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C−2−4 Characterization of 1.5 μm Bubble Devices built on low Magnetization Garnet Films for alleviating Drive Fields

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The introduction of gap tolerant permalloy patterns make it possible to handle smaller bubbles using a given lithography technique[1,2]. Before smaller-bubble devices can be put into practical use, the increase in drive fields mainly attributed to inevitable magnetization increase in small bubble materials must be alleviated[3,4]. Our work in decreasing drive fields is presented in this paper. This decrease is achieved by choosing garnet films with the lower magnetization estimated from Thiele's formula, on 8 μm period circuits with 1 μm minimum features.

According to Thiele, the nominal size of bubble domains is described by the following formula:

$$d = \frac{\sqrt{32Aq}\ (d/\ell)}{4\pi Ms}$$

where the notation is the same as given in Thiele and d/ℓ is a function of h/ℓ. The required bubble size in this experiment is about 1.5 μm which corresponds to the storage density of 10^6 bits/cm^2. The product of A and q is set depending on the operational stability required, then, d/ℓ is varied for the chosen value of magnetization, as shown in Fig. 1. Here in the region we are concerned with, d/ℓ and h/ℓ are directly proportional. Table 1 gives the detailed properties of three sets of specimens in reference to magnetization, whose values are varied by adjusting the amount of Ca-Ge in $(YSmLuCa)_3(FeGe)_5O_{12}$. Note that h/ℓ becomes smaller in specimens with lower magnetization.

Test circuits used to characterize 4πMs dependency are small capacity full major-minor organization chips mainly composed of 8 μm period half disk patterns. The device parameters are very close to those we used before[5], except for the introduction of planar processing[6].

The plots of Fig. 2 show the effect of magnetization values on drive fields, which are defined as the fields necessary to produce the normalized bias margins of 20 % for propagation and 15 % for the stretcher. The drive frequency is a sinusoidal 100 kHz, and the information patterns are 1010··· at the upper bias margins and 1000··· at the lower margins. It is clear that drive fields are lowered as the magnetization decreases. The absolute bias margin did not show any dependency on the value of magnetization, and typically 37 Oe was maintained at the drive field of 55 Oe. The normalized bias margins relatively increased in specimens with lower magnetization. To reveal the critical characteristics in the operation, data longevity was measured at steps up to 10^8. Table 2 shows no special difference ascribed to magnetization values was observed. Fig. 3 shows the operating margins of individual functions in the major-minor circuit buit on specimen #2 in Table 1. We found that bias margin limited by the stretcher at the high bias ends and limited by the generator and the transfer-in gate could be enlarged in the region of low drive fields by using lower magnetization films, and stable operation was achieved at drive fields of less than 50 Oe.

To summarize, the possibility of using garnet films with lower magnetization to alleviate the increase in drive fields was successfully demonstrated through practical circuit operation.

Reference

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	h (μm)	Ws (μm)	l (μm)	Ho (Oe)	4πMs (Gauss)	q	Aq (erg/cm)
# 1	1.80	1.50	0.152	281	490	4.2	5.5×10^{-7}
# 2	1.50	1.52	0.178	207	409	4.8	5.3×10^{-7}
# 3	1.18	1.56	0.197	157	366	5.2	5.2×10^{-7}

Table 1

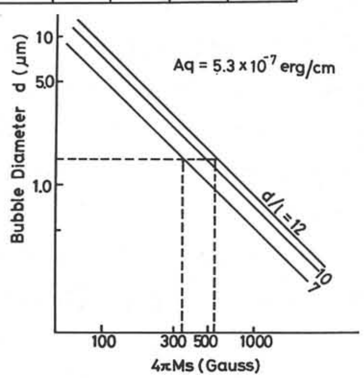

Fig. 1

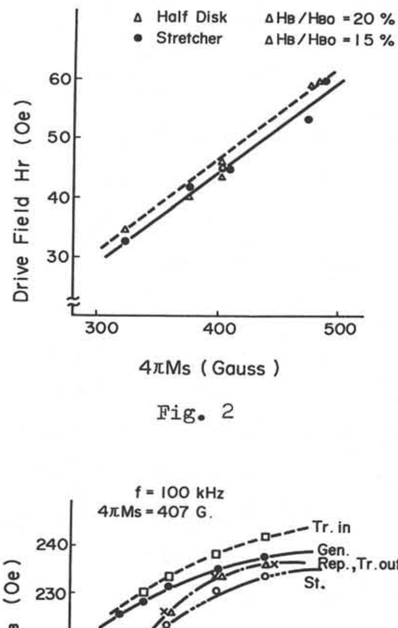

Fig. 2

	4πMs (Gauss)	Ho (Oe)	Stretcher (Oe/dec)	Half Disk (Oe/dec)
# 1	486	278	0.24	0.28
	476	272	0.25	0.28
# 2	409	207	0.20	0.30
	407	199	0.22	0.30
# 3	379	178	0.22	0.30

Table 2

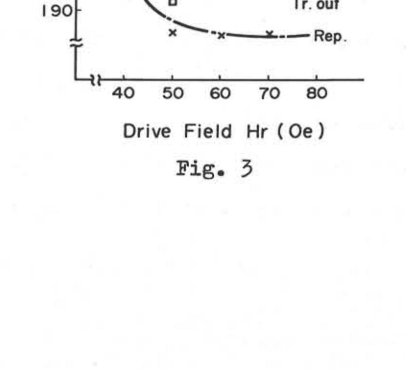

Fig. 3