curves correspond to bipolar creep with the amplitude of the hard-axis field in the vicinity of $0.6 H_k$ to insure that the fundamental creep transitions have a high probability of occurrence without other processes interfering.

The general features of the creep threshold curves for NiFe and CoNiFe films are identical with the threshold curve in Fig. 1 except for the value of $(H_e)_{crit}$ as long as the creep threshold is sufficiently separated from the rotational threshold curve. If the creep threshold curve inferred from the low coercive force, low dispersion samples lies outside of the rotational threshold curve of the sample being considered, then the observed creep threshold will coincide with rotational threshold because the rotational processes, now able to occur at fields below the inferred creep threshold, act to assist or even trigger the creep transition (see Fig. 3). The corresponding displacement characteristics are not

affected by the proximity of the rotational threshold.

If the initial slopes of net wall displacement versus easy-axis bias curves, corresponding to the same degree of hard-axis excitation, are plotted against reciprocal wall coercive force (Fig. 4), it is found that a basic relationship exists between the rate of wall displacement and the coercive force of the samples of this and other reports [1-6] regardless of composition. The data from Middelhoek and two additional NiFe samples, however, are characterized by anomalously high creep rates.

A low coercive force NiFe film [1], $H_c = 0.6$ oe, agrees perfectly with the well behaved data although not shown, and the samples from Telesnin et al., are not shown because the exact wall coercive force was not reported. The source of the NiFe data is indicated by appropriate superscripts in the legend of each figure.

The minimum easy-axis bias necessary for creep motion, $(H_e)_{crit}$, is presented in Fig. 5 as a function of wall coercive force. This critical field is strongly related to the coercive force, but it tends to saturate with continued increase in coercive force beyond 4 oe until rotational processes dominate the creep threshold and a unique definition of $(H_e)_{crit}$ is not possible. Contrary to the displacement data, the creep threshold is especially sensitive to rotational processes in addition to the basic wall structure change.

Most of the samples represented have nominal wall mobilities of 2×10^3 cm/oe-sec. These wall mobilities are the high drive values as discussed in the literature [8]. These films with large, high field wall mobilities are found to have correspondingly large creep rates when compared to low mobility films of the same coercivity explaining why some samples have anomalously high creep rates with otherwise normal film properties.

An additional and unexpected feature of Fig. 4 is that the extrapolated creep rate becomes zero for a large but apparently finite value of coercivity. Creep is effectively eliminated, however, on a practical level when the creep thresholds are forced to approach the rotational threshold curve.

Discussion

The experimental results strongly indicate that the initial slope of the creep displacement curves for Bloch wall films is directly related to the wall mobility and reciprocally related to the wall coercivity and otherwise independent of composition and film thickness. These results are to be expected if the low-frequency creep transition is a gyromagnetic process. Further, the occurrence of a creep transition is closely linked with the observance of an abrupt wall structure change.

Hubert's two dimensional wall calculations [9,10] indicate that the transition from a Bloch to a Néel wall is not smooth because of the incompatibility of the two structures at the time of the transition. An abrupt structure change which begins in the magnetization constituting or soon to constitute the Néel wall tails is consistent with the observed direction of wall displacement for a given wall polarity [11].

In addition to the above results, it is found that the creep rate becomes zero for a finite value of coercivity although the creep threshold curve becomes degenerate with the rotational threshold curve before this extrapolated coercivity is reached.

