Spin Transfer Torque Switching in Pentalayer Nanopillar Having Two Pinned Layers with Biasing

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Introduction

- Recently spin transfer magnetization switching in nanopillar device has been a continuously growing topic, because of its potential application in ultra-high density recording media, magnetic memory devices, read / write heads and microwave frequency generators.
- The speed of switching of magnetization in magnetic multilayer is an issue in magnetic storage and recording industries.
- Spin transfer precessional switching in trilayer nanopillar has been widely studied and various methods used to reduce the switching time.
- Addition of one more pinned layer in the top of trilayer nanopillar provides an additional source of spin-polarized electrons to the free layer which is expected to contribute in the reduction of the switching time.
- In this work, we investigate the spin current induced switching in a pentalayer (pinned/ spacer/ free/ spacer/ pinned) nanopillar structure for standard configuration, pinned layer biasing and free layer biasing configuration.

Geometry of Pentalayer Nanopillar

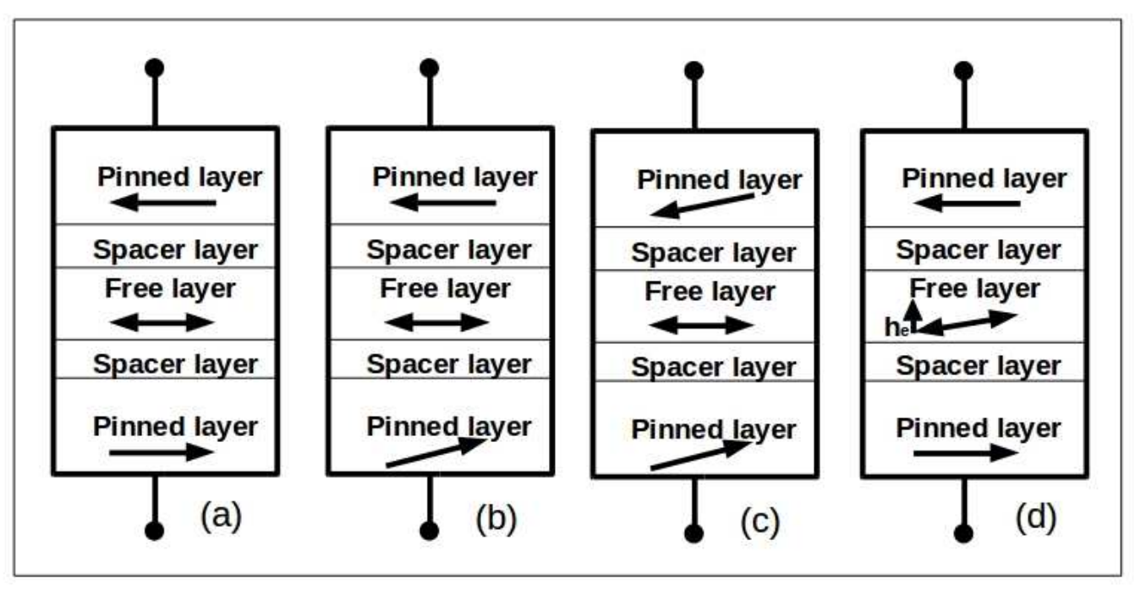

Fig. 1: Schematic sketch of the Pentalayer nanopillar. (a). Standard configuration (b). First pinned layer biasing configuration (c). Both pinned layer biasing configuration (d). Free layer biasing configuration.

Magnetization Switching Dynamics

The magnetization switching dynamics of the free layer in the pentalayer nanopillar is governed by the Landau-Lifshitz-Gilbert-Slonczewski(LLGS) equation & it can be written as,

$$\frac{d\mathbf{m}}{d\tau} = -[\mathbf{m}\times\mathbf{h_{eff}}] - \alpha[\mathbf{m}\times(\mathbf{m}\times\mathbf{h_{eff}})] + a_j[\mathbf{m}\times(\mathbf{m}\times\mathbf{m}_{p1})] - a_j[\mathbf{m}\times(\mathbf{m}\times\mathbf{m}_{p2})]. \tag{1a}$$

$$\mathbf{m} = (m^x, m^y, m^z), \qquad \mathbf{m}^2 = m^{x2} + m^{y2} + m^{z2} = 1. \tag{1b}$$

- $\tau = \gamma M_s t, \qquad a_j = \frac{pJ\hbar}{\mu_0 e d M_s^2}$
- $\mathbf{m_{p1}} = \cos\theta_1\mathbf{e}^x + \sin\theta_1\mathbf{e}^y, \qquad \mathbf{m_{p2}} = \cos(\pi+\theta_2)\mathbf{e}^x + \sin(\pi+\theta_2)\mathbf{e}^y.$

