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APPLICATIONS OF ASYMMETRIC HYSTERESIS LOOPS IN AMORPHOUS ALLOYS

C. D. Graham, Jr.[1], K-H. Shin[2], and Peter Y. Zhou[3]
[1] Dept. of Materials Sci., Univ. of Pennsylvania, Philadelphia PA 19104 USA
[2] Functional Materials Design Lab., Korea Inst.of Science and Technology, Seoul, Korea 136-791
[3] Knogo North America, Hauppauge NY 11788 USA

Abstract-The use of amorphous magnetic alloys as tags or targets in electronic article surveillance systems such as anti-shoplifting desvices is briefly reviewed. Improved tags became possible with the discovery in 1988 of asymmetric magnetization reversal (AMR) in certain amorphous alloys annealed in applied field approximately equal to the earth's field. These asymmetric hysteresis loops are highly unusual, if not unique, and so greatly diminish the probability of false alarms in a detection system. Furthermore, the jump field Hj , which is the coercive field in negative applied fields, can be controlled over a useful range by controlling the field applied to the sample during annealing. By applying several tags to an object, each with a different jump field, it is possible to identify the object with a numeric code that can be remotely read by non-optical means.

INTRODUCTION

Amorphous or glassy magnetic alloys have been used for a variety of purposes since their introduction by Allied Corp. (now AlliedSignal) in late 1973. Among these uses are transformer cores for power and audio frequencies, tape recorder heads, magnetic shielding, pulsed power sources, and others. One other use is as "tags" or "targets" in *electronic article surveillance* systems such as anti-theft or anti-shoplifting systems. In such a system, a small soft magnetic strip or wire is attached to or hidden in an item displayed for sale. If the article is carried through a security gate, the tag is subjected to an alternating magnetic field, which causes the magnetization of the tag to reverse at the frequency of the field. This alternating magnetic dipole creates its own alternating field in space, which is detected by an antenna.*

One requirement of such a system is that it reliably detect the presence of a tag even when the tag is accompanied by other and larger magnetic bodies -- food cans, razor blades, kitchen utensils, etc. The usual way to accomplish this goal is to make the tag of a material with a very low coercive field and a square hysteresis loop, so that its magnetization reversal signal E=k(dB/dt) consists of a single narrow voltage spike with high harmonic content. The harmonic content serves to distinguish the tag signal from background signals. Amorphous alloys are well-suited for this use, since when properly prepared and annealed, they can have very square hysteresis loops with very low coercive fields. Such a system, using either amorphous or crystalline magnetic materials for tags, leads to a good but not a perfect system; false alarms can occur.

* In this paper we will ignore the question of *deactivation*, or making the tag inoperative when the article has been paid for.

ASYMMETRIC MAGNETIZATION REVERSAL (AMR)

In 1988, it was discovered at Knogo Corp. (now Knogo North America) that if an amorphous alloy tag is annealed at a low temperature for several hours in air and in the earth's magnetic field,. it develops an unusual asymmetric hysteresis loop[1,2], as shown in Fig. 1. If the tag is annealed in a positive (+) field, the magnetization reversal from + to - occurs in a single, irreversible Barkhausen jump, but the reversal from - to +

occurs by a continuous, reversible, domain wall motion.

The advantage of such a material in a security tag is that it produces a magnetization reversal signal that is unique. Pocket knives or cans of tuna fish will not have hysteresis loops like that of Fig. 1, and so a detection system designed to recognize the reversal signal from an AMR material is highly unlikely to produce a false alarm.

The phenomenon of asymmetric magnetization reversal, or AMR, was studied in considerable detail in the thesis of K-H. Shin[3]. Among his findings were the following:

1. The appearance of AMR is accompanied by a shift or offset of the hysteresis loop along the field axis, as can be seen by the fact that the reversible (- to +) branch of the loop crosses the H axis to the *left* of H=0. The loop shift and the AMR have different physical origins.

2. The AMR effect, and the shift, are destroyed by chemical etching of the sample which removes the surface layers.

3. AMR can be developed over a range of compositions.

4. The annealing that produces AMR need not be carried out in air, and the oxide coating produced by annealing in air is not necessary to obtain the effect.

