 

# High speed dynamics of the domain wall in garnet films in the large in-plane magnetic fields

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The dynamics of a linear solitary domain wall in the (111) oriented epitaxial ferrite-garnet films has been studied using the two-fold digital high speed photography in the real time. The in-plane magnetic field was used in the experiments; its value was comparable to the sample anisotropy field.

Методом двукратной цифровой высокоскоростной фотографии в реальном времени исследована динамика одиночной прямолинейной ДГ в эпитаксиальной пленке феррита-граната с ориентацией (111). Эксперименты проводили в присутствии плоскостного магнитного поля, его величина была сравнима с полем анизотропии образцов.

## *1. Introduction*

Numerous articles deal with the experimental and theoretical investigations of the domain wall (DW) dynamics in the ferrite-garnet films, including the experiments using the in-plane magnetic fields [1]. The experiments were carried out using both the high speed photography method [2] and the bubble collapse method [1, 3]. The different types of the DW velocity ($V$) dependence on the external pulse magnetic field ($H_p$) were obtained in the investigations. In [4], described result is the linear increasing dependence $V(H)$ up to the maximum DW velocity of 1.6 km/s. The authors [5] have observed the increasing dependence $V(H_p)$ including a section with zero differential mobility in the middle part. The maximal value of the DW velocity was about some hundred meters per second. Furthermore, it was found that under some conditions, the DW becomes diffuse. The authors [3] used a constant magnetic field to make the DW move with a velocity exceeding the Slonchevski one. This field was oriented in the sample plane along the normal to the DW plane; its value was about some hundred Oersted, which is much lower than the anisotropy field.

This work is aimed at experiments continuing the above studies. In order to investigate the high-speed DW dynamics in the ferrite-garnet films, we used the two-fold high speed photography method [6]. In all our experiments, the in-plane constant magnetic field was oriented in the sample plane along the normal to the DW plane. The value of this field was about 90 % of the sample anisotropy field.

## *2. Experimental*

This work describes the study results of the linear solitary domain wall dynamics in the (111) oriented epitaxial BiYFeGa garnet films. The sample anisotropy field was about 5 to 6 kOe and $4\pi M_s = 80$ Gs. The solitary DW was formed using a gradient magnetic field ($6 \cdot 10^3$ Oe/cm). This field was oriented perpendicularly to the sample plane. The dynamical DW was illuminated by two red light pulses of 0.25 ns duration. The delay time between these pulses was 6

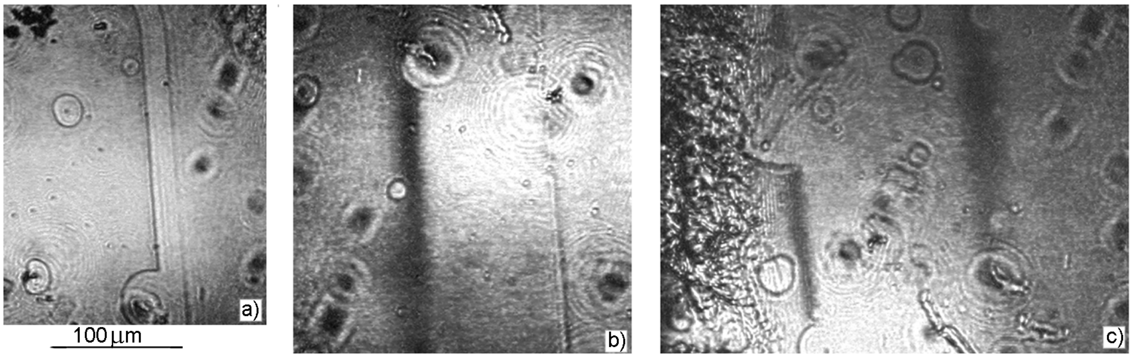


Fig. 1. The two-fold high speed photographs of a dynamical DW in the ferrite-garnet film made in the DW contrast. The DW moves from right to left at a with velocity (km/s): 1.8 (a); 9.5 (b); 14.5 (c).

to 14 ns. The pulse magnetic field H that moved the DW had the amplitude less than 800 Oe. The two-fold high velocity photography method allows determining the DW velocity and its visible width in the dynamics.

The photographs were made in the DW contrast (Fig. 1) as well as in the domain contrast (Fig. 2). The photographs show that the visible width of the dynamical DW is 3–5 μm when the DW velocity is less than certain critical value $V_{max}$. If the DW velocity exceeds that threshold, the DW becomes diffuse and its visible width increases (Fig. 1b, c). The blurred the right edge on the photograph (Fig. 2b) demonstrates that the DW in this position is already diffuse.

