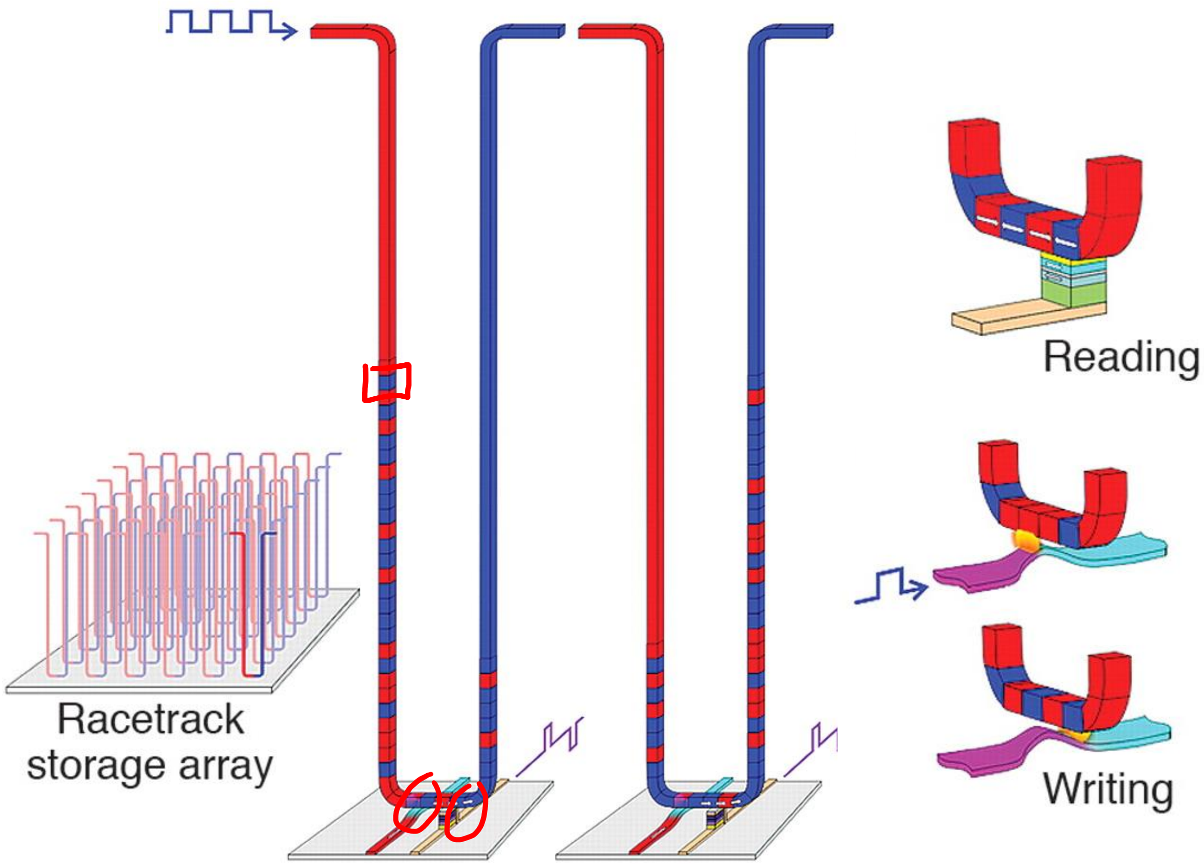
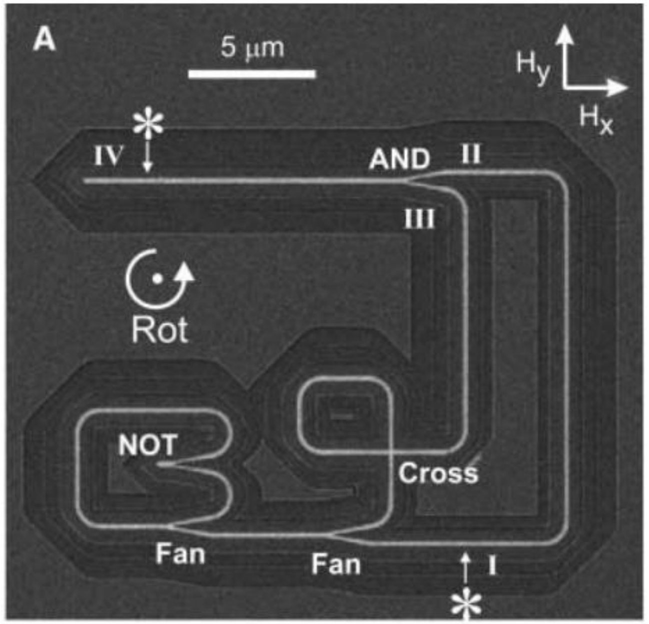
HIGH-TECH MAGNETISMUS

① RACETRACK MEMORY



② LOGIKA NA DOMÉNOVÝCH STĚNÁCH



D. A. Allwood. *Science* **309**, 1688 (2005)

S. Parkin et al. *Science* **320**, 190 (2008)

S. Parkin & S. H. Yang. *Nature Nanotechnology* **10**, 195 (2015)

J. Sampaio. *Handbook of Surface Science* **5**, 335 (2015)

PODIVNÉ CHOVÁNÍ FEROMAGNETŮ

Feromagnet (Ocel: Fe, C ...)

- ? Většina oceli bez vnějšího mg. momentu
- ? Pokud se zmagnetuje, pak téměř navždy
- ? Magnetizace >> než u paramagnetů

$$B = \mu_0 (M + H) = \mu_0 \mu_r H = \mu_0 (1 + \chi_m) H$$

$$\left.\begin{array}{l} \text{šroubovák:} \quad \mu_0 H \sim 5\,mT \\ Al: \quad \chi_m \sim 2 \cdot 10^{-5} \end{array}\right\}$$

$$\mu_0 H = \chi_m \mu_0 H$$

$$\mu_0 H = \frac{5\,mT}{2 \cdot 10^{-5}} \sim \underline{\underline{250\,T}}$$

MIKROMAGNETICKÁ ENERGIE

$E_{TOT} = \int_V \underline{\varepsilon_{TOT}}\, dr^3$

① $\boxed{\varepsilon_{EX}}$ $\boxed{\varepsilon_{TOT} = \varepsilon_{EX}}$ ~~EXCHANGE~~ EXCHANGE E.

$1-\frac{\theta^2}{2}$

$$E_{EX} = -\sum_{ij} \underline{\underline{J}}\, \vec{S}_i \cdot \vec{S}_j = \sum JS^2 \cos\theta_{ij} \approx \text{const.}\ \frac{JS^2}{2} \sum \theta_{ij}^2$$

$\Sigma \to \int$

směr. vekt. $\vec{M}$

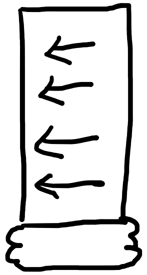
$$E_{EX} = A \int_V (\nabla e_M)^2 dr^3 = \underbrace{A \int_V (\nabla\theta)^2 d^3r}$$

↑ ↑ ↑ ↑

$A = 2JS^2 \frac{z}{a}$

z ← počet at. v mřížce

a ← mříž. konst.



② $\boxed{\varepsilon_d}$ Demag. energie

$$\underbrace{B = \mu_0 (H+M) \qquad \nabla\cdot B = 0}$$

$$\boxed{\nabla\cdot H = -\nabla\cdot M}$$

$$H = -\nabla\varphi_m \quad : \quad \underbrace{-\nabla^2\varphi_m + \overset{\rho_m}{\nabla\cdot M} = 0}_{\text{POISSON. RCE}}$$

objem. náb.

$\nabla^2\varphi_m = -\rho_m$

rozhraní: $B_1^\perp = \mu_0(H_1^\perp + M^\perp) = B_2^\perp = \mu_0 H_2^\perp$

$\Rightarrow \quad H_2^\perp - H_1^\perp = M^\perp = \vec{M}\cdot\vec{e}_n = \sigma_m$

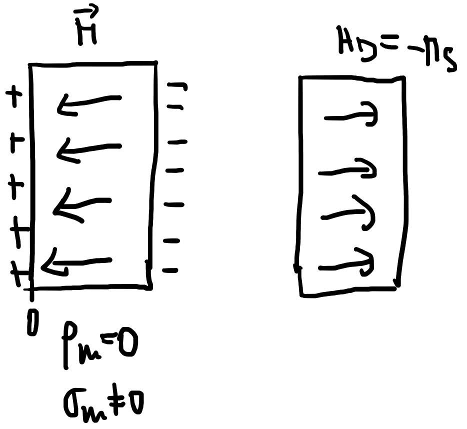
povrch. náb.

$$E_D = \int_V B\cdot H\, dr^3 =$$

$$= \frac{1}{2} \int_{\text{prostor}} \mu_0 H_d^2\, dr^3 =$$

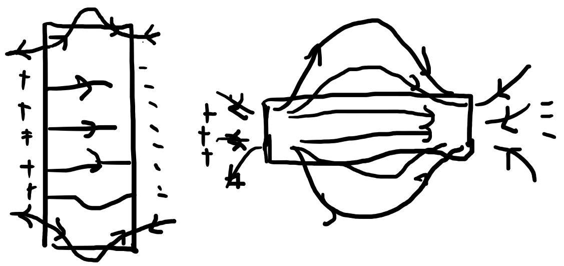
$$= -\underbrace{\frac{1}{2} \int_V \mu_0 H_d \cdot M\, dr^3}$$

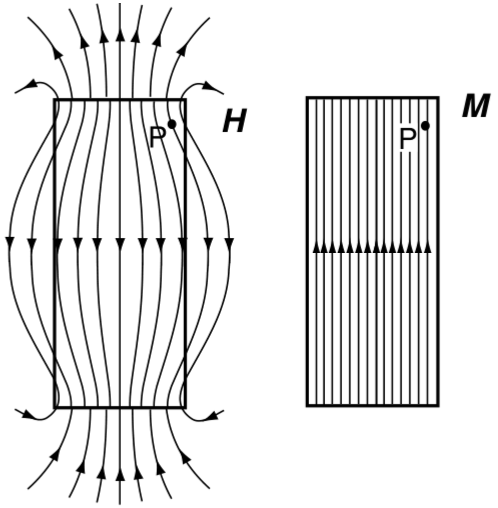
MIKROMAGNETICKÁ ENERGIE



$\rho_m = 0$

$\sigma_m \neq 0$





nekon : $\nabla \cdot H_D = -\nabla \cdot M = 0$ $\Rightarrow$ minimal. ρ_m a σ_m $\Rightarrow$ snížení H_D $\Rightarrow$ snížení E_D