Effective field in the free layer

Total Effective Field : $\mathbf{h}_{eff} = \mathbf{h}_{shape} + \mathbf{h}_{ma} + \mathbf{h}_{ext}.$

Shape Anisotropy : $\mathbf{h}_{shape} = -(N_x m^x \mathbf{e}^x + N_y m^y \mathbf{e}^y + N_z m^z \mathbf{e}^z),$

Magnetocrystalline Anisotropy : $\mathbf{h}_{ma} = h_a m^x \mathbf{e}^x$

External Magnetic Field : $\mathbf{h}_{ext} = h_e \mathbf{e}^y$

Total Effective Field : $\mathbf{h}_{eff} = h_a m^x \mathbf{e}^x + h_e \mathbf{e}^y - N_z m^z \mathbf{e}^z.$

Numerical Parameters

Parameters / Constants	Symbol	Value
Charge of electron	e	$1.602 \times 10^{-19} C$
Reduced Planck's Constant	$\hbar$	$1.0551 \times 10^{-34} Js$
Gyromagnetic ratio of free e^-	γ	$2.21 \times 10^5 mA^{-1}s^{-1}$
Permeability of free space	μ_0	$1.257 \times 10^{-6} JA^{-2}m^{-1}$
Polarization factor	p	0.3
Gilbert damping parameter	α	0.003
Magnetocrystalline anisotropy of NiFe	h_a	0.01
Saturation magnetization of NiFe	M_s	$0.795 \times 10^6 Am^{-1}$
Thickness of the free layer	d	$2.8 \times 10^{-9} m$
Applied current density	J	$3.0 \times 10^{11} Am^{-2}$
Applied magnetic field	h_e/h_a	0.4

Table: Values of various parameters / constants used in the Numerical simulation.

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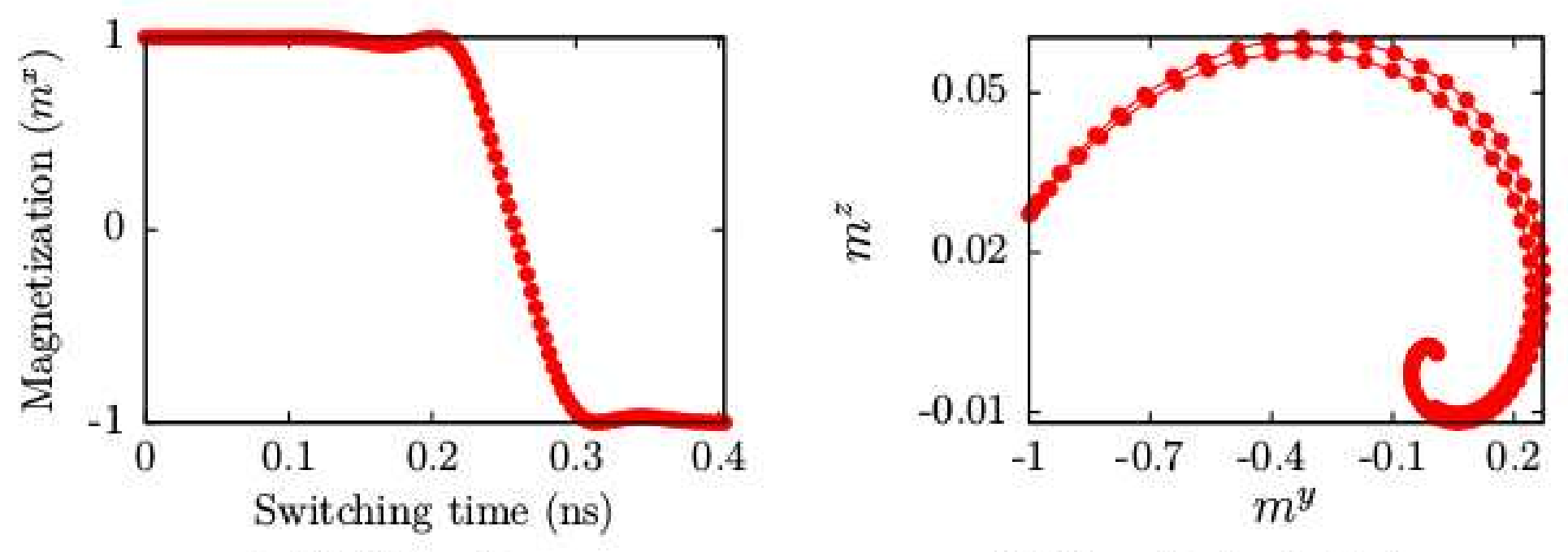
Standard Configuration