The DW velocity dependence on the pulse magnetic field at different in-plane constant magnetic field values (Fig. 3a) was determined using photographs similar to those of Fig. 1–2. The pulse magnetic field increases, the DW velocity increases at first and reaches the value $V_{max}$. This value remains constant within a certain interval of $H$ values. At the further increase of the magnetic field $H$, the DW becomes diffuse and its velocity grows. In some parts of the sample, there were random domain formation in front of the dynamical domain wall. The DW velocity (including the diffuse DW) was measured in those sample parts where the random domains formation was not observed. It is obvious that the measurement accuracy of the diffuse DW velocity was lower than that of the DW velocity at a small visible width (Fig. 3a). The possibility of a supersonic DW motion in the ferrite-garnet films under special conditions was theoretically predicted in [7]. However, no such high- velocity DW motion in ferrite-garnet films was observed before.

The dependences of the DW velocity on the pulse magnetic field in the presence of

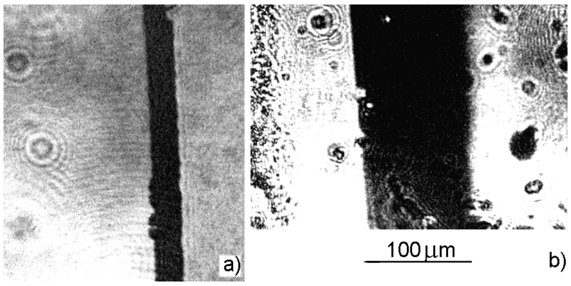


Fig. 2. The two-fold high velocity photographs of the dynamical DW in the garnet film are made in the domain contrast. The DW moves from left to right at a speed (km/s): 2.4 (a); 10 (b).

an in-plane magnetic field of different value $H_{pl}$ are shown in Fig. 3b. It is possible to describe these dependences by equation:

$$V(H_{imp}) = \frac{\mu \cdot H_{imp}}{\left[1 + \left(\mu \cdot H_{imp}/V_{\max}\right)^2\right]^{1/2}} \quad [8],$$

where μ is the DW mobility. Authors [8] compared their theoretical results with the experimental results obtained in [9] where the maximum DW velocity did not exceed 1 km/s.

The character of the $V(H)$ dependences remains unchanged at different values of the in-plain magnetic field. The $V_{max}$ value increases linearly as the in-plain magnetic field $H_{pl}$ grows (Fig. 4) and trends to the sound sed in the ferrite-garnet films as the in-plane magnetic field value approaches the material anisotropy field. The interval of $H$ values where the DW speed remains constant decreases when the in-plane magnetic field $H_{pl}$ value increases.

Numerous articles deal with the effect of constant in-plane magnetic field on the DW dynamics in the ferrite-garnet films [1, 3]. However, in those experiments the values of

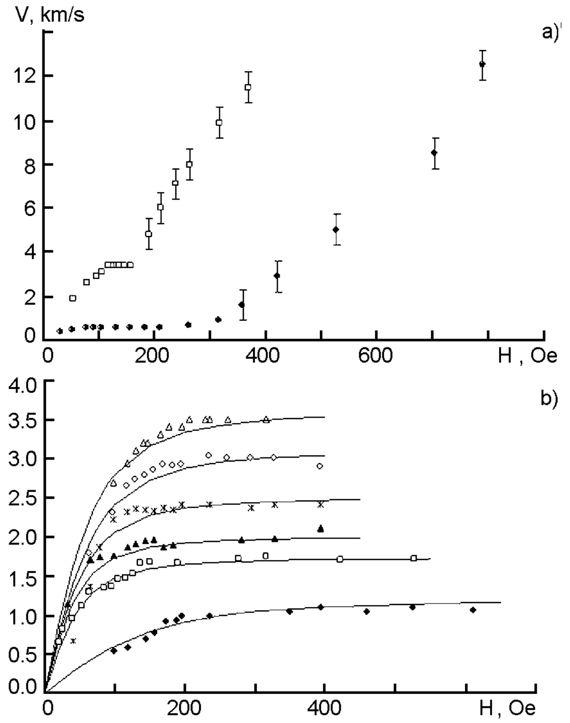


Fig. 3.(a). The dependences of the DW velocity on the pulse magnetic field in the in-plane constant magnetic field: $H_{pl}$ = 0.8 kOe (●); $H_{pl}$ = 4.4 kOe(□). (b). The dependence of the DW velocity on the pulse magnetic field in the in-plane constant magnetic field: $H_{pl}$ = 1.3 kOe (♦); $H_{pl}$ = 2 kOe(□); $H_{pl}$ = 2.5 kOe (▲); $H_{pl}$ = 3.4 kOe(*); $H_{pl}$ = 3.9 kOe (○); $H_{pl}$ = 4.4 kOe (Δ).