$H_D = \text{konst.}$

$M(0^-) = 0$

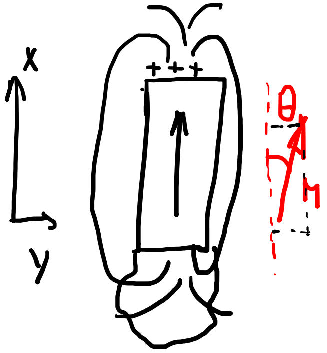
$M(0^+) = M_s$

$\Rightarrow H_D(0^+) = -M_s$

$\Rightarrow$ venku $H_D = 0$

kon : $|H_D| \leq M_s$

$H_D = \mathcal{N} M_s$



$\mathcal{N}_x \to 0$

$\mathcal{N}_y \to -M_s$

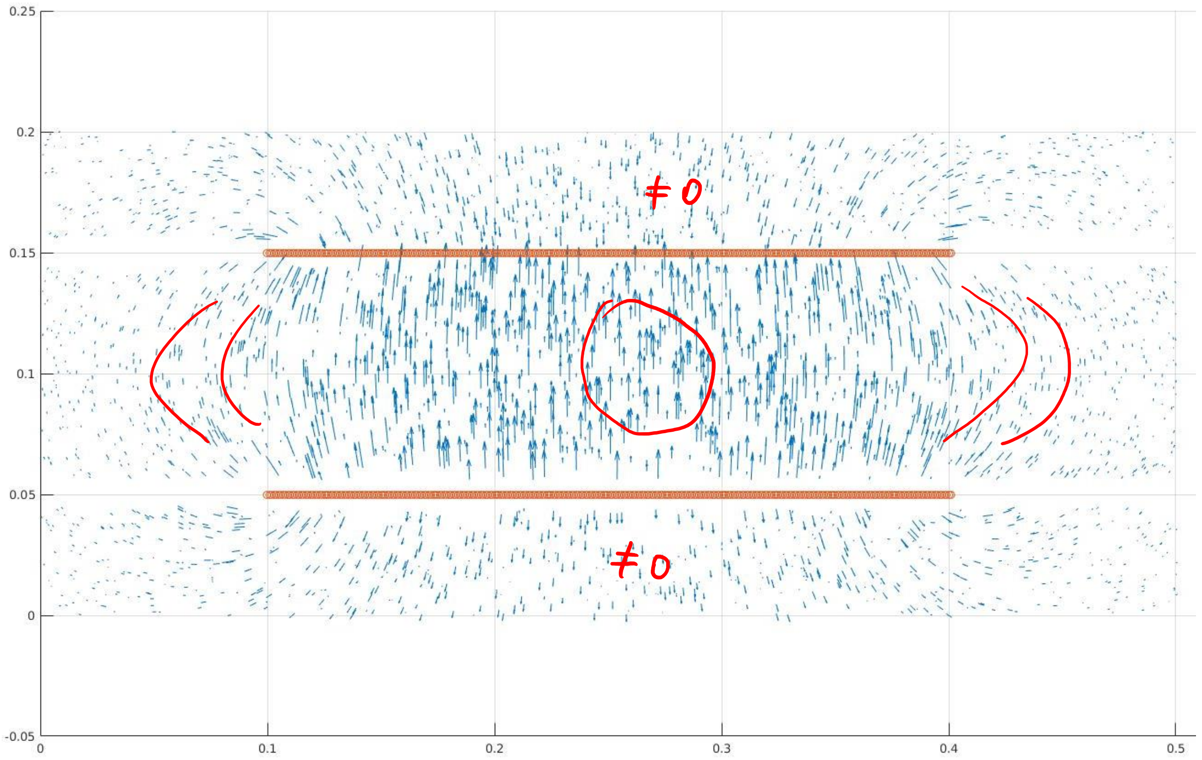
$H_D = -M_s$

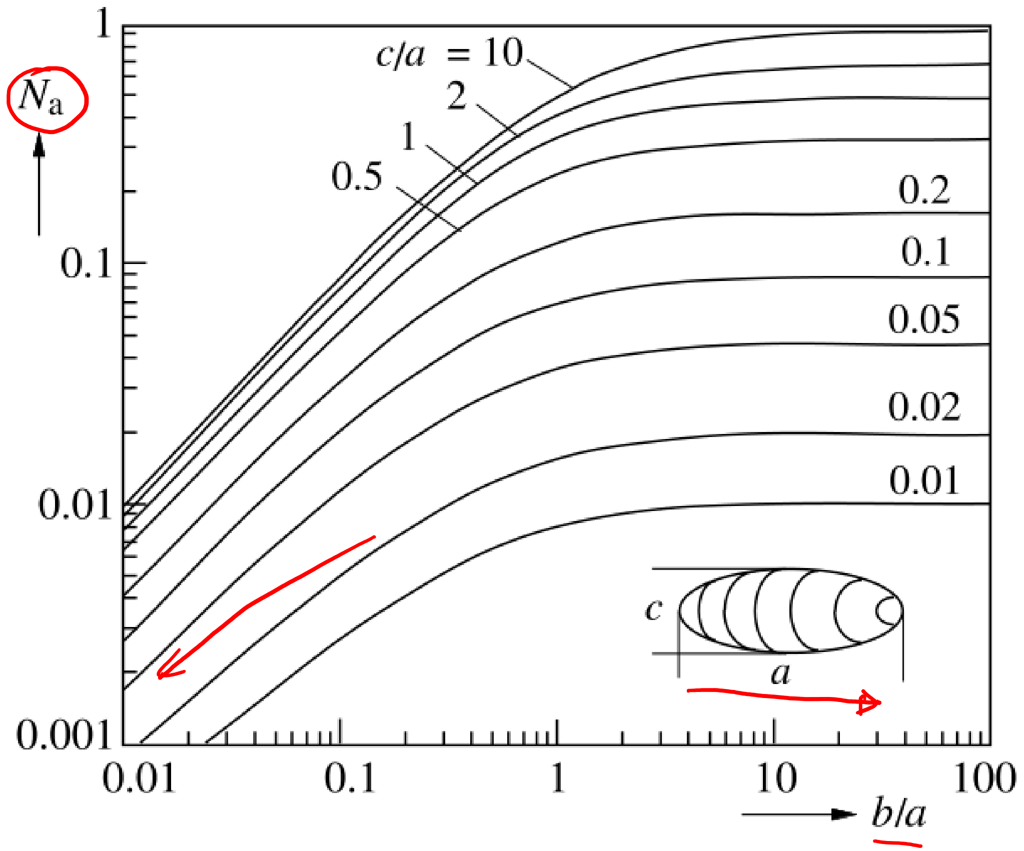
$-H_D \cdot M_s = -M_s^2$

$$\Rightarrow E_D = \underbrace{\int_V \frac{1}{2}\mu_0 M_s^2 \sin^{②}\theta \, dr^3}_{}$$

SHAPE
ANISOTROPY

MIKROMAGNETICKÁ ENERGIE

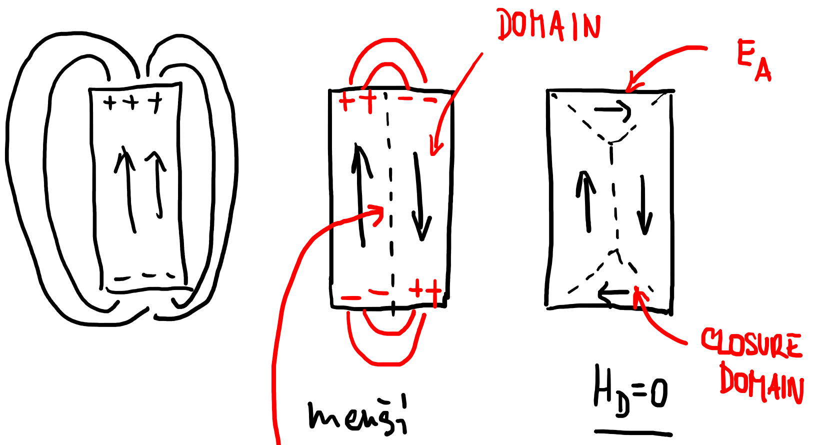




https://github.com/uladkasach/finite-capacitance

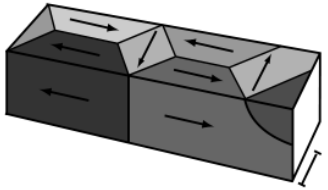
A. Hubert, R. Schäfer, Magnetic domains: the analysis of magnetic microstructures, Springer 1998

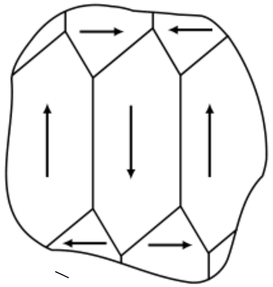
MIKROMAGNETICKÁ ENERGIE



menší H_D

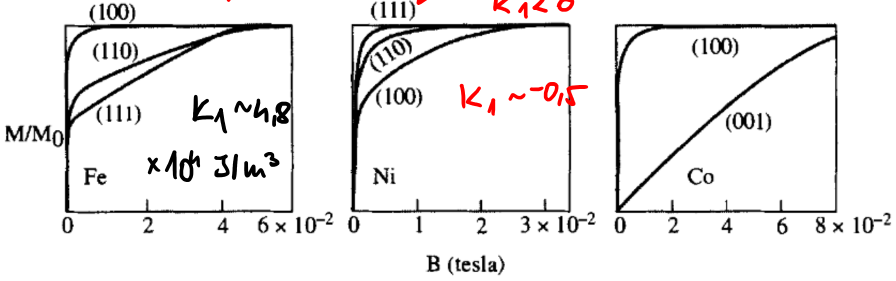
cena:
E_{EX} ZA DOMÉNOVOU STĚNU





100 je EASY pro $K_1>0$

111 je easy $K_1<0$



$K_1 \sim 4{,}8$ $\times 10^4$ J/m^3

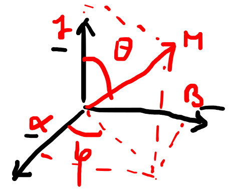
$K_1 \sim -0{,}5$

③ $\boxed{E_A}$ MAGNETOKRYSTALICKÁ ANISOTROPIE

S-O INTERAKCE ← ORBIT. MOMENT + EL. POLE KRYSTALU

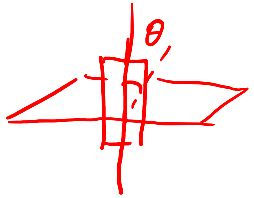
→ ZÁV. NA ÚHLU : směr. cos

ex. $\gamma = \cos\theta$



- UNIAX. : sym. (C_n)

$$E_A = \int_V K_1 \sin^2\theta \, dr^3 = \int_V \underset{K_u}{K_1} (1-\gamma^2)$$

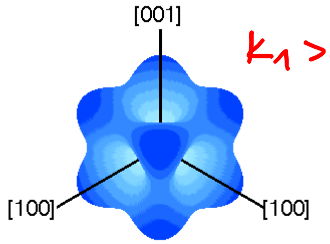


$K_u > 0$ → OSA je EASY AXIS
$K_u < 0$ → ⊥ rovina je EASY

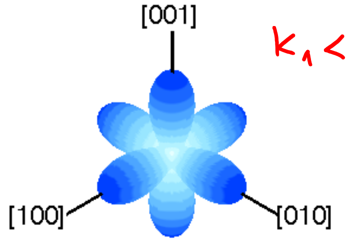
- KUBICKÁ:

$$E/V = K_1\left(\alpha^2\beta^2+\beta^2\gamma^2+\gamma^2\alpha^2\right) + \overset{\approx 0}{K_2}\alpha^2\beta^2\gamma^2$$

$$E = K_1\left(\frac{1}{4}\sin^2\theta\sin^2 2\phi+\cos^2\theta\right)\sin^2\theta+\frac{K_2}{16}\sin^2 2\phi\sin^2 2\theta\sin^2\theta+\cdots$$



$K_1 > 0$



$K_1 < 0$

MIKROMAGNETICKÁ ENERGIE

- $\mathcal{E}_S$: SURFACE ANIS. : $E_S = \int_V K_S \sin^2\theta \, dr^3$

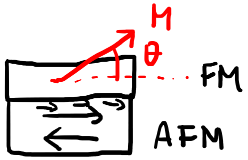
$K_S > 0$ INPLANE

$K_S < 0$ OUT OF PLANE

EA

- $\mathcal{E}_{ST}$: STRAIN ANIS : –||–

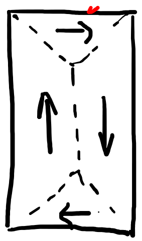
- $\mathcal{E}_{EX-BIAS}$: EXCHANGE BIAS :



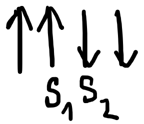
UNIDIRECTIONAL :

$\mathcal{E}_{EX-B} = \int_V K_{EB} \sin\theta \, d^3r$ ↙ mocnina 1

DOMÉNOVÉ STĚNY



→ rychlý skok?