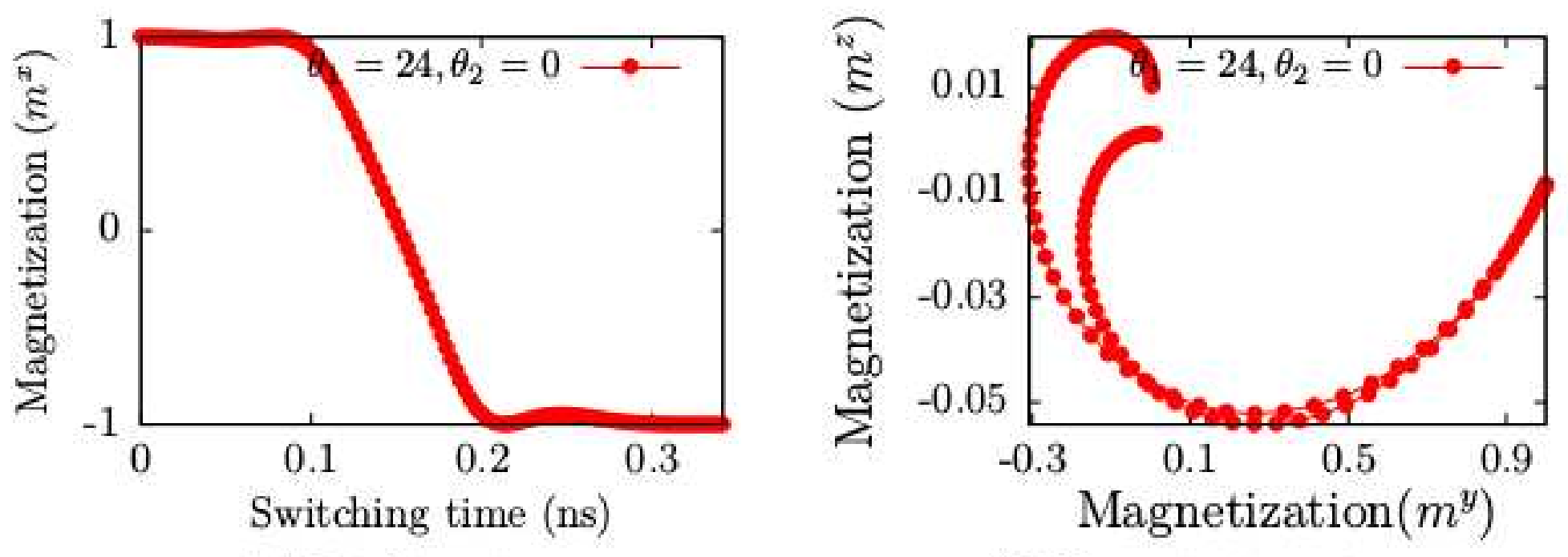
(a) Switching time

(b) Magnetization trajectory

Fig. 2: (a). A plot of magnetization versus switching time (b). Magnetization trajectory in y-z axis for the pentalayer nanopillar in the standard configuration.

Switching Time = 0.296 ns.