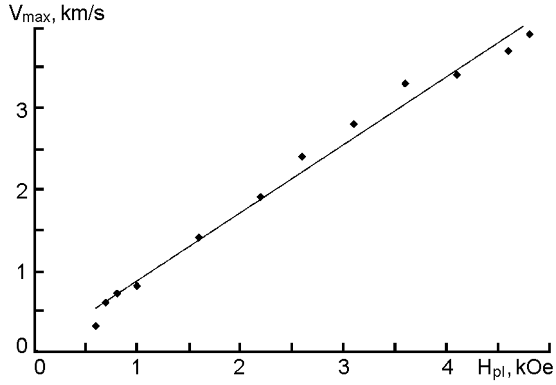


Fig. 4. The dependence of the saturation velocity $V_{max}$ on the in-plane magnetic field $H_{pl}$.

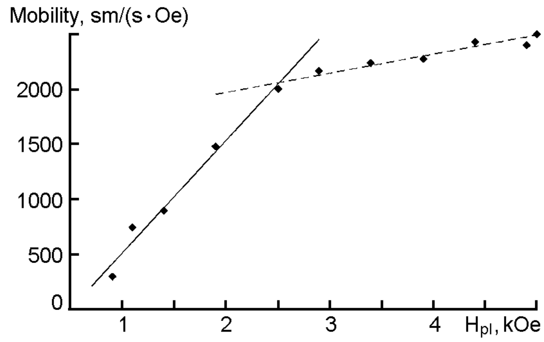


Fig. 5. The dependence of the DW mobility μ on the value of the in-plane magnetic field $H_{pl}$.

the in-plane magnetic field did not exceed 40 % of the sample anisotropy field. In our experiments, the maximum value of the in-plane magnetic field was not lower than 90 % of the sample anisotropy field. The linear increasing dependences $V_{max}(H_{pl})$ are described in [1, 3]. In this case, the DW velocity did not exceed 100 m/s.

The DW mobility μ was determined from the initial linear sections of the $V(H_p)$ dependences obtained at different in-plane magnetic field $H_{pl}$ values. The DW mobility dependence on the in-plane magnetic field $H_{pl}$ is shown in Fig. 5. It is possible to distinguish two linear sections with different slopes in this ploth. The DW mobility increases sharply at low $H_{pl}$ values and reaches $\mu = 2\cdot 10^3$ sm/(s·Oe) at $H_{pl}$ = 2 kOe. The further mobility increase becomes smoother.

The experimental studies of the DW mobility dependence on the in-plane constant magnetic field value are described in [10]. The authors of that work discovered an almost linearly increasing dependence. In these experiments, the values of the in-plane constant magnetic field did not exceed 40 % of the sample anisotropy field. This dependence of the DW mobility on the in-plane magnetic field is similar to the initial section of the dependence presented in Fig. 5. The application of the in-plane magnetic field with value close to the anisotropy field revealed another type of the $\mu(H_{pl})$ dependence.

The constant in-plane magnetic field $H_{pl}$ stabilizes the DW structure, therefore, the DW velocity value $V_{max}$ increases. If the DW velocity exceeds $V_{max}$, the DW structure becomes unstable. However, it is difficult to observe the DW dynamics at the in-plane magnetic field values close to the anisotropy field, because the domain structure contrast drops down in these conditions. The DW velocity measurement accuracy decreases sharply when the random domains formation is observed in front of the dynamical DW in the presence of high in-plane magnetic fields.

According to the theory of the DW mobility dependence on the in-plain magnetic field, it is possible to discriminate different contributions to relaxation considering the experimental $\mu(H_{pl})$ dependence [11]. It is impossible to distinguish the different contributions defining the DW mobility value from the analysis of experimental $\mu(H_{pl})$ dependences if these dependences do not contain peculiarities. The experimental DW mobility values are much lower than the predicted ones. Moreover, the theoretical curves show only the general type of the experimental dependences [10].

### 4. Conclusion

To conclude, the DW moved in the ferrite-garnet film at a velocity close to the sound one due to the constant in-plane magnetic field with value close to the sample anisotropy field. An unusual dependence of the DW mobility on the in-plane constant magnetic field has been obtained. These results provide new opportunities for the practical application of the ferrite-garnet films and form a basis for further studies.

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## Високошвидкісна динаміка доменних меж у плівках феритів-гранатів у сильних площинних полях

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Динаміку одиночної прямолінійної доменної межі досліджено в епітаксійній плівці фериту-гранату з орієнтацією (111) методом дворазової цифрової високошвидкісної фотографії у реальному часі. Експерименти виконано у присутності площинного магнітного поля, величина якого була порівнянною з полем анізотропії зразків.