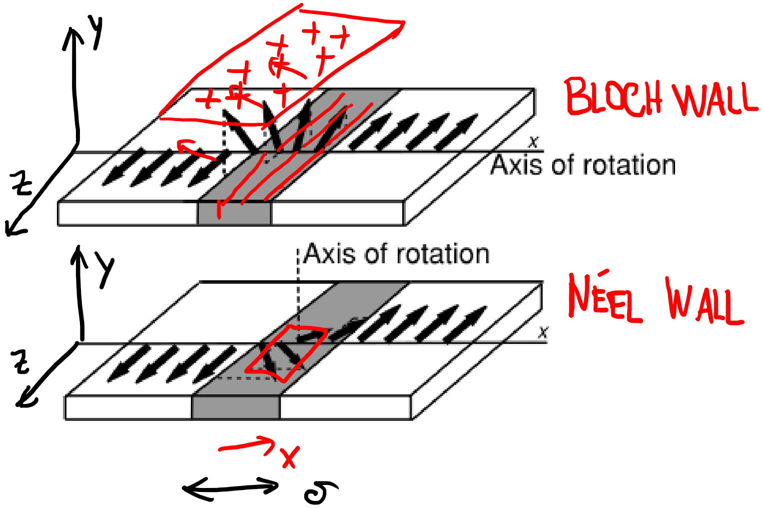
$$E_{DW} = -2J\underbrace{S_1\cdot S_2}_{\cos\theta} = \frac{2JS^2}{a^2} \sim \underline{0.1\ J/m^2}$$

Σ

$\theta = \pi$

mříž. konst

⇒ N kroků na otočku



☺ $\nabla\cdot M = 0$ v objemu $\Rightarrow \rho_m = 0$

☹ $\underline{\underline{\sigma_m \neq 0}}$

} tlusté vrstvy

$$\nabla\cdot M = \underbrace{\frac{\partial M_x}{\partial x}}_{M_x=0} + \underbrace{\frac{\partial M_y}{\partial y} + \frac{\partial M_z}{\partial z}}_{=0 \text{ pro } x} = 0$$

☺ $\sigma_m = 0$

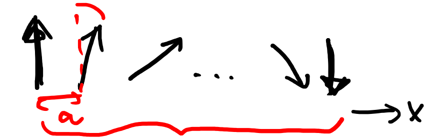
☹ $\nabla\cdot M \neq 0 \Rightarrow \underline{\underline{\rho_m \neq 0}}$

} tenké vrstvy

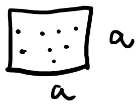
$$\frac{\partial M_x}{\partial x} \neq 0 \qquad \frac{\partial M_y}{\partial y} + \frac{\partial M_z}{\partial z} = 0$$

- ŠÍŘKA DW δ, E_{DW} :

$\theta = \pi/N$



$Na = \delta$



$$E_{DW} = E_{EX}^{LOK} + E_A$$

UNIDIR.

$1-\theta^2/2$

$$E_{EX} = -2JS^2\cos\theta\cdot N\frac{1}{a^2} \sim JS^2\theta^2\frac{N}{a^2} = JS^2\frac{\pi^2}{a^2}\frac{1}{N}$$

$N\to\infty$

$E_{EX}\to 0$

$$E_A = \int_0^\delta k\sin^2\theta\,dx = \left|\begin{matrix}\theta = \pi\, x/\delta \\ d\theta = \pi/\delta\, dx\end{matrix}\right| \cdot \frac{\delta}{\pi}\int_0^\pi k\sin^2\theta\,d\theta = Na\frac{k}{2}$$

$\pi/2\cdot k$

$$E_{DW} = JS^2\frac{\pi^2}{Na^2} + \frac{Nka}{2}$$

DOMÉNOVÉ STĚNY

$$E_{DW} = JS^2 \frac{\pi^2}{Na^2} + \frac{NKa}{2} \rightarrow \frac{\partial E_{DW}}{\partial N} = 0 \Rightarrow 0 = -JS^2 \frac{\pi^2}{N^2a^2} + \frac{Ka}{2}$$

$$N^2 = JS^2\pi^2 \frac{2}{a^2 Ka} \Rightarrow \underbrace{N = S\pi\sqrt{\frac{2J}{Ka}}\,\frac{1}{a}}_{\delta = Na}$$

$$\boxed{Na = \delta = \pi\sqrt{\frac{A}{K}}}$$

$\theta \to 0 \Rightarrow \delta \to \infty$

$\delta \to 0$

$$A = \frac{2JS^2}{a}$$

$$2J = \frac{A}{S^2}a$$

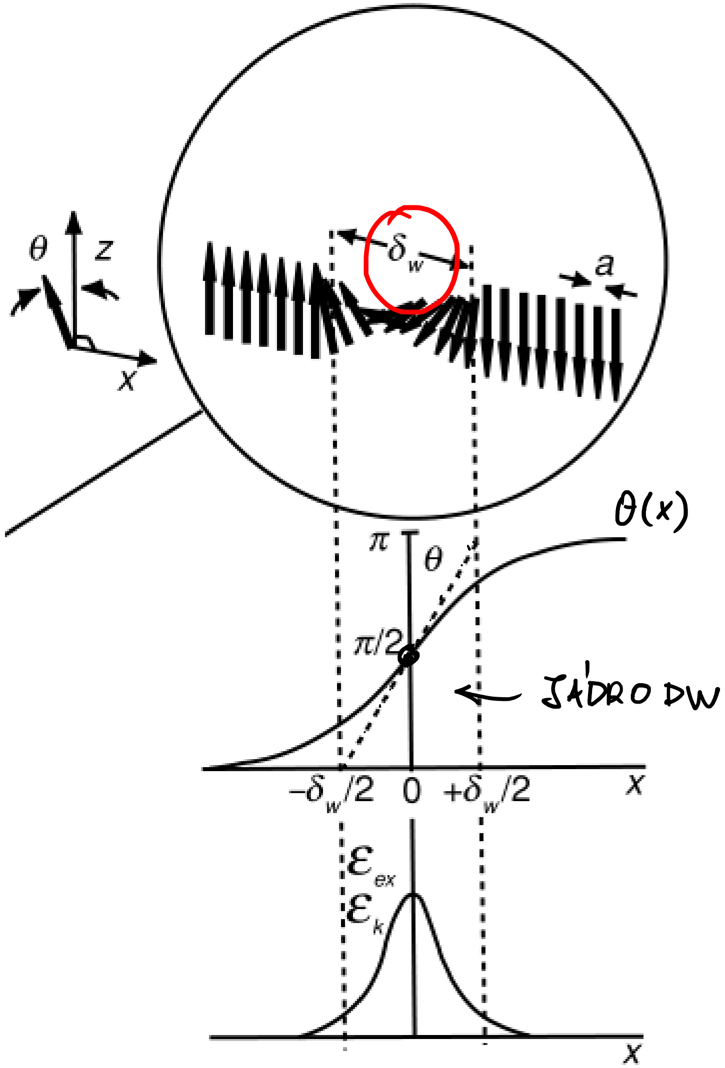
$$\boxed{E_{DW} = \ldots = \pi\sqrt{AK}}$$

DOMÉNOVÉ STĚNY

x realita : $E_{DW} = \int_V \varepsilon_{EX} + \varepsilon_A \longrightarrow$ Euler rce

$\uparrow \cos\theta$ $\quad \nwarrow \sin^2\theta$

$$\theta(x) = 2\,\mathrm{arctg}\left(e^{\pi x/\delta}\right)$$



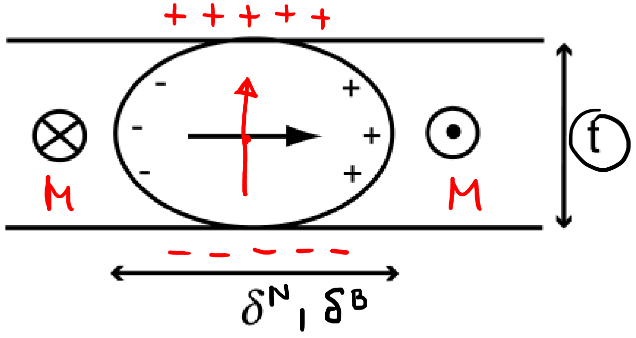
$\uparrow\downarrow \sim 0.1\ \mathrm{J/m^2}$

	M_s (MA m^{-1})	A (pJ m^{-1})	K_1 (kJ m^{-3})	δ_w (nm)	γ_w (mJ m^{-2})
$Ni_{80}Fe_{20}$	0.84	10	0.15	2000	0.01
Fe	1.71	21	48	64	4.1
Co	1.44	31	410	24	14.3
CoPt	0.81	10	4900	4.5	28.0
$Nd_2Fe_{14}B$	1.28	8	4900	3.9	25
$SmCo_5$	0.86	12	17 200	2.6	57.5
CrO_2	0.39	4	25	44.4	1.1
Fe_3O_4	0.48	7	−13	72.8	1.2
$BaFe_{12}O_{19}$	0.38	6	330	13.6	5.6

DOMÉNOVÉ STĚNY

- Néel stěna : $E_{DW}^{N} \sim \sqrt{AK}$

  $\delta^{N} \sim \sqrt{\frac{A}{k}}$



BLOCH W

NÉEL W.

→ [illegible]: válcem

$N_a = \frac{a}{a+b}$

ve směru

energie na 1m²

$$E_D = \mu_0 M_S H_D = \mu_0 M_S^2 N \delta$$

N_t

$$E_N = \underbrace{\frac{A\pi^2}{2\delta} + \frac{k\delta}{2}} + \frac{t}{\delta+t}\,\delta M_S^2 \mu_0$$

N_δ

$$E_B = \frac{A\pi^2}{2\delta} + \frac{k\delta}{2} + \frac{\delta}{\delta+t}\,\delta M_S^2 \mu_0$$

$x = t/\delta$

$$\frac{1}{1+x} \overset{x\sim 0}{\approx} 1-x = 1 - t/\delta$$

$E_N \nearrow$ pro $t \uparrow$ $(\propto (\boxed{t} - t^2/\delta)\,\delta$

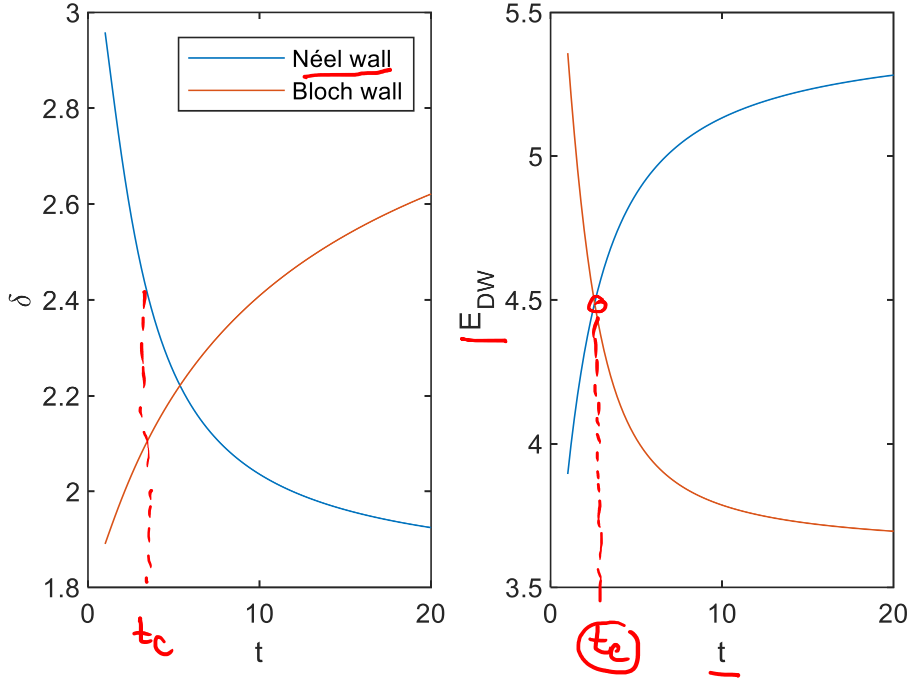
$E_B \searrow$ pro $t \uparrow$ $(\propto (1 - \underline{\underline{t}}/\delta)\,\delta^2)$