First Pinned Layer Biasing Configuration



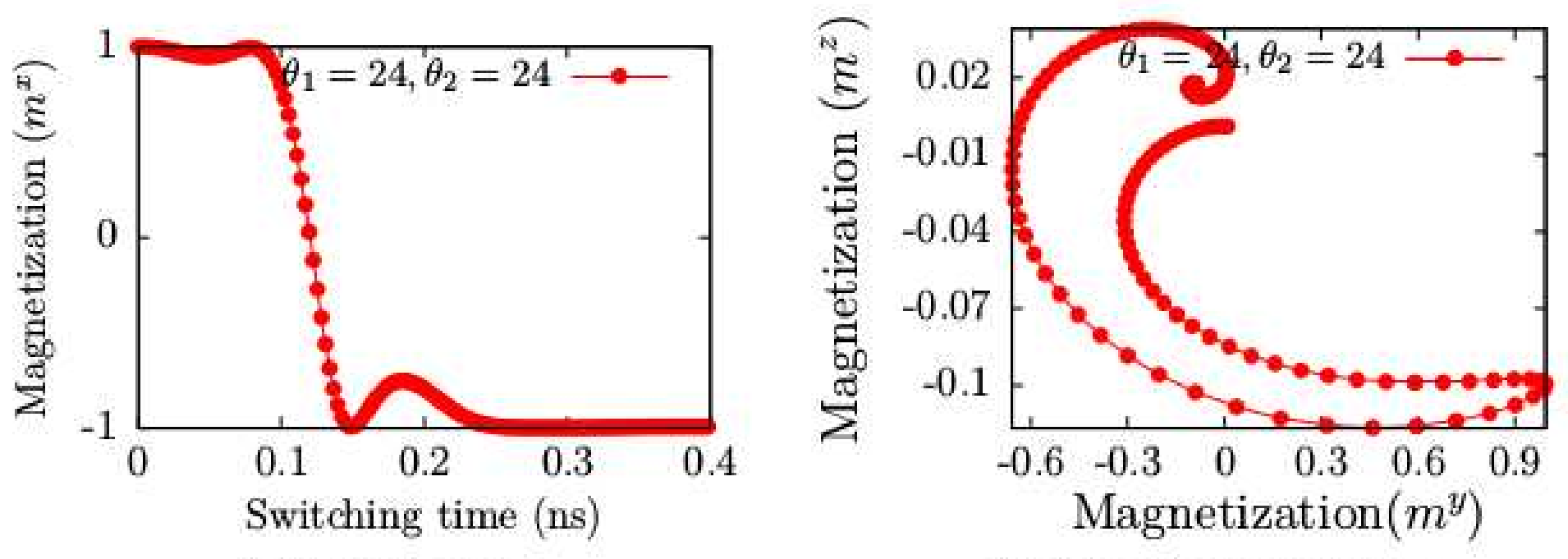
(a) Switching time

(b) Magnetization trajectory

Fig. 3: (a). A plot of magnetization versus switching time (b). Magnetization trajectory in y-z axis for first pinned layer biasing in the pentalayer nanopillar.

Switching Time = 0.195 ns.

Double Pinned Layer Biasing Configuration



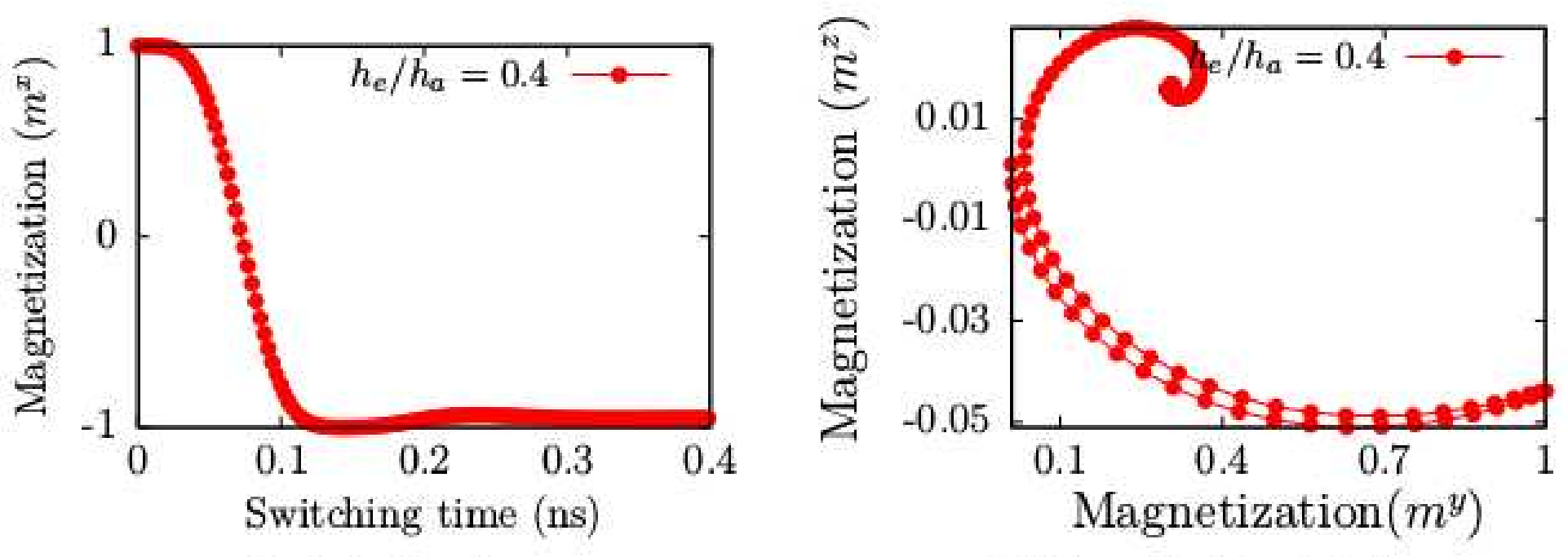
(a) Switching time

(b) Magnetization trajectory

Fig. 4: (a). A plot of magnetization versus switching time (b). Magnetization trajectory in y-z axis for double pinned layer biasing in the pentalayer nanopillar.

Switching Time = 0.140 ns.

Free Layer Biasing Configuration



(a) Switching time

(b) Magnetization trajectory

Fig. 5: (a). A plot of magnetization versus switching time (b). Magnetization trajectory in y-z axis for free layer biasing in the pentalayer nanopillar.

Switching Time = 0.108 ns.

Conclusions

- The spin current induced magnetization switching dynamics in a pentalayer nanopillar was studied for different biasing configurations by solving the governing LLGS equation numerically.
- The switching time reduces when the layers are biased and the lowest switching time is obtained for the free layer biasing configuration.

References

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