DOMAIN TIPS: STRUCTURE AND MOBILITY IN UNIAXIAL AMORPHOUS THIN FILMS

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Abstract. – Statics and dynamics of domain tips have been investigated by high resolution Kerr effect using digital contrast enhancement. The magnetic structure is affected by demagnetizing effect. The internal wall structure is visible and a transition between asymmetric Bloch wall to Néel one is shown. Tip propagation along the easy axis is measured.

1. Introduction

The domain tip structure is a very important configuration for uniaxial materials. This structure is encountered in various situations like in longitudinal recording with head on domains limited by a zigzag wall or for shift register memories with isolated lozenge type domains [1]. It was also claimed [2] that domain tip propagation could be an intermediate mode in the switching mechanism of thin films.

We had found a simple system which allowed the propagation of an isolated lozenge-type domain along the hard axis [1]. The motion was explained as due to local variable coercivity due to wall transformation from asymmetric Bloch wall to asymmetric Néel wall.

The purpose of this work is to elucidate, by direct observation the magnetic structure near a domain tip and its dynamics. Tip observations have been performed by high resolution Kerr effect using a 16 bits image treatment apparatus [3] which permits in our case to detect segments and lines in the walls. The investigated samples are amorphous soft NiCoP samples.

2. STATICS: Magnetization around tips and wall structures

We have nucleated one zigzag wall on a NiCoP film (see Fig. 1). Under the microscope, the easy axis of the sample is perpendicular to the incident plane of light. Therefore, only regions where M is no longer parallel to the easy axis give rise to longitudinal Kerr effect. The processed image is made by subtraction of two different states of magnetization later called initial state (i) and final one (f). We do keep in mind that between these two states the observed contrast is reversed (black, white).

Zigzag boundaries are charged walls. Usually the magnetization can turn in order to spread the magnetic charges through Néel tails giving rise to 180° uncharged walls (aera AC in Fig. 2b). This is no longer true at the tips where we observe two supplementary short walls (BD, BE) at which rotation angle 2θ is equal to the vertex angle $\widehat{ABC}$. Therefore, near B the main walls become $(180-2\theta)^\circ$ walls. These assumptions are supported by the fact that wall segments BD and BE start perpendicular to AB and CB respectively and vanish perpendicular to the easy axis in order to avoid charges in B and spread them away. This mechanism explains the white (black) contrast observed near the tip between BA and BD (BC and BE) corresponding to areas where M is tilted away from the anisotropy axis and leading to Kerr effect. Similar results apply to the lower tips (Fig. 1). These observations are in agreement with the model proposed in [1].

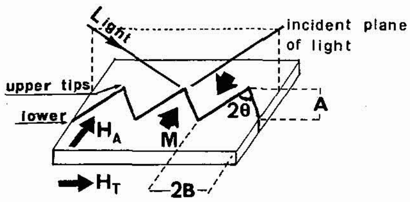


Fig. 1. – Schematic representation of the zigzag structure and the applied field distribution.

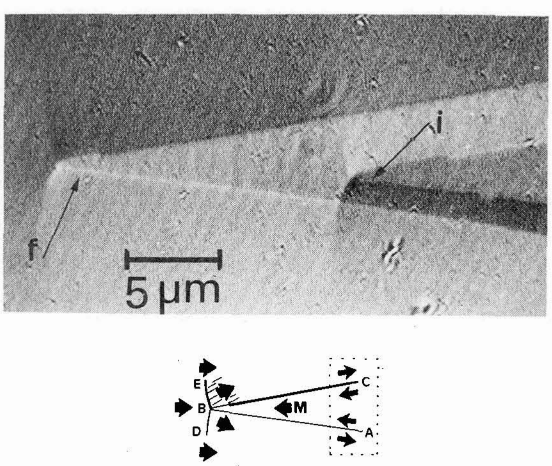
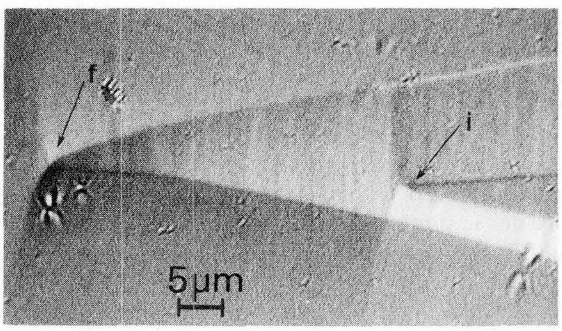


Fig. 2. – a) Kerr micrograph of a domain tip; b) magnetization distribution in the final state (f).