DOMÉNOVÉ STĚNY

$$\frac{\partial E_N}{\partial \delta} = 0 \Rightarrow \delta_{MIN} \Rightarrow E_N(t)$$

totéž pro E_B

} numericky Matlab/Octave

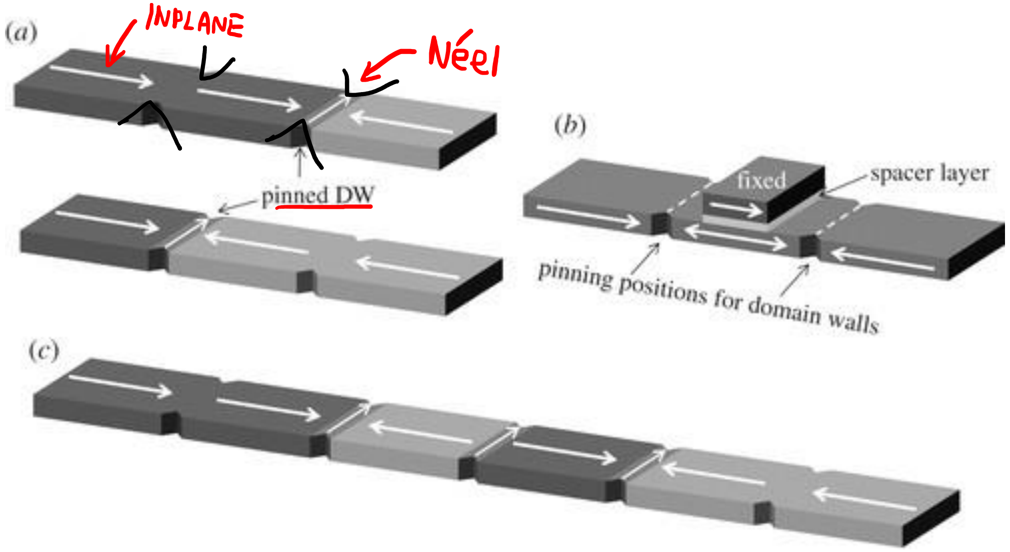


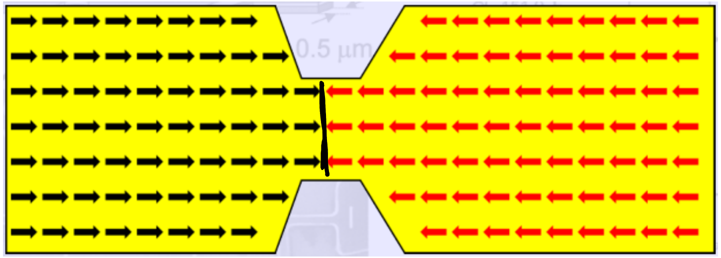
pro

$A = 1$

$K = 1$

→ Redukce E_{DW} snížením plochy → "PINNING"





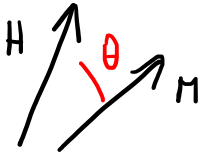
G. Hrkac et al. *Phil. Trans. R. Soc. A.* **369**, 3214 (2011).

MANIPULACE S DOMÉNAMI

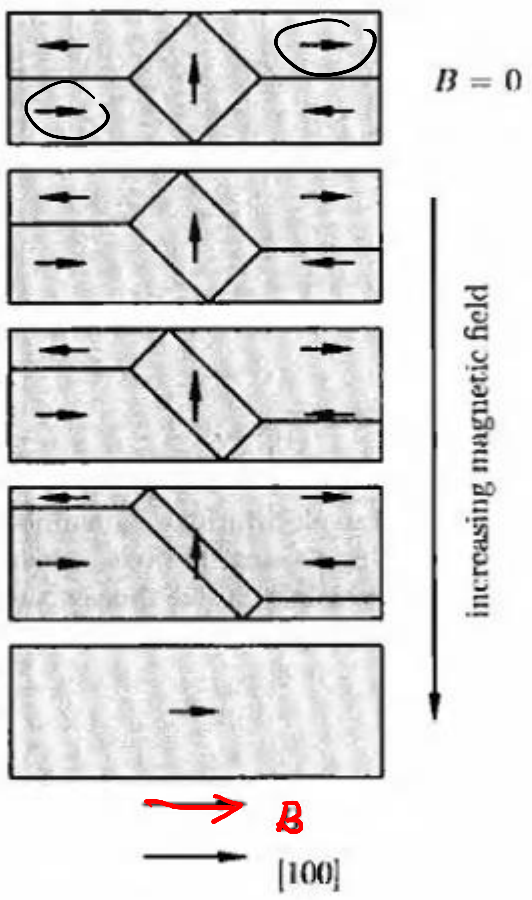
- ZEEMANOVA ENERGIE: $E_z = \int_V -\mu_0 \, M \cdot H \, d^3r$

① KOHERENTNÍ ROTACE 1 DOMÉNY

② POHYB DOMÉNOVÉ STĚNY



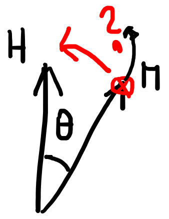
$E_z \propto -\cos\theta$



KOHERENTNÍ ROTACE DOMÉNY

Zeeman :

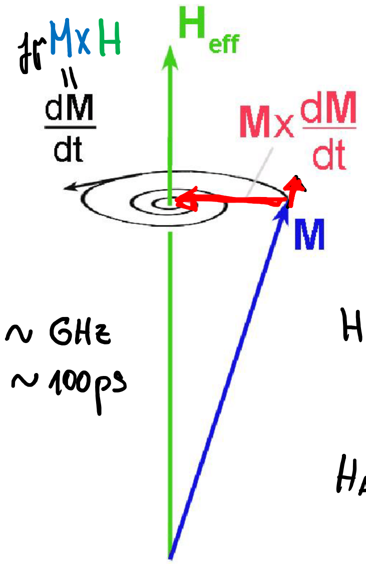
$$E = \int -\mu_0 MH\cos\theta$$



$\frac{\partial}{\partial r}$

NE! F = žádná síla v homog. H směru = 0

Γ (= H × M homog.)



~ GHz
~ 100ps

LLG :

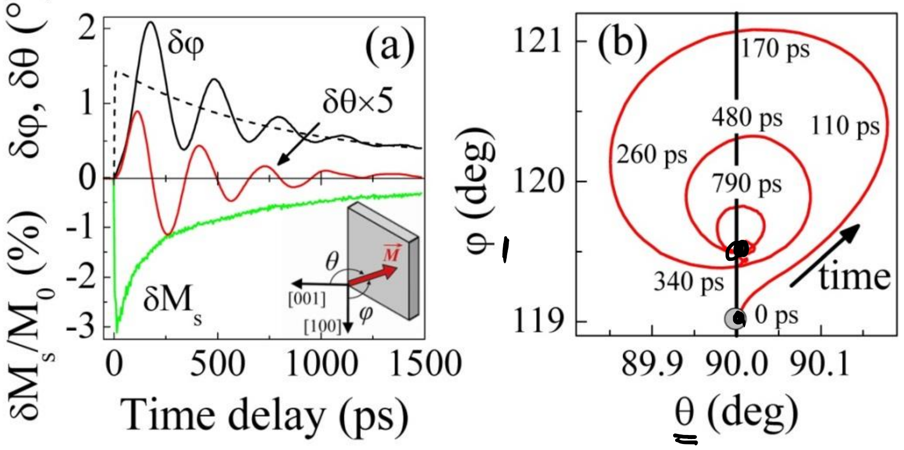
$$\frac{\partial M}{\partial t} = \gamma\mu_0 M \times H - \frac{\alpha}{M_s} M \times \underset{\sim}{\frac{dM}{dt}}$$

Damping

$$H_{eff} \sim \underbrace{H_A}_{} \sim \frac{\partial E_A}{\partial M}$$

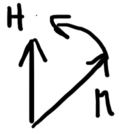
$$H_A' \rightarrow H_A''$$

MAGNETO-OPTICKÉ POZOROVÁNÍ



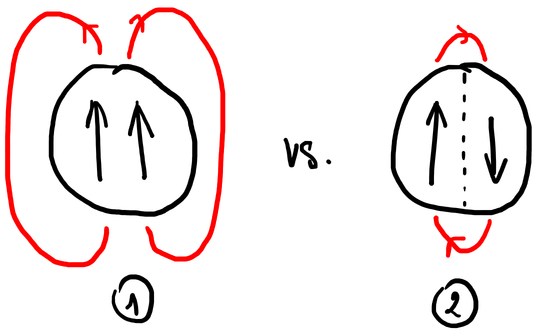
Tesarova et al., *Appl. Phys. Lett.* **100**, 102403 (2012).

→ MAKROSKOP. ČASY :



KOHERENTNÍ ROTACE DOMÉNY

- 1 DOMÉNA ?

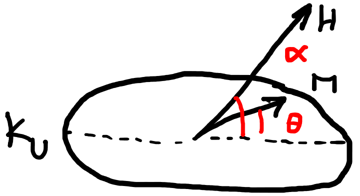


$$E_D^{①} = \frac{1}{2}\mu_0 N M_S^2 V \qquad N = 1/3 \qquad V = \frac{4}{3}\pi r^3$$

$$E_D^{②} = \frac{1}{2}E_D^{(1)} + \pi\sqrt{AK}\,\pi r^2 = \frac{1}{9}\pi r^3 \mu_0 M_S^2 - \pi^2 r^2 \sqrt{AK} \overset{!}{=} 0$$

$$\Rightarrow r_c = \frac{9\pi\sqrt{AK}}{\mu_0 M_S^2} \sim \frac{10\sqrt{10^{-11}\,10^{7}}}{10^{-6}\,(10^{6})^2} \approx \underline{100\ nm}\,.$$

- STONER–WOHLFARTHŮV MODEL:



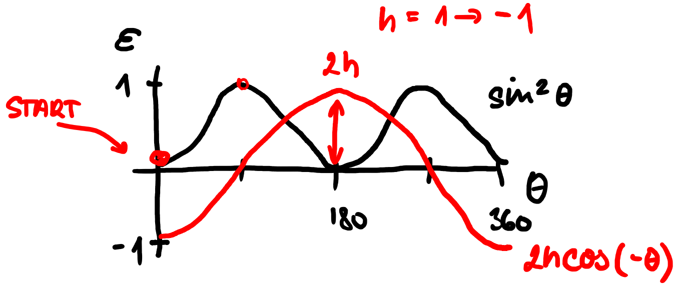
$$E_{TOT} = K_U V \sin^2\theta - V\mu_0 H M_S \cos(\alpha-\theta)$$

$$\varepsilon = \frac{E_{TOT}}{VK_u} = \underbrace{\frac{1}{2} - \frac{1}{2}\cos 2\theta} - \underbrace{2h\cos(\alpha-\theta)}$$

$$h = \frac{\mu_0 H M_S}{VK_u}$$

$$\frac{\partial\varepsilon}{\partial\theta} = \sin 2\theta - 2h\sin(\alpha-\theta) \overset{!}{=} 0 \quad (1)$$

$$\frac{\partial^2\varepsilon}{\partial\theta^2} = 2\cos 2\theta + 2h\cos(\alpha-\theta) \overset{!}{=} 0 \quad (2)$$



