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THE MOVEMENT OF BUBBLES IN ROTATING FIELD GRADIENTS[1]

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Using a method of a rotating field gradient the dynamic properties of buble films have been studied. The experimental results and the theory of the motion make it possible to derive the coercive field and the mobility of the domain wall.

ДВИЖЕНИЕ ПУЗЫРЕЙ ВО ВРАШАЮШЕМСЯ ПОЛЕ С ГРАДИЕНТОМ

В работе приводятся результаты изучения динамических свойств пузырчатых пленок при помоши метода вращающегося а градиентом. Экспериментальные результаты и теория движения позволяют вывести коэрцитивную силу и подвижность границы домена.

I. INTRODUCTION

The dynamic characterization of bubble materials usually relies on bubble translation measurements in magnetic pulse fields [1]. This method, however, brings uncertainties associated with nonlinear bubble behaviour that occurs at the beginning and at the end of the field pulse. In order to avoid these difficulties the rotating field gradient method has been recently suggested [2]. In this experiment a magnetic bubble is propagated in continuous circular motion. The rotating field gradient, having the components

$$\frac{dH_z}{dx} = BI_a \sin \omega t, \quad \frac{dH_z}{dy} = BI_a \cos \omega t ,$$

is generated by two mutually orthogonal ac currents which are 90° out of phase. The z coordinate is perpendicular to the film, x and y coordinates lie in the plane of the sample and the parameter B is a function of the conductor geometry. The position of the bubble is given by

$$x(t) = R \cos (\omega t + \varphi), \; y(t) = R \sin (\omega t + \varphi) ,$$

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where φ is a phase lag between the velocity and the field gradient direction. The parameter R is the radius of the bubble trajectory (Fig. 1).

The equation of motion is given by [3]

$$v = \frac{\mu}{2}\left(h_t - \frac{8}{\pi} H_c\right), \tag{1}$$

where $v = R\omega$ is the magnitude of the bubble velocity, μ is the wall mobility, the tangential drive field $h_t = dBI_a \cos\varphi$ is the component of the field gradient in the direction of the velocity time bubble diameter d and H_c is the dynamic coercive field. Equation (1) has been used to determine the basic dynamic parameters.

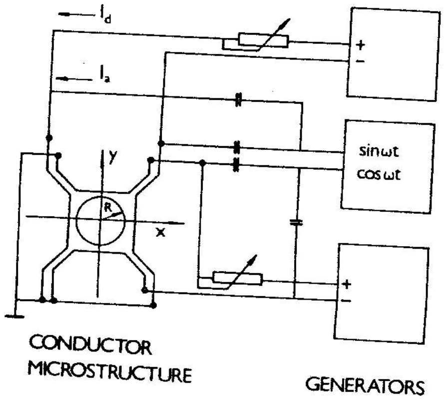

Fig. 1. The block diagram of the circuitry. The test area of the conductor microstructure has the 95×95 μm² size.

II. EXPERIMENT

The simplified block diagram of the circuitry is shown in Fig. 1. The gold conductor microstructure was electroplated to a thickness of 9 μm on a glass substrate. The combination of the external bias field H_{ze} and the bias field well, generated by the dc current I_d, makes it possible to isolate one bubble in the test area from any external domains. If the ac current I_a is varied, the bubble moves along different circular trajectories.

During the experiment the experimentally measured parameters were ω, I_a, I_d, R and H_{ze}. The phase lag was not measured assumed to be small [4]. Magnetic field and gradients generated above the conductor microstructure were computed in the approximation of the infinitely thin and long conductors. The strong dependence of the field gradient on the distance z_0 is shown in Fig. 2.

III. EXPERIMENTAL RESULTS AND DISCUSSION

A sample having a good Faraday contrast and an appropriate bubble diameter was chosen for the experiments. The film was grown by liquid phase epitaxy on a (111) oriented GGG substrate. The composition is $Y_{1.50}Sm_{0.30}Lu_{0.25}Ca_{0.96}Fe_{4.09}Ge_{0.91}O_{12}$ and the sample was not implanted. The static parameters are: thickness $h = 9.2$ μm, stripe domain period $p = 21$ μm, bubble collapse field $H_{bc} = 70.8$ Oe, stripe collapse field $H_{sc} = 55.3$ Oe, ratio of characteristic length to thickness $1/h = 0.138$ and magnetization $4\pi M_s = 150$ Gauss.

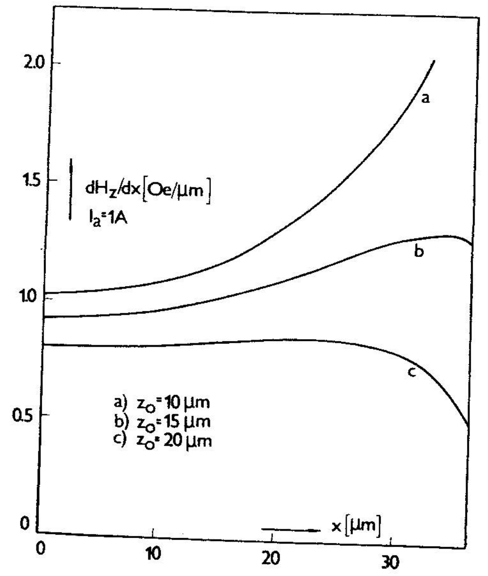

Fig. 2. The field gradient as a function of the x-coordinate ($I_a = 1$ A). The parameter z_0 is the vertical distance from the conductor microstructure.

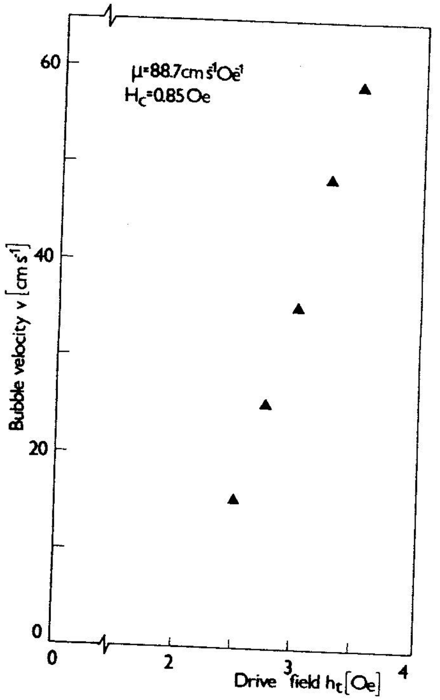

Fig. 3. The bubble velocity v as a function of the tangential drive field h_t.

The bubbles generated in the film were mainly $S = 0$ (S is the state number of the bubble). The distance $z_0 = 21$ μm and the measurements were performed at the frequency $f = 7.813$ kHz.

The bubble velocity — drive field relations are shown in Fig. 3. The dependence is linear and no velocity saturation was observed. From these data, using the equation of motion (1) the values of the dynamic parameters obtained by linear regression method were

$$\mu = 88.7\ \mathrm{cm\,s^{-1}\,Oe^{-1}} \quad \text{and} \quad H_c = 0.85\ \mathrm{Oe}\,.$$

The small value of the derived mobility is surprising and the large contribution of Sm^+ ions to the damping ($\mu \sim 1/\alpha$) [5] is believed to be one of the possible reasons for the explanation of the fact.

In addition, the experimental value of μ can be decreased by other contributions (e.g. the bubble-strip domains interactions, crystal defect, etc.). For more precise results new measurements are in preparation.

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