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Figure Captions

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- Fig. 2. Net creep displacement versus easy-axis bias for several NiFe and CoNiFe samples. Superscripts in legend indicate data source.
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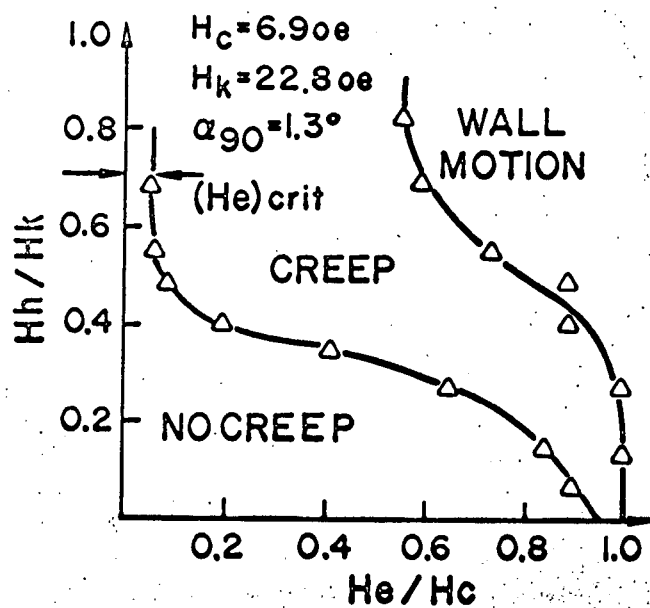
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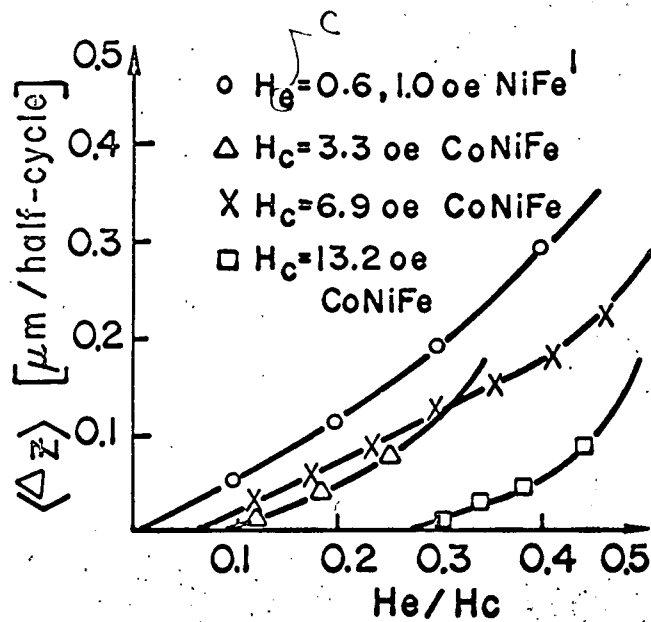
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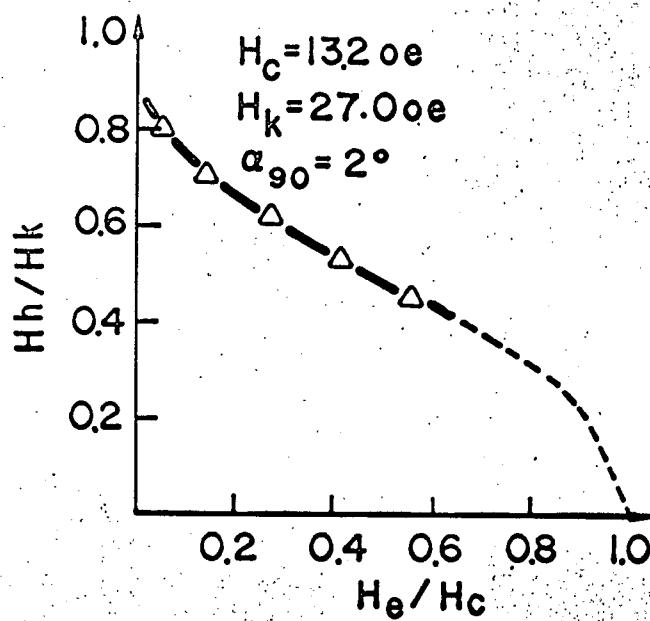
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Fig. 1. Bartran, Bourne, Chow



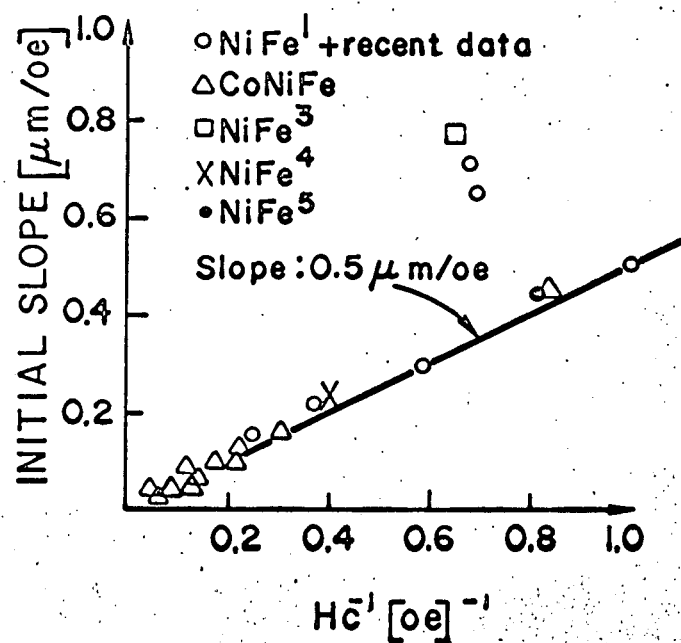
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Fig. 2 Bartman, Bourne, Chow