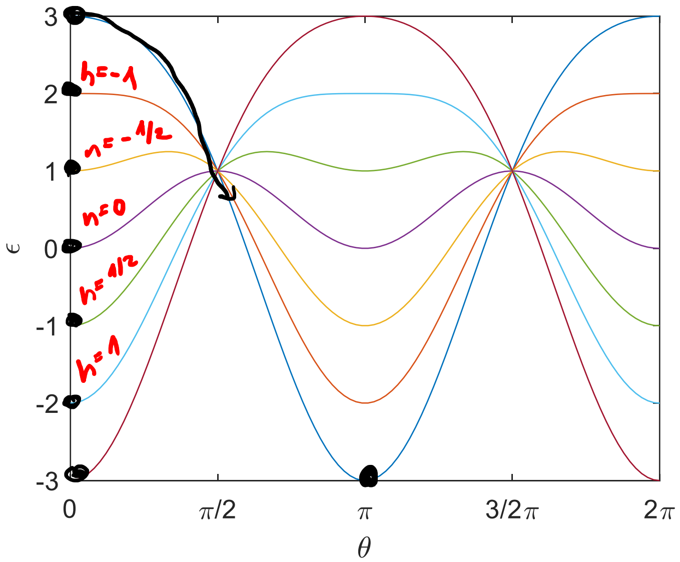
$\underline{\alpha = 0°}$

(1) $\theta = 0°$ pro $\forall$ h ale také pro π

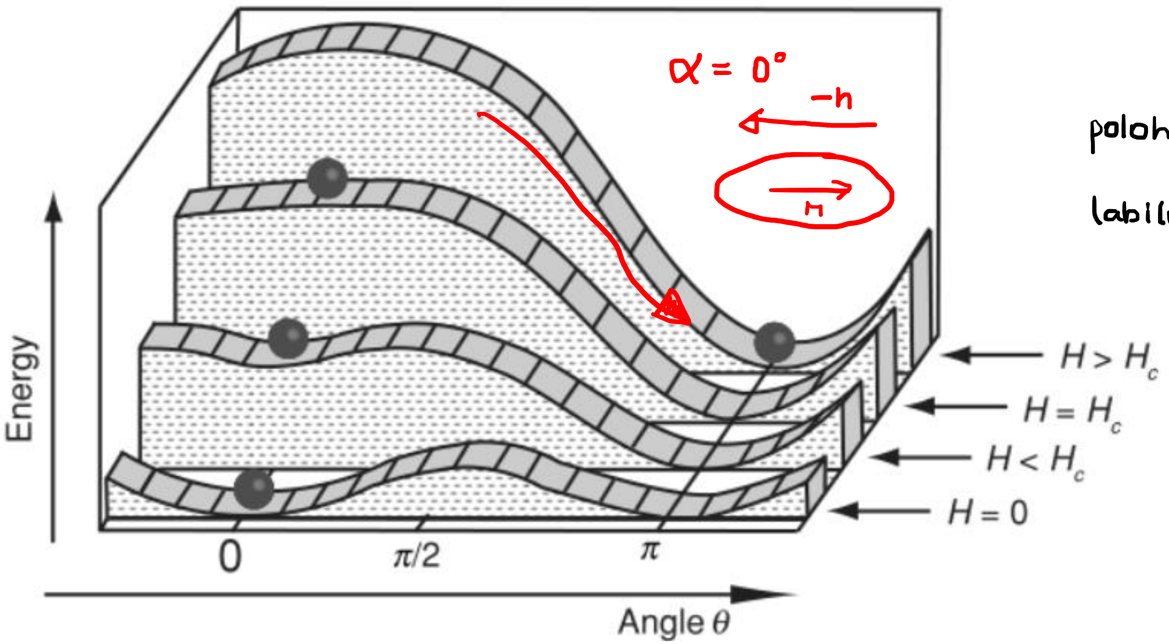
(2) $\theta = 0°$? $\quad 2 + 2h = 0$

$$\underbrace{h = -1}$$

COERC. FIELD



KOHERENTNÍ ROTACE DOMÉNY



$$\varepsilon = \frac{E_{TOT}}{VK_u} = \frac{1}{2} - \frac{1}{2}\cos 2\theta - 2h\cos(\alpha-\theta)$$

poloha extr. $\frac{\partial\varepsilon}{\partial\theta} = \sin 2\theta - 2h\sin(\alpha-\theta) \overset{!}{=} 0$ (1)

labilita: $\frac{\partial^2\varepsilon}{\partial\theta^2} = 2\cos 2\theta + 2h\cos(\alpha-\theta) \overset{!}{=} 0$ (2)

$\underline{\alpha = 90°}$

(1) = 0 $\quad \sin 2\theta - 2h\cos\theta = 0$

$2\cos\theta\sin\theta - 2h\cos\theta = 0$

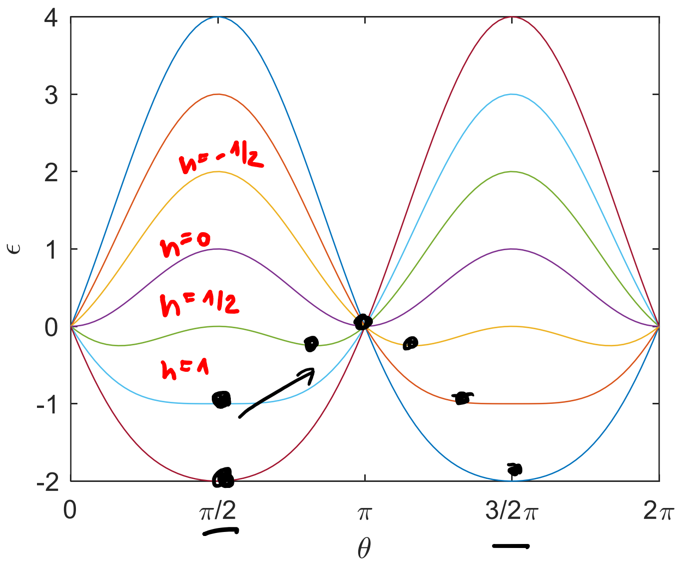
$\underline{\sin\theta = h}$

$\theta \sim h$

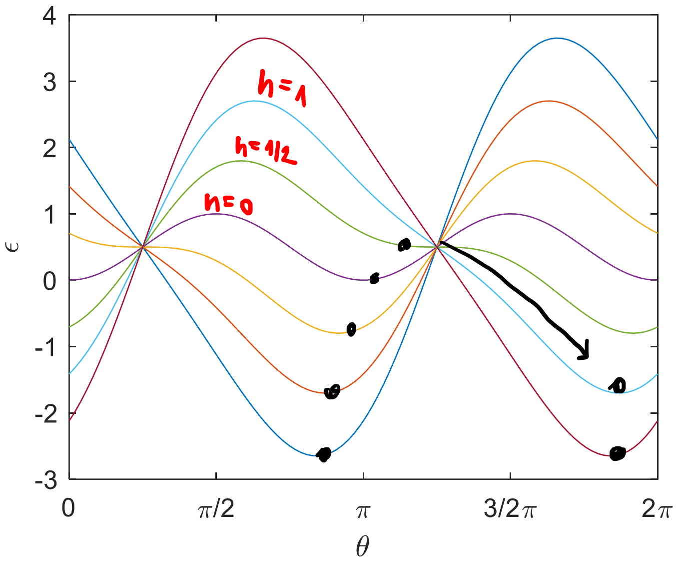
$h < 1$

(2) = 0 $\quad 2\cos 2\theta + 2h\sin\theta \overset{!}{=} 0$

$\underbrace{\cos^2\theta - \cancel{\sin^2\theta} + \cancel{\sin^2\theta}} \geqq 0$

