THE INFLUENCE OF THE DEMAGNETIZING ENERGY ON CONVENTIONAL AMORPHOUS WIRES' MAGNETIC ANISOTROPY

BY

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Abstract. In this paper we initiate a study concerning the influence of demagnetizing energy on conventional amorphous wires' (CAW) magnetic anisotropy. Normally, if we want to calculate the magnetic anisotropy of CAW we must take into account the magnetoelastic energy as the most influent energy in the expression of magnetic anisotropy. The importance of this energy is determinant in domain walls creation and, consequently, in amorphous material magnetic behavior. There is a critical value of radius/length ratio for which the effects of demagnetizing field, the field depending on wire form, can't be no more neglected. We have established this ratio. It exhibits a great importance, especially when we wish to avoid these demagnetizing effects and to have a better control of final magnetization. What it counts, undoubtedly, in all applications involving CAW.

Key words: CAW; magnetic anisotropy.

1. Introduction

The conventional amorphous wires (CAW) are prepared by the in-water quenching technique. This procedure has a very high cooling rate from the molten alloy and introduces internal stresses within the conventional amorphous wires. These stresses, which couple with material magnetostriction give rise to large magneto-elastic anisotropies. The distribution of these anisotropies determines the domain structure and magnetization process of CAW.

The absence of long-range order, which is a property of magnetic amorphous materials, implies the absence of magnetocristaline anisotropy. Consequently, the magnetoelastic anisotropy and the anisotropy induced by form are the main causes which the magnetization processes in this type of materials are based on. The form is a geometrical factor, thus it could be properly chosen in order to minimize the demagnetizing field or neglect it. So, in most of the cases, the only one that present some interest in this matter is the magnetoelastic anisotropy. This anisotropy originates in coupling between the

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internal stresses, induced by the fabrication process, and magnetostriction. Therefore it depends on value and distribution of internal stresses and on the intensity of magnetoelastic coupling with magnetostriction. By a proper choose of the composition we could have some control concerning the magnetostricition constant of the alloy we have working with, but in internal stresses we don't have it at all. These stresses are a consequence of the rapid quenching process and not depend in most of the cases on composition. Their dependence is on the cooling rate and on the temperature gradient within CAW during the rapid solidification process. The distribution of magnetoelastic anisotropy is the main factor which decides the configuration of the magnetic domain walls; this is the reason why the magnetization processes are directly influenced by it, (Chiriac & Ovari, 1996).

Therefore, the determination of magnetic anisotropy is important because knowing it this will recommend the magnetic material properties for proper applications. Basically, the magnetic anisotropy decides the magnetic properties of the amorphous materials.

In general, in cases discussed so far, the magnetic structure is formed by minimization of the total energy:

$$E = E_{me} \tag{1}$$

where the right term represents the magnetoelastic energy which results from coupling between the induced mechanic stresses and magnetostriction. This approach represents a particular case of a more general case which includes the magnetostatic energy, not considered above. There are yet situations when this energy should not be neglected. For example, when the wires dimensions play an important role in the balance of energies, this energy could not be a negligible quantity.

In the following we will show how the magnetic anisotropy can be expressed by taking into account the influence of demagnetizing factor.

2. The Critical Radius/Length Ratio in CAW

Consider the general expression of the total energy:

$$E = k \cdot \cos^2 \theta \tag{2}$$

where k is the anisotropy constant, θ is the angle between spontaneous magnetization axis and axis of easy magnetization. In equation (2) the Zeeman term was neglected because the exterior magnetic field is missing.

Consider now that the anisotropy constant has the general form:

$$k = k_{\sigma} - \frac{1}{2} N \cdot M_s^2 \tag{3}$$

where the first right term is the magnetoelastic anisotropy generated by the stresses and magnetostriction coupling. The second right term is so-called the demagnetization term, with *N* the demagnetization factor.

By introducing (3) in (2) and do the multiplications we will then observe that the general expression of the energy contains two terms. The first one corresponds to the magnetoelastic energy, while the second one describes the demagnetization energy:

$$E_d = -\frac{1}{2} N \cdot M_s^2 \cos^2 \theta \tag{4}$$

In the case of a conventional amorphous wire which can be approximated by an elongated spheroid with an axis much longer than the other, we will have (Severino *et al*., 1992):

$$N = \frac{4r^2}{L^2}\left[\ln\left(\frac{L}{r}\right) - 1\right] \tag{5}$$

where L and r are the length and the radius of the wire. Under these conditions the magnetic anisotropy constant has the expression:

$$k = \frac{3}{2}\lambda \cdot \sigma - 2\frac{r^2}{L^2}\left[\ln\frac{L}{r} - 1\right] \cdot M_s^2 \tag{6}$$

The demagnetizing term contribution is now very important because, in the surface region of the amorphous wire, it will appear some closing magnetic domains. This fact changes the magnetic behavior of the amorphous wire. This changing could recommend it for other applications.

Under the hypothesis that magnetoelastic energy is independent from the wire dimensions, we must do now, twice, the derivation of the equation (6), with respect to *r/L* ratio. We obtain some information about the values of this ratio which began to count.

By making the first derivative equal to zero we obtain:

$$\frac{r}{L} = \mathrm{e}^{-\frac{3}{2}} \tag{7}$$

and by the equalization of the second derivative to zero we obtain the inflection point:

$$\frac{r}{L} = e^{-\frac{5}{2}} \qquad (8)$$

The second value, (8), exhibits greater importance because, for lower values, the demagnetization corresponding term contribution can be neglected, while at higher values it can't. The first ratio, (7), is therefore a maximum which corresponds to instability. The structure of magnetic domains will be influenced by the size of the wire.

In practice the diverse situations occurred require a different approach to this problem. The term corresponding to demagnetization is usually neglected if its absolute value is at least 3-5 orders of magnitude lower than the corresponding magnetoelastic term, to work with a great accuracy.

3. Conclusions

In this work we studied the influence of demagnetizing energy on the magnetic anisotropy of CAW. If we routinely calculate the magnetic anisotropy of CAW we must consider the magnetoelastic energy as a dominant term in this respect. This energy dictates the magnetic behavior of the material through the creation of magnetic domain walls. Nevertheless, there is a critical value of the radius/length ratio for which the influence of demagnetizing field must be no longer neglected. We calculated this critical ratio. It exhibits a great importance especially in the context of avoiding such demagnetizing effects and a better control of the final magnetization of the material. Fact of great practical importance.

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