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이온주입식 자기버블 전산기 기억소자에서의 자기버블 전파실패에 관한 연구

°조순철

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A Study On The Propagation Failure Modes of Ion Implanted Magnetic Bubble Computer Memory Devices

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Abstracts

Typical magnetic bubble propagation failure modes of ion implanted magnetic bubble computer memorydevices were observed and their failure mechanisms were analize. The skidding failure mode is due to the pushing of a strong repulsive charged wall. If this pushing is stronger than the edge affinity of the bubble in the cusp, the bubble moves out of the cusp when it is supposed to stay there. The stripeout failure modes across the adjacent track or along the track can be explained by considering the relative strength of the charged wall and the edge affinity encountered by both ends of the stripe. The skipping of the first cusp of a track is believed to be due to the whipping motion of the charged wall. The bubble moves directly to the second cusp via the long charged wall pointing to the second cusp skipping the first cusp.

1. Introduction

Magnetic bubble memory devices[1,2] are non-volatile magnetic digital information storage units which do not employ mechanical parts such as electric motors that are used in other magnetic information storage devices such as magnetic disks or tapes. They are non-volatile in the sense that the stored information is not lost in the event of power failure unlike most semiconductor memory devices. The data are encoded as the presence or absence of magnetic bubbles which are cylindrical magnetic domains in thin epitaxial magnetic garnet films grown on non magnetic substrates, and which exist in certain range of magnetic field applied perpendicular to the films.

In ion implanted devices[1], bubbles move along the ion implanted patterns attached to the so called charged walls created at the boundary of the ion implanted patterns in the presence of a rotating in-plane magnetic field. Therefore, the bubbles exist and propagate only in certain ranges of a couple of magnetic fields. At the extremes of these field ranges, the bubbles do not propagate properly, collapse or stripe out forming stripe domains instead of bubble domains. Some of these bubble propagation failure modes were mentioned in the literatures[1]. However, their origins and mechanisms have not been explained for most of the failure modes.

In this paper, the failure modes of bubble propagation observed in the ion implanted devices are listed and their failure machanisms are explained.

2. Bubble propagation in ion implanted devices

Ion implanted devices use charged walls as the bubble driving force which are created at the boundary of the implanted patterns as shown in Fig.1. The charged walls are positively or negatively charged and therefore attract bubbles whose tops are negatively or positively charged, respectively. As the in-plane field rotates, so do the charged walls dragging the bubbles along. The bubbles actually propagate along the boundary for about one third to one fourth of a cycle of the rotating field and stay at the cusps of the patterns for the remainder of the cycle. Therefore, bubbles move from cusp to cusp or tip to tip during a cycle of the field. Charged walls are formed on both sides of an unimplanted disk as shown in Fig.2.

On the right-hand side of the disk, a positive charged wall is created by the convergence of the magnetization and across the disk on the left-hand side, a negative-charged wall is created by the divergence of the magnetization. A bubble is attracted to an oppositely polarized charged wall. As the applied in-plane field is rotated, the charged wall rotates dragging along the bubble. Actual propagation tracks are formed by contiguously joining many of these propagation elements together as was shown in Fig.1.

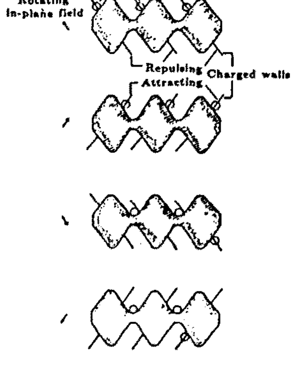

Fig.1 Bubble propagation along ion implanted tracks

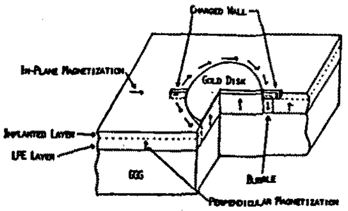

Fig.2 Perspective view of an ion implanted device

One of the major difficulties that has confronted the designers of the ion implanted devices has been the anisotropic propagation of bubbles[3]. Bubble propagation in ion implanted devices is much more difficult in certain crystal orientations than in other directions. Typical bias margins for propagation tracks oriented in [$\bar{1}\bar{1}2$] and [$\bar{1}10$] directions are shown in Fig.3. The bias margin is the figure of merit of the bubble device. It indicates the bubble device operating range in the bias field-drive field plane. If both applied fields are located inside curve, the bubbles propagate properly. As is shown in Fig.3, the bubbles propagated on one side of the tracks (bad tracks) oriented in [$\bar{1}10$] direction have a much smaller bias margin than the bubbles on the other side of the tracks (super tracks). The bubbles on the tracks oriented in [$\bar{1}\bar{1}2$] direction propagate equally well on both sides of the tracks and those tracks are called good tracks.