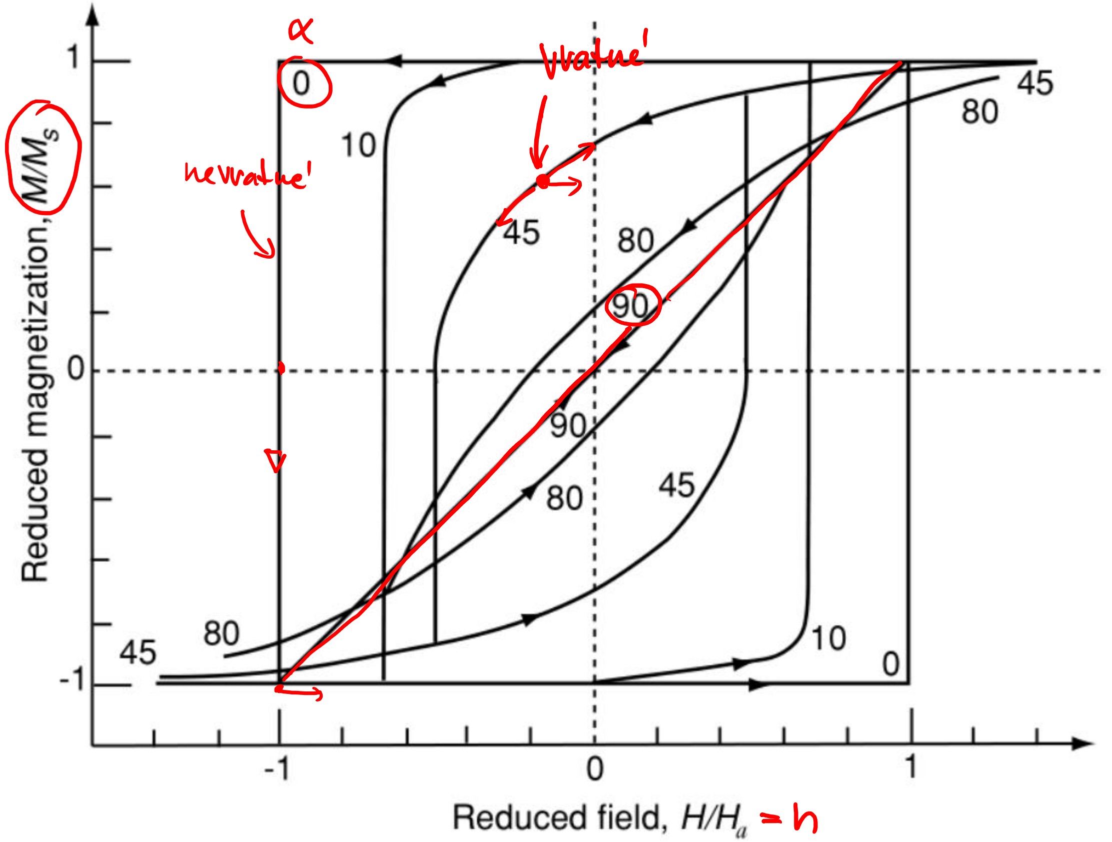


KOHERENTNÍ ROTACE DOMÉNY



$\alpha = -\pi/4$ něco mezi

$$M_{\parallel} = \frac{M}{M_s} \cos(\alpha - \overset{\sin\theta}{\theta})$$



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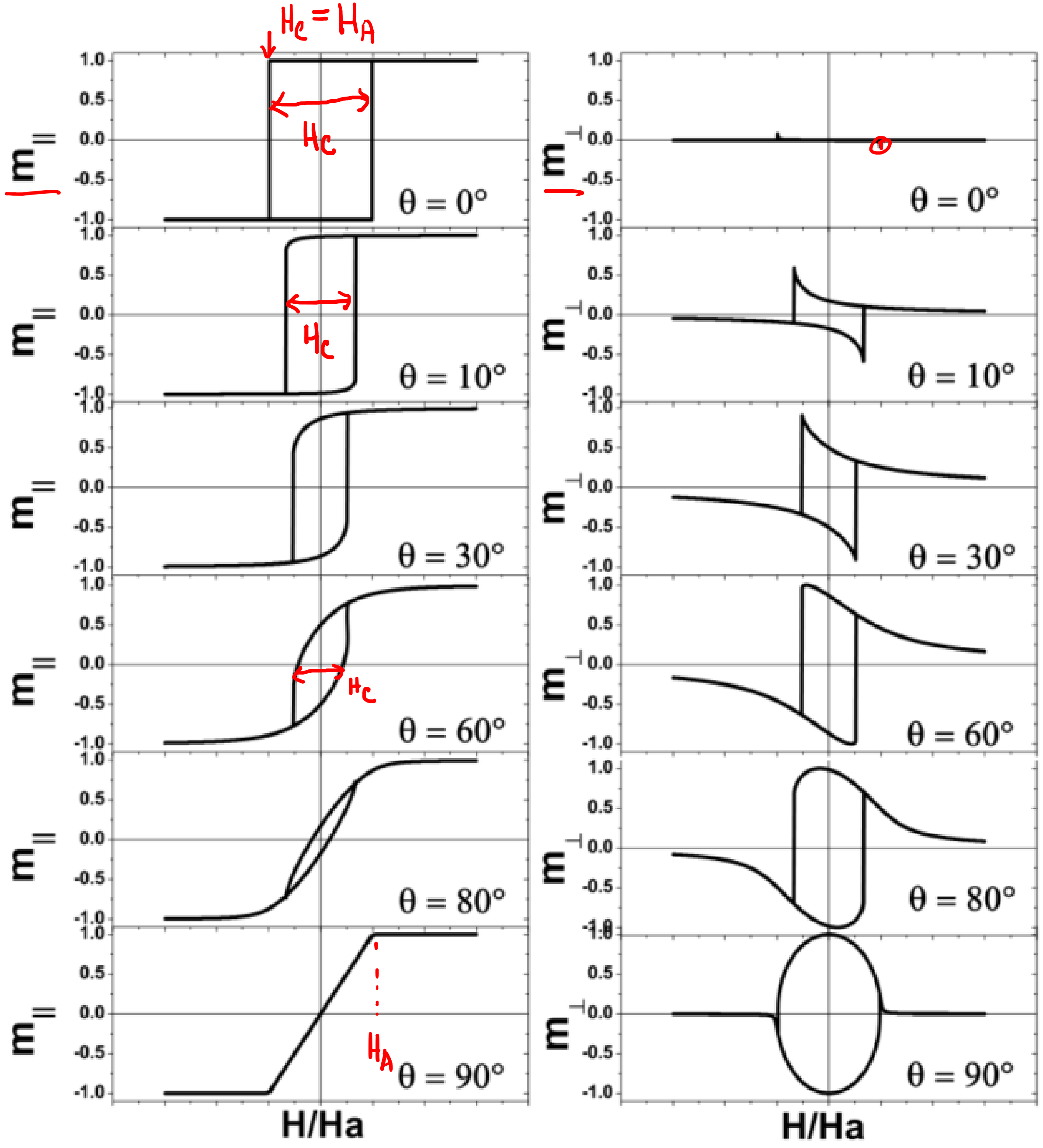
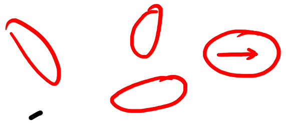
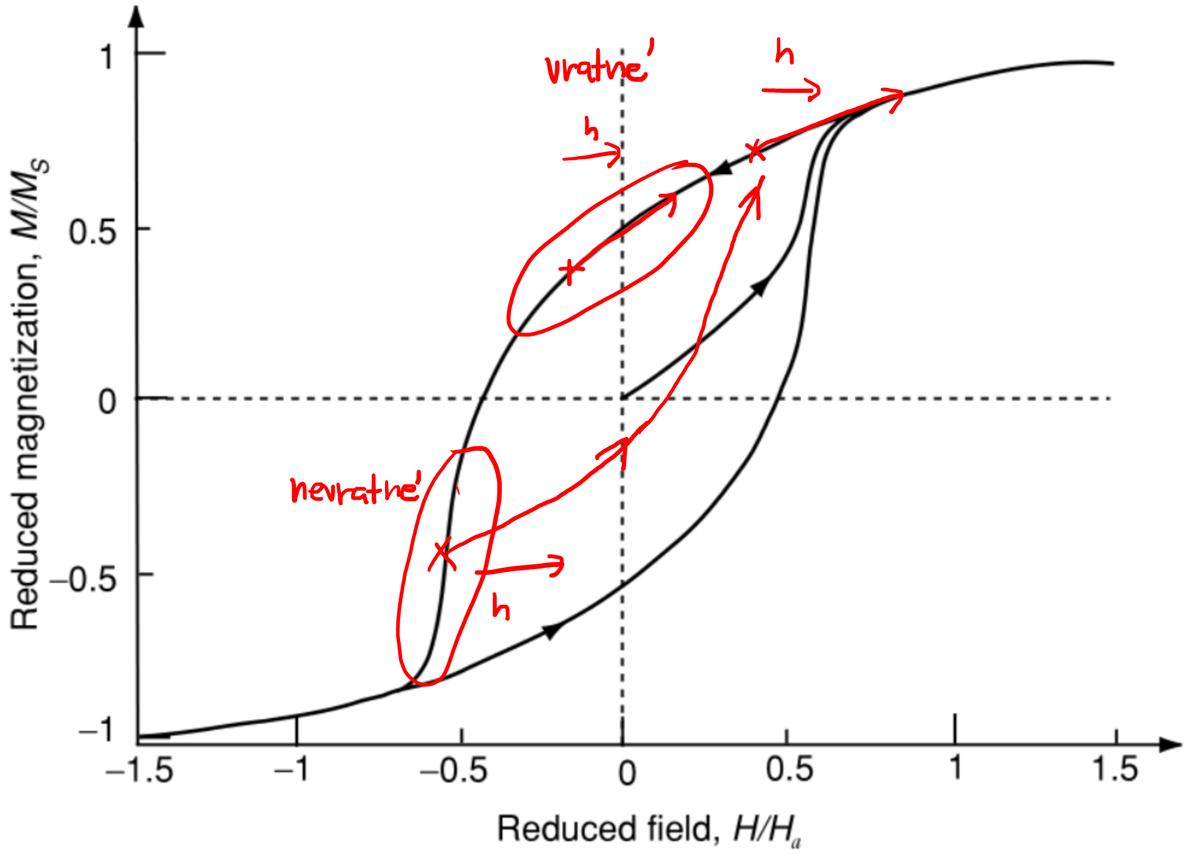


Radu F., Zabel H. (2008) Exchange Bias Effect of Ferro-/Antiferromagnetic Heterostructures. Springer Tracts in Modern Physics

KOHERENTNÍ ROTACE DOMÉNY

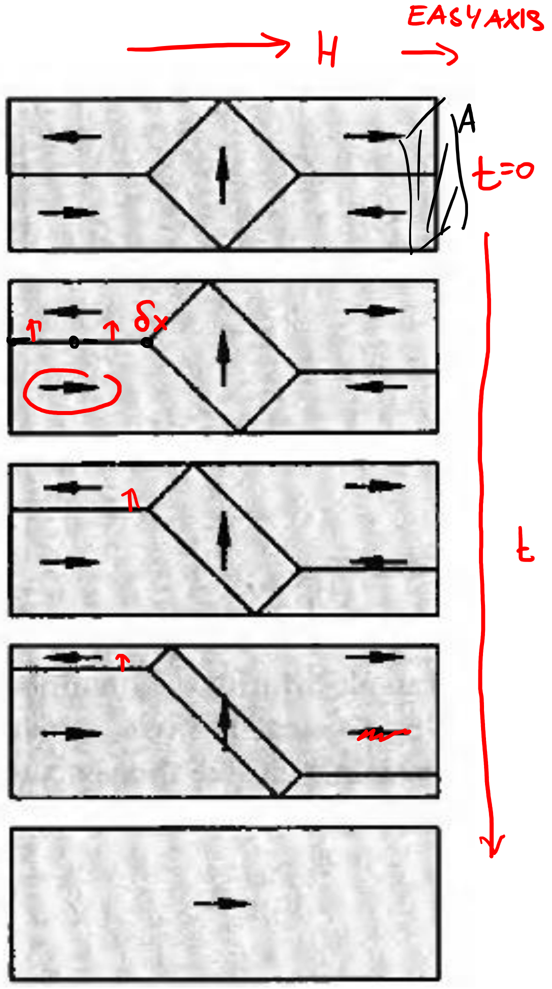


NÁHODNĚ ORIENTOVANÉ KU PRO MNOHO DOMÉN (POLYKRYSTAL)



POHYB DOMÉNOVÉ STĚNY (DOMAIN WALL MOTION = DWM)

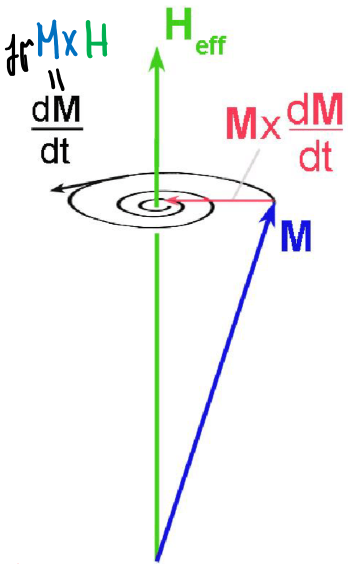
② - Pomocí B-POLE



Blundell.

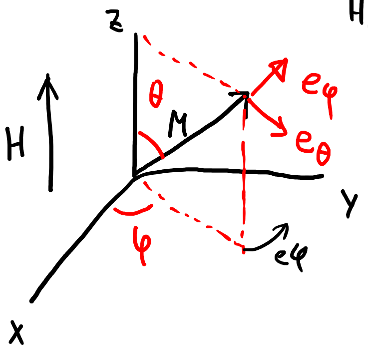
Při pohybu o δx $\delta E_z = 2\mu_0 M H \underline{\delta x} A$

- rychlost: $\boxed{v} = \eta\,(H - H_{DEPINNING})$



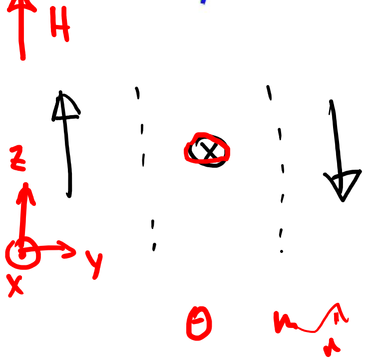
$$\text{LLG}: \boxed{\frac{\partial M}{\partial t} = \gamma \overbrace{H_{EF} \times M}^{\Gamma} + \overbrace{\frac{\alpha}{\underline{M_S}} M \times \frac{dM}{dt}}^{\text{Damping}} + \dots}$$

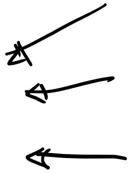
$H_{EF} = \underline{\underline{H}} + \underline{\underline{H_D}}$ ← na domén. stěně



$$\dot{\theta} = -\frac{\gamma}{M_S}\Gamma_\theta = \frac{\partial M}{\partial t}$$

$$\dot{\varphi} = -\frac{\gamma}{M_S}\Gamma_\varphi = \frac{\partial M}{\partial t}$$





$\Gamma_H = M \times H$

$\Gamma_{Hd} = M \times H_D$

$\Gamma_{H\alpha} = M \times H_\alpha = M \times \frac{\alpha}{\underline{\gamma} M_S}\frac{\partial M}{\partial t}$

$\theta = \pi/2$ → střed DW

POHYB DOMÉNOVÉ STĚNY (DOMAIN WALL MOTION = DWM)