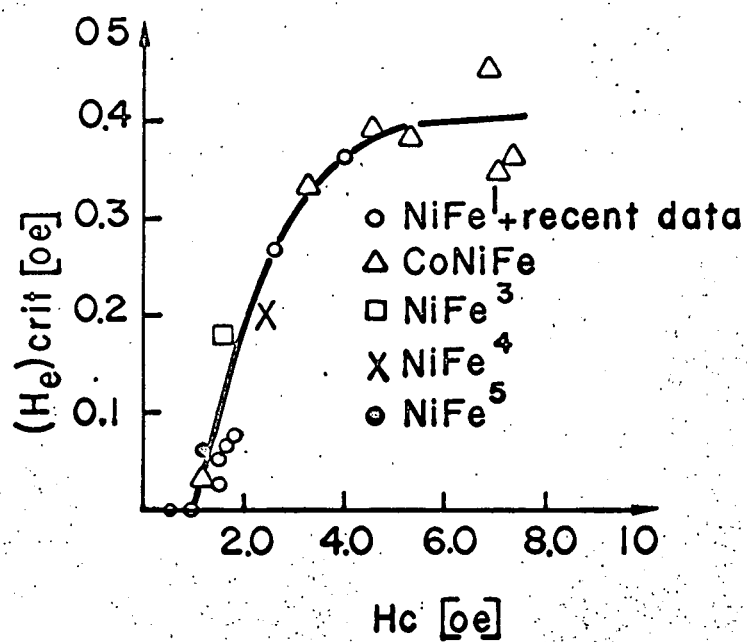
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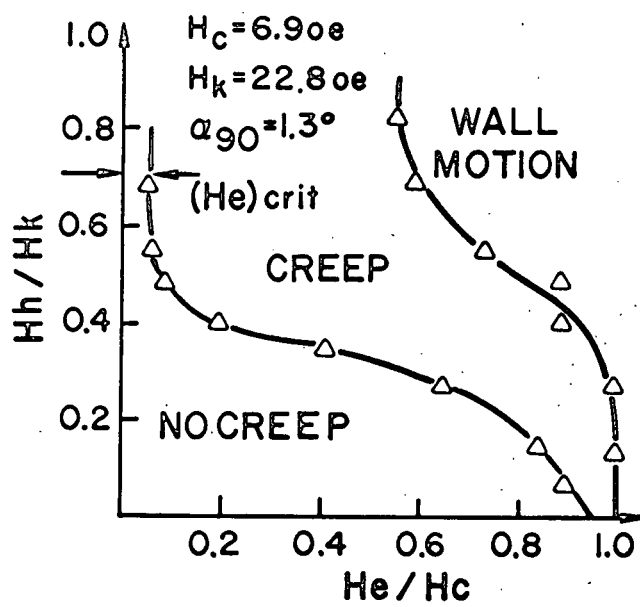
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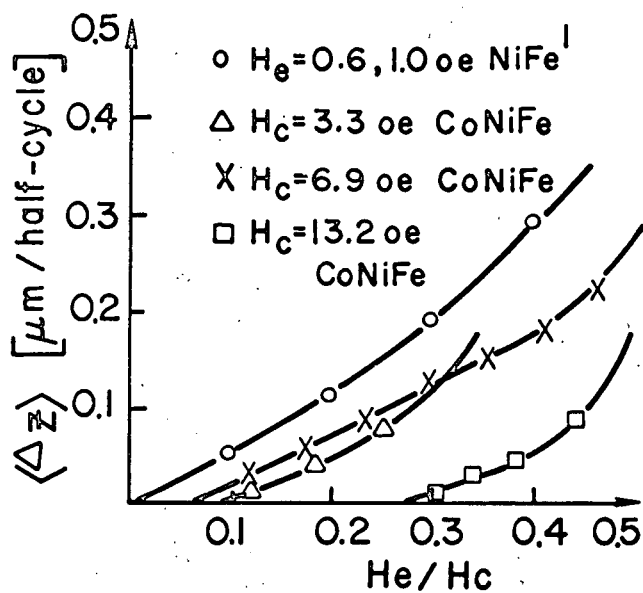
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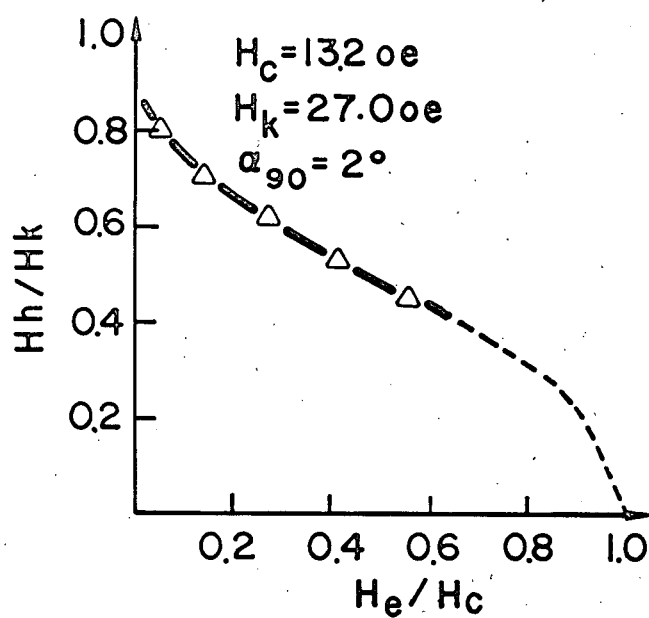
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Fig. 1, Bartran, Bourne, Chow