The main walls AB and CB show alternate segments indicating that,in the vicinity of the surface, the magnetization inside the walls belongs to the surface plane of the sample corresponding to an asymmetrical Bloch wall character (4). Furthermore, a fine observation in figure 2a shows a weak fluctuation of the contrast perpendicular to the easy axis inside the region ABC in the final state. This can be due to a ripple structure.

Under an applied bias field H_t, perpendicular to the easy axis, the entire structure becomes asymmetric. The area near BD (Fig. 3a, b) increases. The wall segment BD starts no longer perpendicular to BC and vanishes in D perpendicularly to the new direction of M in the sample away from the anisotropy direction by an angle $\delta = H_t/H_k$. On the contrary, the white area near BE, where locally M has a strong component opposite to H_t, shrinks and the BE segment is folded towards the main wall BC.



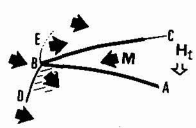


Fig. 3. – a) Kerr micrograph of a domain tip submitted to a transverse field H_t=1 Oe; b) deduced magnetization distribution in state (f).

We have seen in the previous paragraph that under no bias field the walls BA and BC show segments of alternate chirality (black, white contrast). In the near vicinity of B, these walls are $(180-2\theta)^\circ$. This is equivalent to pure 180° walls already submitted to a virtual transverse field $H_v = H_k \sin\theta$ [1]. We observe that under a bias field H_t=2 Oe, the wall AB where both H_v and H_t are parallel has the same chirality. This mechanism applies only to the other wall BC for higher value of H_t=4.5 Oe. At that time both walls appear with the same contrast. Higher values of H_t no more affect the contrast. Although we cannot simultaneously observe the contrast on both sides of the sample, yet it seems to us that the wall contrast modification is an indication of a wall structure transition to an asymmetric Néel one which qualitatively confirms our model.

3. DYNAMICS: Domain tip propagation along the easy axis

The speed of a domain tip, like the velocity of sidewise wall motion, increases linearly with the applied field H_a according to $V_t = \mu_t^* (H_a - H_{ct})$, where μ_t is the tip mobility and H_{c_t} the tip coercivity. It must be emphasized that both upper and lower tips have the same mobility $\mu_t = 2.2\times10^4$ cm/s.Oe (to be compared to wall mobility $\mu_w = 1.9\times10^3$ cm/s.Oe). Nevertheless, the upper tips start to move for $H_a >$ 0.5 Oe while the lower ones only move when the applied field H_a reaches 1.3 Oe (H_c=0.9 Oe for 180° wall). The discrepancy between the coercivities of upper and lower tips may be explained as follows. The zigzag structure is stabilized by the coercivity of the media. Assuming H_c= 0 the upper tips would move towards the top of figure 1 while the lower ones move to the bottom leading to an alternate 180° domain structure. Under an applied field H_a all the zigzags will move to the top (i.e. the same sense as the natural motion of the upper tips) in order to saturate the sample. Therefore, the effective coercivity is equal to the mean coercivity of the sample plus the algebraic value of the resulting contribution due to the static force:

$$H_{c_t} = H_c \mp \alpha . |F| / M$$

where α is the slidingd friction coefficient, in our case $\alpha = 0.7$. The high value of the tips mobility is still puzzling and cannot be explained by geometrical effect.

Conclusion

We have observed by high resolution Kerr effect the magnetization distribution inside walls and around tips. Inside the wall, the magnetization near the surface turns in order to belong to the surface plane of the sample leading to an asymmetrical Bloch character. Under a transverse field and above a critical value the contrast (chirality) of the walls is uniform in agreement with the field direction. The new nature of the walls may be regarded as of asymmetric Néel type.

The tip displacements have been measured. The mobility is one order higher than that of sidewise 180° wall. The discrepancy between upper and lower tip coercivities is explained.

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