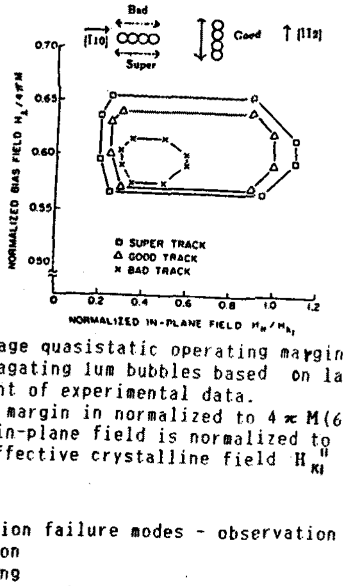

Fig.3 Average quasistatic operating margins for propagating 1um bubbles based on large amount of experimental data.
Bias margin in normalized to 4π M(600 G).
The in-plane field is normalized to an effective crystalline field $H_{KI}^{\parallel}$

3. Propagaion failure modes - observation and discussion

3.1 Skidding

Skidding is a failure mode in which a bubble moves generally two periods of a propagation track during one period of rotating in-palne field cycle, which is explained in Fig.4.

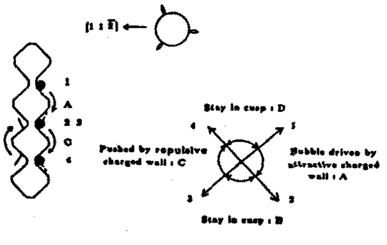

Fig.4 Skidding failure mode

The bubble positions on the track and the corresponding in-plane field (H_{xy}) directions are shown in the figure. During the Phase A, the bubble is driven by an attractive charged wall (normal propagation mode) from the top cusp to the center cusp. The bubble stays in the cusp during the Phase B. During a normal propagatin cycle, the bubble would stay in the cusp through Phases B,C and D and would be picked up by an attractive charged walls when the in-plane field points in direction 1. However, during skidding the bubble is pushed along the track by a repulsive charged wall and arrives at the bottom cusp during the Phase C. The bubble then stays in the cusp during the Phase D until an attractive charged wall drives it out of the cusp.

The skidding failure mode happens basically because the affinity[1] of the cusp is not strong enough to hold the bubble in the cusp against the pushing of the repulsive charged wall. It happens most often in bad tracks because the repulsive charged wall is strong. It is often observed that the bubble wiggles in the cusp before it starts to move out of the cusp under the influence of the repulsive charged walls as the bias field is increased. The bubble wiggles in the cusp because of the pushing of the repulsive charged walls. If the bubble dose not succeed in moving out, it falls back to the cusp. Every time a repulsive wall passes over the bubble, it is pushed and moved in the direction of the wall movement, then once the size of the bubble becomes small enough due to increased bias field, the bubble finally moves out of the cusp. Usually the skidding a bubble collapses soon after it comes out of the cusp as the bias field is increased. The collapse field of a skidding bubble is quite low compared with other bubbles because it is under the influence of a repulsive charged wall instead of an attractive charged wall.

3.2 Stripeout

As the bias field is lowered, bubbles start to stripe out. There are two modes of stripeout. The first is bubble stripeout across the adjacent tracks. The second is stripeout along the pattern edge. The former is more common and the latter occurs when the charged wall is not strong compared with the edge affinity along the pattern edge. Bubbles then stripe along the pattern edge rather than along the charged wall which is approximately perpendicular to the edge.

3.2.1 Stripeout Across Adjacent Tracks

Bubble stripeout failure modes across adjacent good tracks are shown Fig.5.

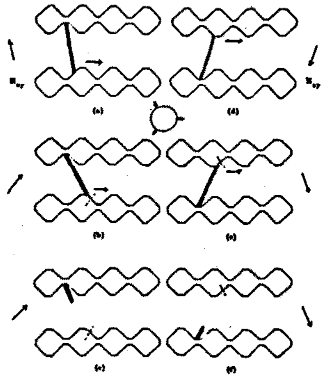

Fig.5 Bubble stripeout across adjacent track: Bubble moving up [(a)-(b)-(c)] or moving down [(d)-(e)-(f)] can occur

Diagrams (a), (b) and (c) show the failure mode when the in-plane field rotates clockwise and (d), (e) and (f) show the failure mode when the in-plane rotates counterclockwise. When the in-plane field points near one of the easy stripe directions in (a), the bubble on the bottom track stripes out and is stretched all the way to the cusp of the top track because at this field direction the cusp has an attractive charged wall. As the field rotates the bottom side of the stripe rotates to the direction of the hard stripeout direction (b). As this point, the stripe shrinks to the cusp of the top track if the cusp is much more attractive to the bubble than the bottom track. In most conventional devices (highly anisotropic), bubble move up which indicates that the attractive charged wall strength at the hard stripeout charged wall (flip) position is weak. If the field rotates clockwise in diagram (a) the stripe shrinks back to the bottom track, because the cusp of the top track encounters a repulsive charged wall. Diagrams (d),(e) and (f) show the failure mode when the in-plane field rotates counterclockwise. The processes are similar to what happens in case of the clockwise rotating field. This time the stripe shrinks to the bottom cusp and the bubble thus moves down to the adjacent track. Similar propagation failure occurs between good and super tracks as shown in Fig.6.

