

Modeling of microwave-assisted switching in magnetic ellipsoid

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The fundamentals of fast magnetisation switching is one of the important problems in magnetism, related to technological applications. Among various possibilities, the microwave-assisted (mw) switching with linearly-polarized excitation could be implemented based, for example, on fast magneto-optic Kerr set-up, synchronized with a microwave field [1]. It has been shown that the mw-assisted switching requires smaller dc external field [1]. The process of understanding the underlying physics is still on going and several ideas which include fast precessional switching [2], nonlinear phenomena [3], enhanced nucleation or increased domain wall mobility [1] could be found in the literature.

In the present work and with the aim to understand the mw-assisted switching in large magnetic elements [1], we use a micromagnetic model to simulate a permalloy ellipsoid of $4\mu\text{m} \times 2\mu\text{m} \times 25\text{nm}$ dimensions with easy axis parallel to the large ellipsoid dimension (y-axis). Initially the ellipsoid is magnetised along this axis and the dc-applied field is also applied parallel to it in the opposite direction. The ac field with large amplitude is directed perpendicular (x-axis). First of all, we notice that the largest effect of the coercivity reduction comes from the deviation of the magnetisation from y-axis, following the ac-field. Thus, the coercivity is reduced simply due to the fact that most of time the resulting field is applied at some angle to the easy axis. Consequently, we compare the mw-assisted switching with the situation when we the dc field is applied at an angle equal to that formed during the mw-assisted case with the maximum amplitude of the ac field. Our results show that even with this fair comparison, the mw-assisted switching requires less dc field.

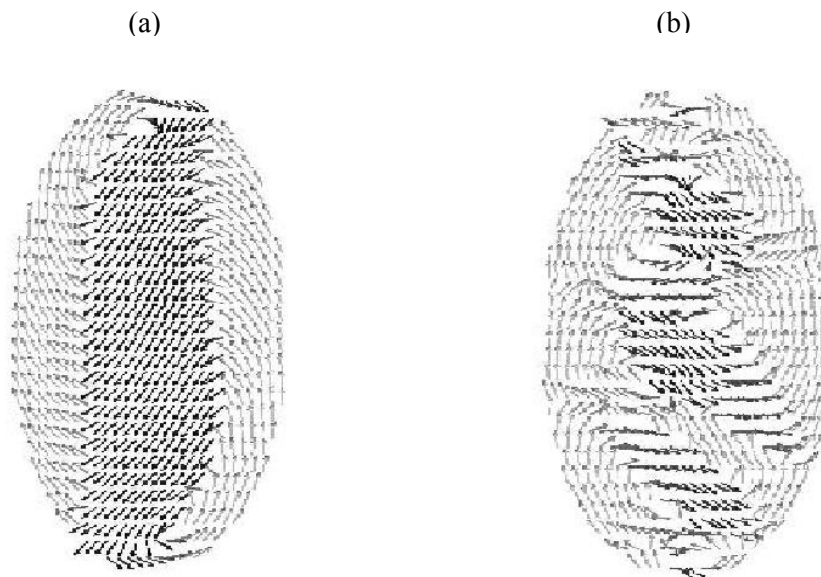


Figure 1: Dynamic magnetisation configurations during (a) static hysteresis and (b) mw-assisted processes.

Figs. 1(a) and (b) show the magnetisation configurations during the static and mw-assisted reversal. We clearly observe that during the mw-assisted switching the ellipsoid is dynamically divided into “domain” structures. The number of “domains” depends strongly on the mw frequency and may be related to the length of the spinwave mode, excited in the system. The division of the ellipsoid into domains during mw-assisted switching is experimentally confirmed by Kerr images in Ref. [4]. Therefore, the mw-assisted case is characterized by a reversal mode different to the one appearing during the static hysteresis.

The results presented in Fig.2a show oscillations of the magnetisation reversal time as a function of mw frequency for various mw field amplitudes.

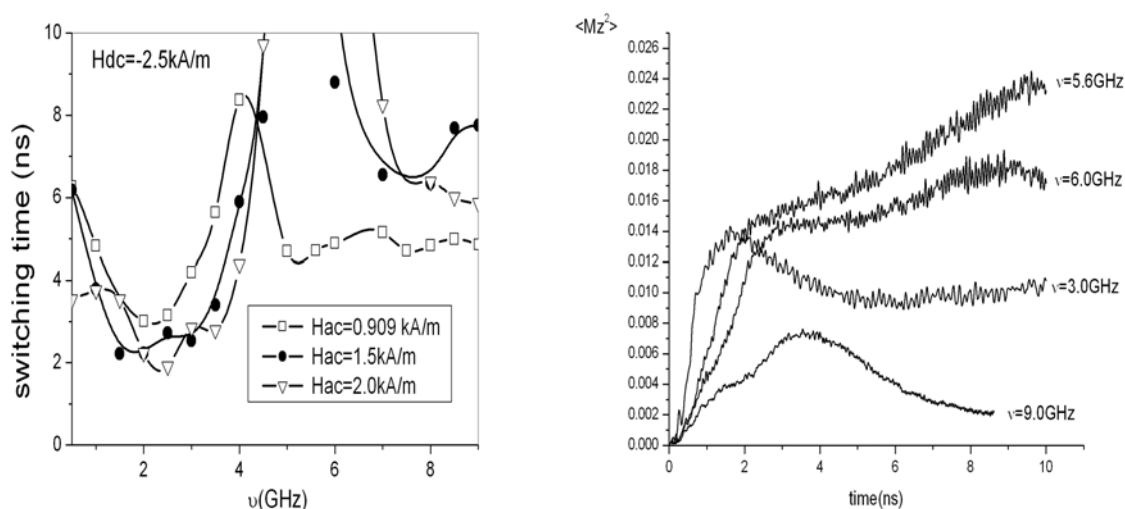


Figure 2: (a) Switching time for the ellipsoid as a function of the mw frequency ν (b) Temporal evolution of the average $\langle M_z^2 \rangle$ component, characterizing the precessional energy, for $H_{ac} = 2 \text{ kA/m}$.

Having analyzed in detail the switching process, we observed that the nucleation process is similarly fast in all cases (although slightly faster with frequencies multiple to the FMR frequency). However, a strong precession of magnetic moments is observed when the switching time is large (see Fig.2b). The corresponding frequencies approximately coincide with the multiples of FMR frequencies when the average magnetization is pointed in the direction parallel to the applied field. Consequently, due to the coupling of the mw to the precessional motion, the energy is transferred into this motion and not to the switching process [4]. We have also observed nonlinear shifts of the frequencies at large ac field amplitudes. Finally, we conclude that several of the effects reported previously in the literature, as precessional switching, vortex and domain wall enhanced mobility etc. coincide, making the overall process complicated. However, our simulations clearly confirm the fact that the mw-assisted switching requires less external field and is faster.

References:

- [1] H.T.Nembach et al, *Appl. Phys.Lett.*, vol. 90 (2007) p.1.

- [2] G.Bertotti et al, IEEE Trans Magn 39 (2003) 2504.
- [3] C.Thirion et al, Nature Mater. vol. 2 (2003) p.524.
- [4] P.Martin Pimentel et al, J Appl. Phys. 102, 063913 (2007)