5. The field at which the irreversible magnetization jump occurs (called Hj in refs [1-3]) can be controlled over a fairly wide range by controlling the magnitude of the field applied during annealing (Figs. 2 and 3).

From a practical point of view, an important property of the AMR effect is that it is largely unaffected by applied ac magnetic fields up to 150 Oe or more (Fig. 4). This means the effect is stable after exposure to any fields likely to exist in normal commercial or industrial environments.

Understanding of these phenomena was greatly advanced by careful domain observations on similar materials by Schäfer et al.[4]. This work showed that AMR results from domain nucleation occurring at different physical locations in the tag, depending on whether the reversal is going from + to - or from - to +.

REMOTE READING, NON-OPTICAL CODING

A way to take advantage of phenomenon #5 above in a more advanced security device has been proposed [5]. Since it is possible to prepare tags with a range of jump fields H_j, an article can have attached to it a series of tags, each with a different jump field.

The tags are small, perhaps 50 × 1 × 0.025 mm, so that several tags can easily be attached to an article of reasonable size. Say that tags can be made with four easily distinguishable values of coercive field, and that four tags can be attached to an article. Then we will have 4^4=256 distinguishable combinations, which can be read by a suitably programmed detection system connected to the detection gate. This has the advantage over optical systems, such as bar code readers, that the tags need not be visible. They can be attached to or hidden in the object itself, not in or on its packaging. The use of such a system would not be for anti-shoplifting, but for identification of items in automated manufacturing or shipping operations.

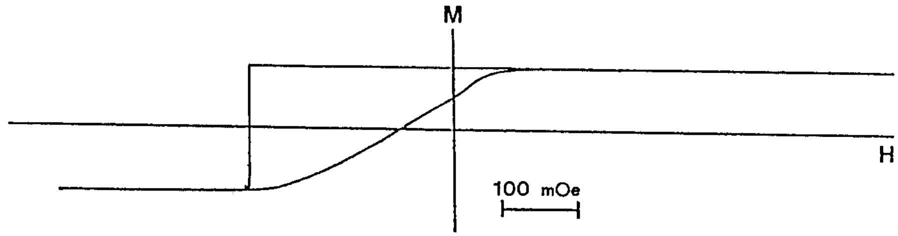

Fig. 1. Hysteresis loop showing Asymmetrical Magnetization Reversal (AMR). The figures shown in this paper are all from zero-magnetostriction amorphous alloys of composition $Co_{70.5}Fe_{4.5}Si_{10}B_{15}$ and are taken from ref [3]..

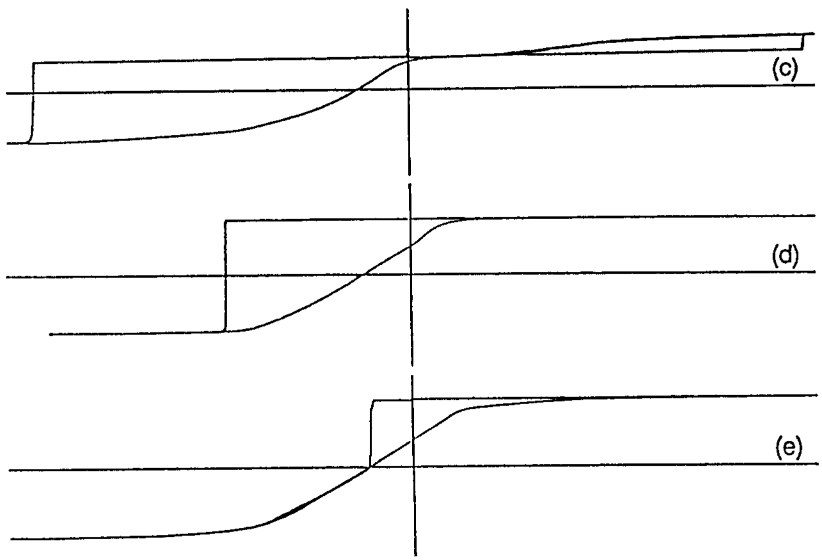

Fig. 2. Asymmetric loops obtained by annealing in fields of (c) 25, (d) 100, (d) 300 mOe.