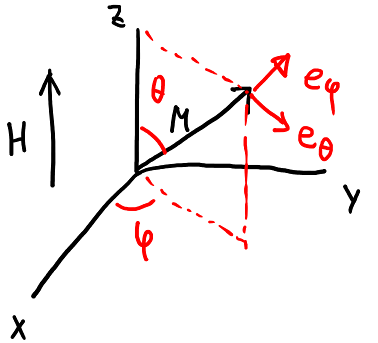
→ do $\begin{pmatrix}\theta\\ \varphi\end{pmatrix}$:

$$\Gamma_H = \begin{pmatrix} 0 \\ -M_S \sin\theta \end{pmatrix} H$$

$$\Gamma_{H_D} = \begin{pmatrix} [N_y - N_x] \sin\theta \sin\varphi \cos\varphi \\ [N_z - N_y \sin^2\varphi - N_x \cos^2\varphi] \sin\theta \cos\theta \end{pmatrix} 4\pi M_S^2$$

$$\Gamma_{H\alpha} = \begin{pmatrix} \dot\varphi \sin\theta \\ -\dot\theta \end{pmatrix} \frac{\alpha M_S}{\gamma}$$

$$\dot\theta = -\frac{\gamma}{M_S}\Gamma_\theta$$



$\Gamma_\theta = + \dots +$

steady motion

$$\Gamma_\varphi = + \dots + = \underbrace{0 = \dot\varphi}$$

$\theta = \pi/2$ - střed PW

$\dot\varphi = 0$

$$\Gamma_\varphi = 0 = -M_S H - \frac{\alpha M_S}{\gamma}\dot\theta = -M_S H + \alpha\Gamma_\theta = -M_S H + 4\pi M_S^2 (N_y - N_x) \sin\varphi\cos\varphi \cdot \alpha \overset{!}{=} 0$$

$$\Rightarrow \underbrace{\sin 2\varphi = \frac{H}{2\pi M_S (N_y - N_x)\alpha}}$$

$H \leq 2\pi\alpha M_S (N_y - N_x) = H_W$ Walker field

promalé φ: $\varphi \propto H$

$$v \propto \dot\theta = -\gamma 4\pi M_S (N_y - N_x) \cos\varphi \sin\varphi$$

max v … $\varphi = \pi/4$

POHYB DOMÉNOVÉ STĚNY (DOMAIN WALL MOTION = DWM)

pro $H \geq H_W$: $\dot{\varphi} \neq 0$ → precesní pohyb $\varphi, \dot{\theta}, \Gamma_\theta, v$

↕

$M_s H \gg \frac{\alpha M_s}{\gamma}\dot{\theta}$

$\Gamma_H \gg \Gamma_\theta$

precese

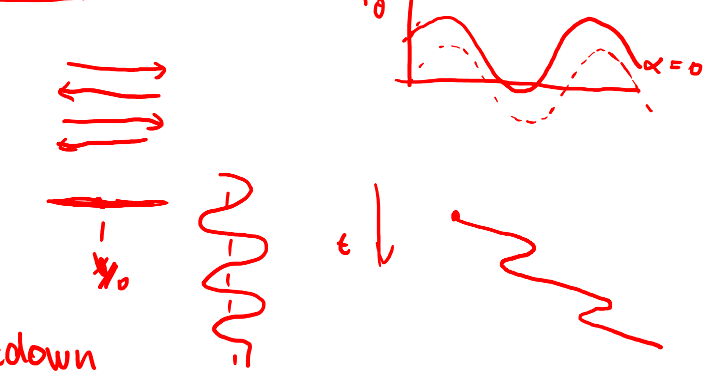
damping

φ lineárně narůstá s časem

$$v \propto \Gamma_\theta = \underbrace{2\pi M_s (N_y - N_x)\sin 2\varphi} + \underbrace{\frac{\alpha M_s}{\gamma}\dot{\varphi}}$$

konst.

$\boxed{\alpha = 0}$

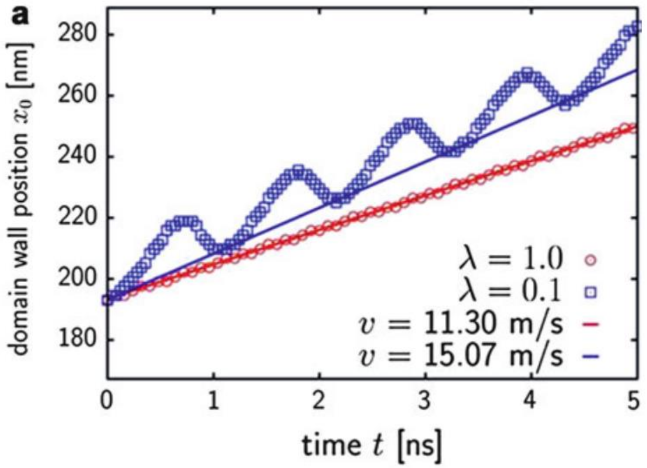


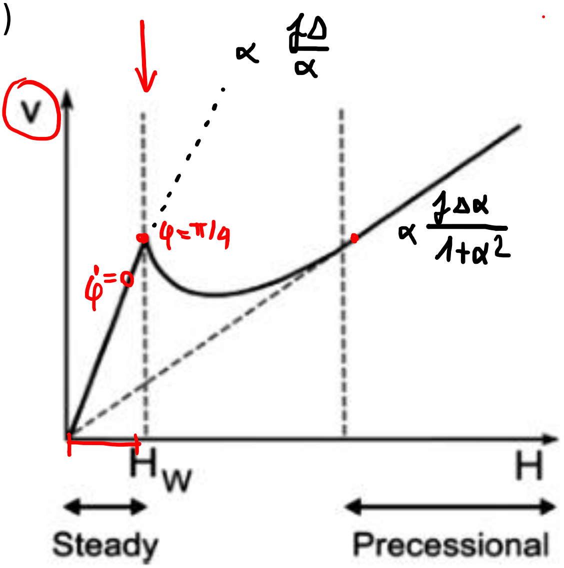
$\langle \Gamma_\theta \rangle_t \neq 0$

$\alpha \neq 0$

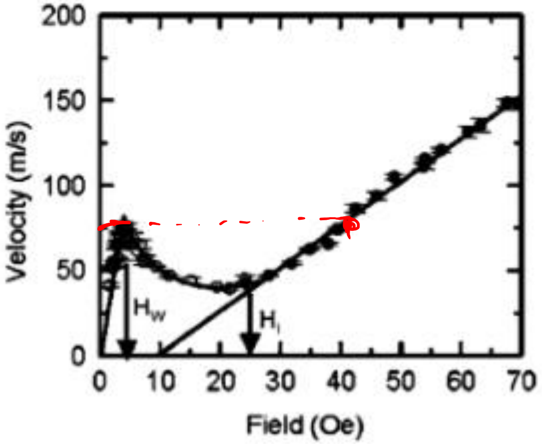
Walker breakdown

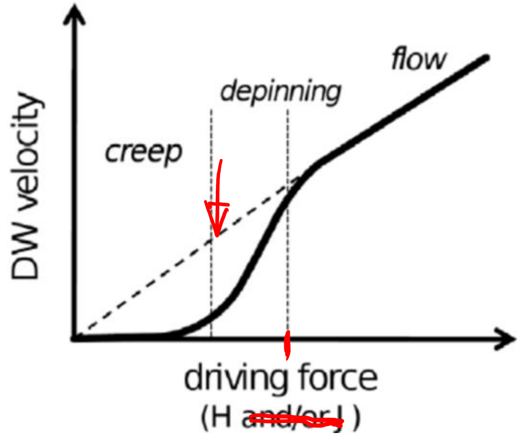
Hinzke et al. *Phys. Rev. Lett.* **107**, 027205 (2011)





Beach et al., *Nat. Mat.* **4**, 741 (2005).





POHYB DOMÉNOVÉ STĚNY (DOMAIN WALL MOTION = DWM)

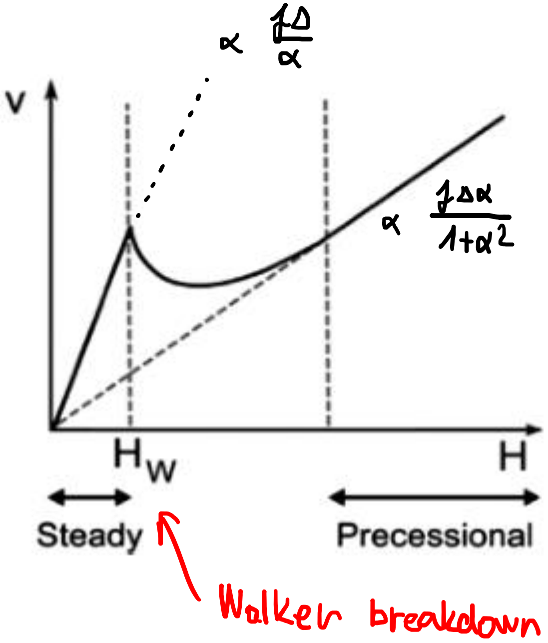
Hinzke et al. *Phys. Rev. Lett.* **107**, 027205 (2011)

$\propto \frac{\gamma\Delta}{\alpha}$

$\propto$

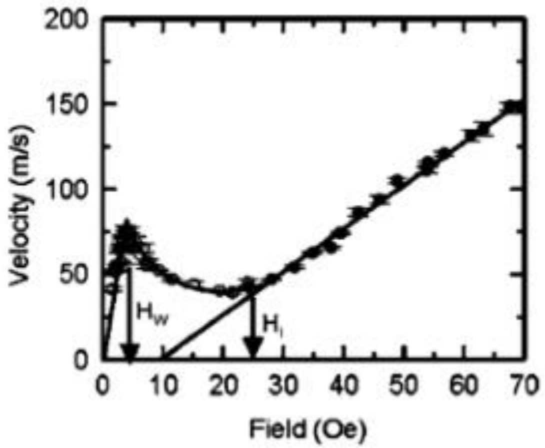
Walker breakdown

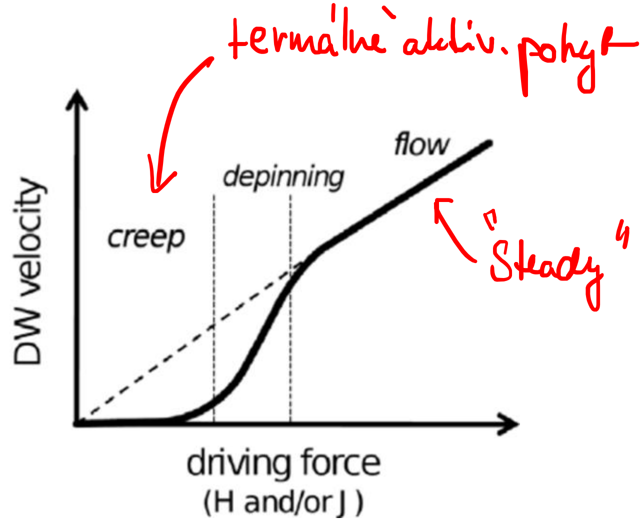
$H_W \sim \alpha M_s$



$H_W \sim \alpha M_s$

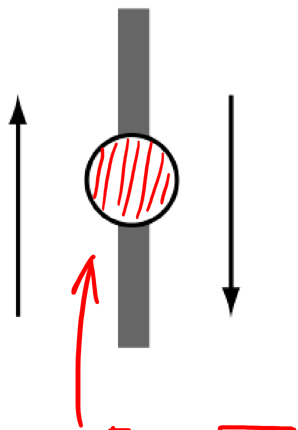
Beach et al., *Nat. Mat.* **4**, 741 (2005).