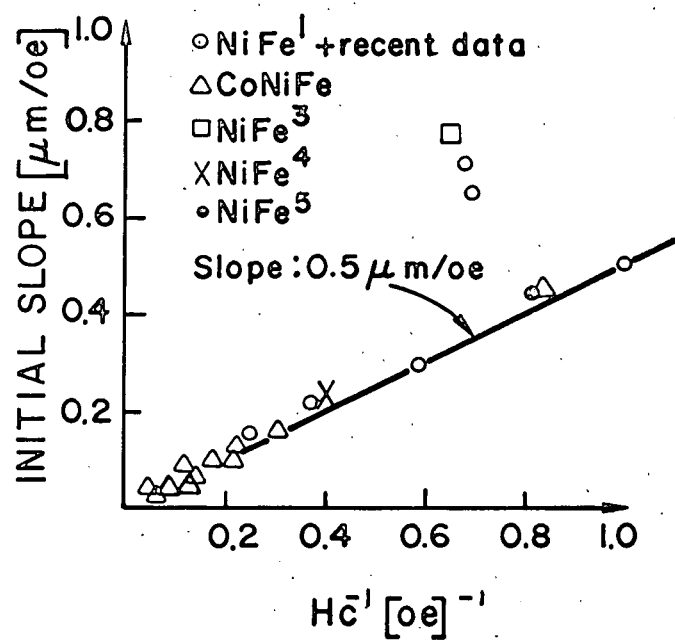
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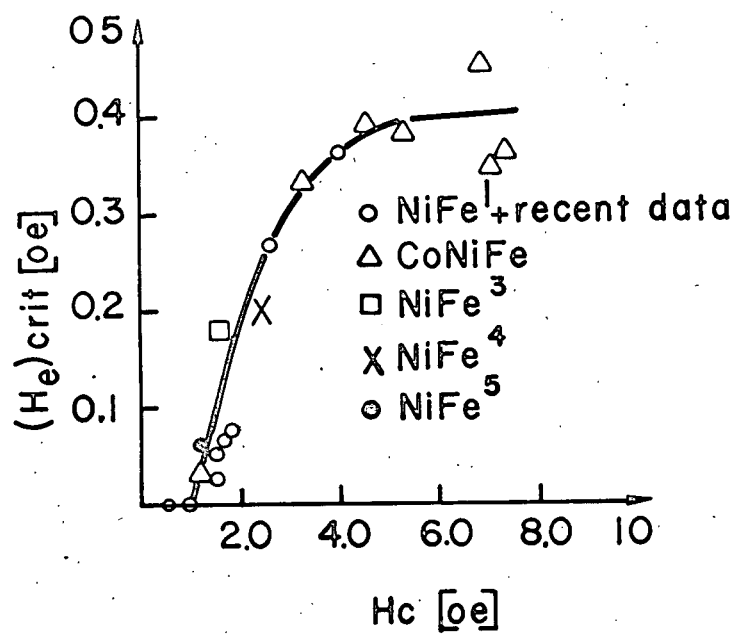
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