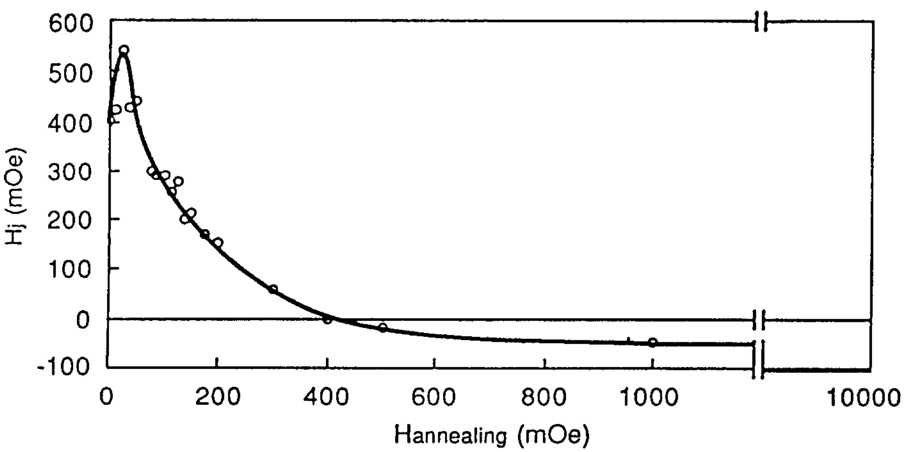

Fig. 3. Dependence of jump field H_j on field applied during annealing.

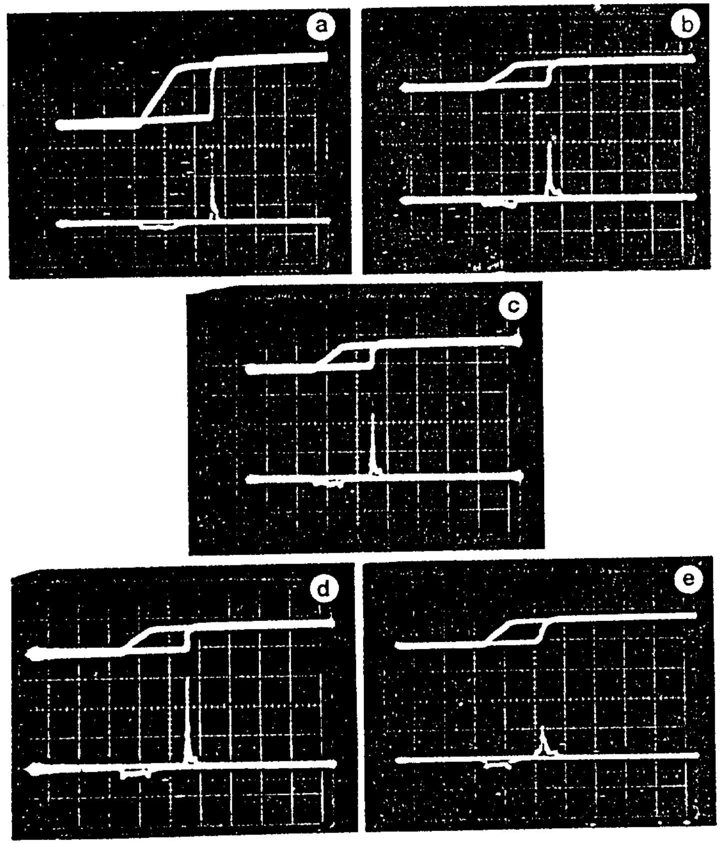

Fig. 4. AC loops and time derivative signals of AMR loop after exposure to ac fields of (a) 0, (b) 30, (c) 60, (d) 160, and (e) 300 Oe. Measuring field ±1.2 Oe, 60 Hz. This figure shows the sharp voltage spike in the dM/dt signal.

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