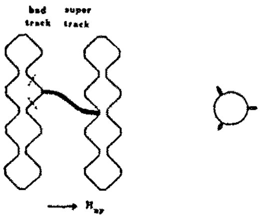

Fig.6 Bubble stripeout between bad and super tracks

When the field points into the cusp of the super track, the attractive charge wall is formed there and the bubble on the bad track is striped out and stretched into the cusp. However this time the rotating field sense does not make a difference. As the field rotates in either direction, stripe end on the bad track side encounters charged wall flip positions shown as dotted lines and shrinks to the cusp on the super track in most cases. Therefore, the bubble moves mostly to the right (super) track.

3.2.2 Stripeout Along the Track

This failure mode occures when the bubble is in the cusp at low bias field and generally at high in-plane field. At high in-plane field, the charged wall influence over the bubble (stripe) domain is diminished and the effect of edge affinity therefore becomes relatively stronger. When the in-plane field is directed along the boudary of the pattern as shown in Fig.7(a), the bubble stripes out along that boudary.

As the field rotates counterclockwise as shown in Fig.7(b), the stripe generally shrinks back to the cusp and forms a bubble again. However, the stripe can also stretch out from one cusp to the next as shown in the figure. As the field further rotates Fig.7(c), the stripe shrinks back to the next cusp and eventually forms a bubble there. Thus the bubble moves one bit position to the right while it is supposed to stay at the cusp.

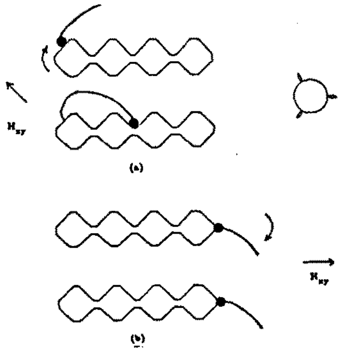

Fig.7 Stripeout along the track

3.3 Skip

This failure mode happens when the bias field is low and the drive field is also low. In most cases a bubble skips the first cusp as it turns around (clockwise) the end of the track as shown in the bottom in the Fig.8.

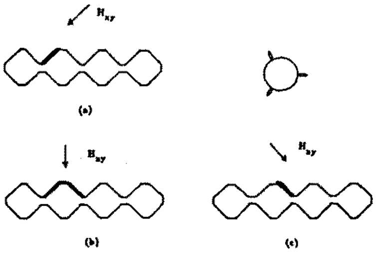

Fig.8 First cusp skip

It happens more frequently in close-packed tracks than in isolated tracks. Most interestingly, it does not happen on the right side of the track when the track is oriented with respect to the crystal orientation as shown in the figure.

At low bias and low drive field, the charged wall can become very long during the whip motion which occurs when the in-plane drive field points in the easy stripeout direction. As is shown in the bottom track of Fig.8, the long charged wall bends in between two adjacent tracks and reaches the second cusp from the end of the track casuing the bubble to jump to the cusp if it has lower potential well, skipping the first cusp. This failure happens mostly at the end of the track , because further inside, the charged wall during the whip motion does not grow so long because of the adjacent track. In the top track of Fig.8(a), the charged wall is not forced to bend by the adjacent track and it more often does not reach a cusp. Then the bubble propagates normally.

The reason the same failure mode does not occur on the right side of the track is shown in Fig.8(b). Here, the whip motion occurs when the field direction points to the right and by the time the charged wall enters the region between the tracks it actually undergoes a flip motion. Therefore there does not exist a long charged wall which could reach the second cusp and the bubble does not skip the first cusp as it rounds the end of the track.

3.4 Trap at Cusp (Hang Up)

This is the most common failure mode at low drive field. At low drive field the charged wall does not move smoothly and jumps at the flip directions leaving the bubbles in the cusps. As the bias field is increased, the bubble sizes shrink and the bubbles can move easily and follow the charged wall, giving the negative slope at the lower left corner of the bias margin. The bubbles are most often trapped in the cusps of the end of the track.

4. Conclusions

The observation and analysis of the magnetic bubble failure modes in the ion implanted magnetic bubble devices leads to the following conclusions. [1] The skidding failure mode is due to the pushing of a strong repulsive charged wall. Since the repulsive charged wall is strongest in the "bad" track, this failure mode is most pronounced in the "bad" track. [2] The stripeout failure mode at low bias fields can be explained by the relative strength of the charged wall at one end of the stripe and the edge affinity at the other end. The stripe shrinks back to the location where the attraction is stronger. [3] The first cusp skipping failure mode is due to the whipping motion of the charged wall at low bias fields. The long charged wall provides the bridge to the second cusp causing the premature propagation to that position.

5. Acknowledgement

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6. References

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