POHYB DOMÉNOVÉ STĚNY (DOMAIN WALL MOTION = DWM)

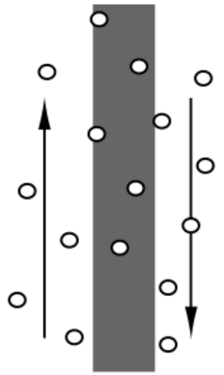
STRONG PINNING

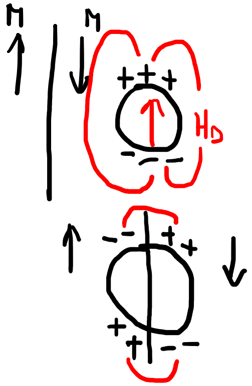


$E_{DW} \propto \sqrt{AK}$

- Lokální změna A, K
- nebo zkrácení stěny
- menší demag. energ. na poruše

WEAK PINNING

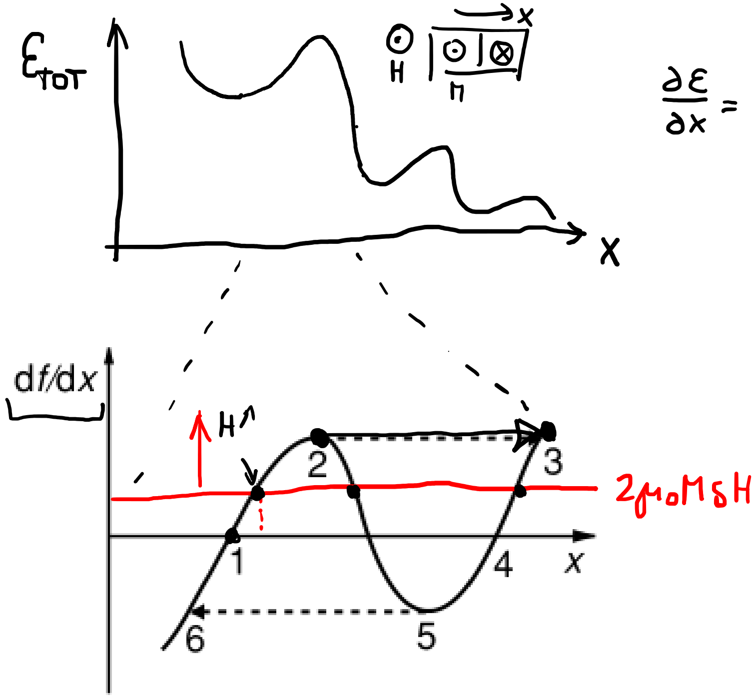


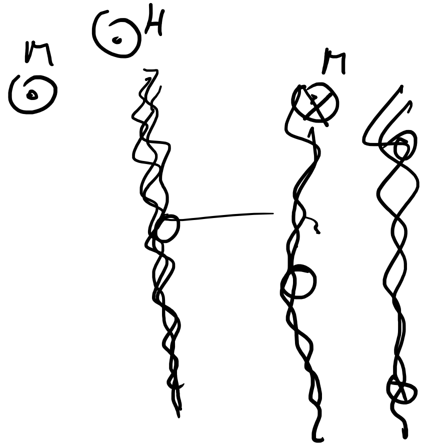


CELKOVÝ POHYB DOMÉNY :

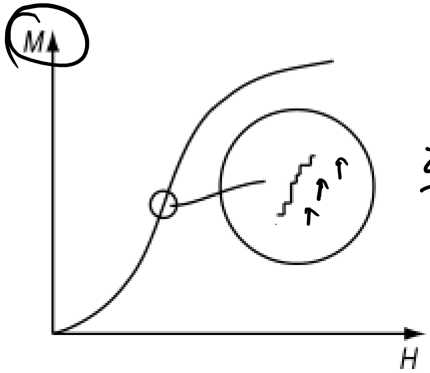
$$\varepsilon_{TOT} = \underbrace{F(x)} - \overset{\text{Zeeman}}{2\mu_0 M_s H \underline{\underline{x}}}$$

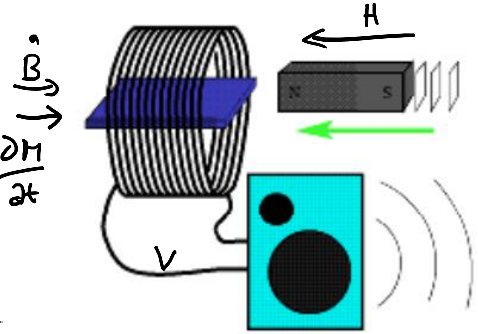
$$\frac{\partial \varepsilon}{\partial x} = \underbrace{\frac{\partial F}{\partial x}} - \underbrace{2\mu_0 M_s H} = 0$$

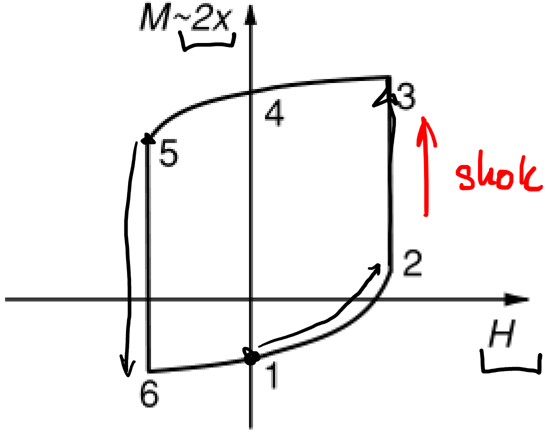




⇒ BARKHAUSEN JUMPS





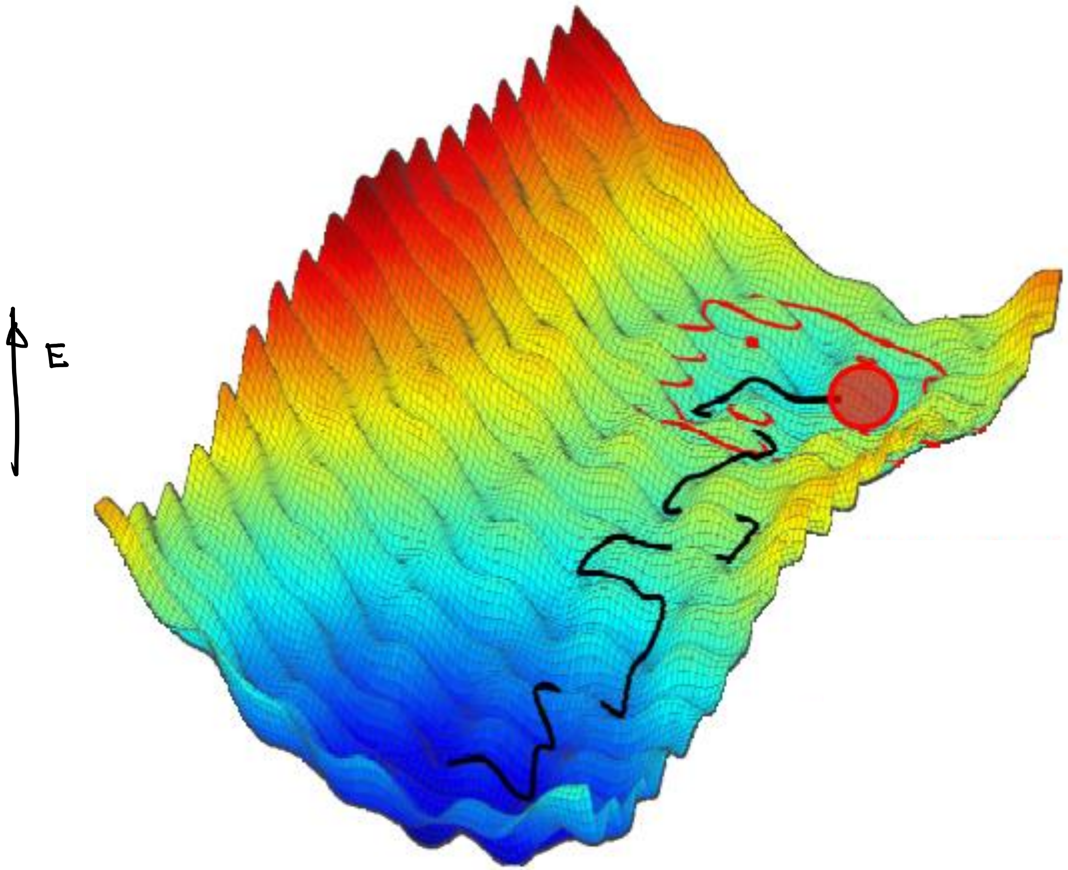


skok v x ⇒ skok v M

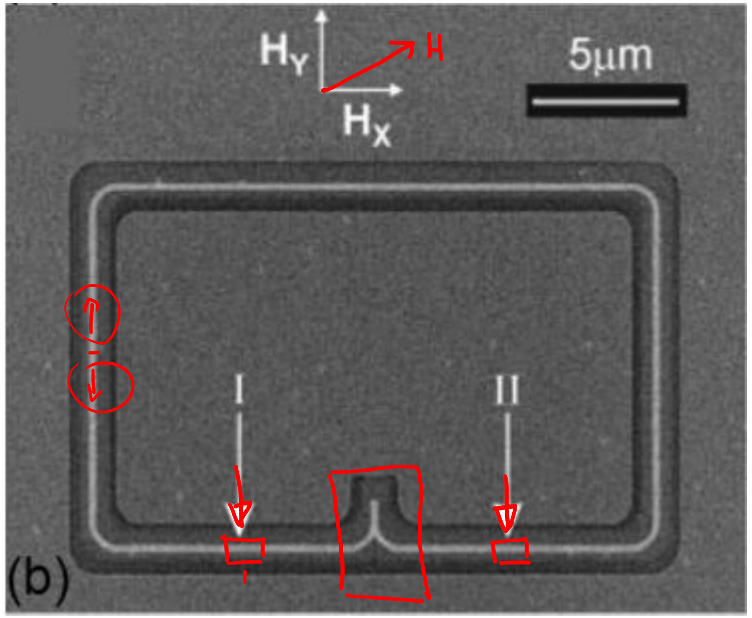
nevratný proces

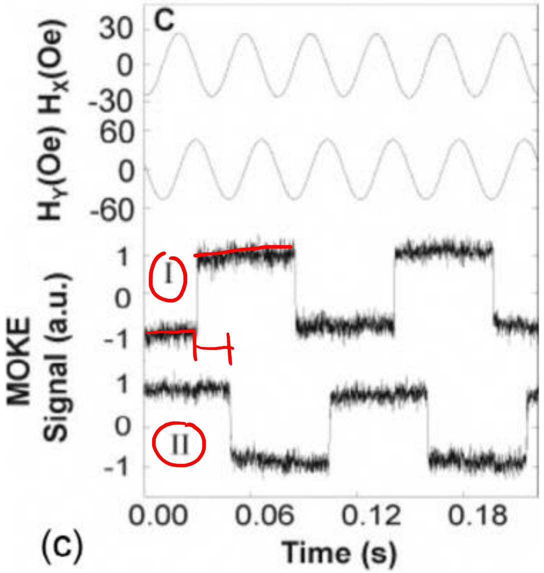
(stejně jako u STONER-W modelu)

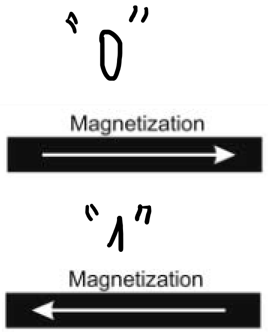
POHYB DOMÉNOVÉ STĚNY (DOMAIN WALL MOTION = DWM)

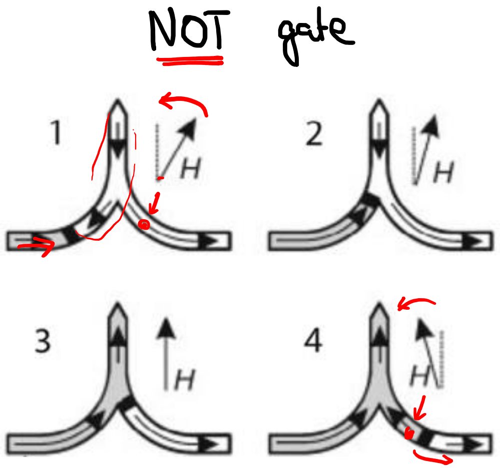


PROCESOR NA DOMÉNOVÝCH STĚNÁCH

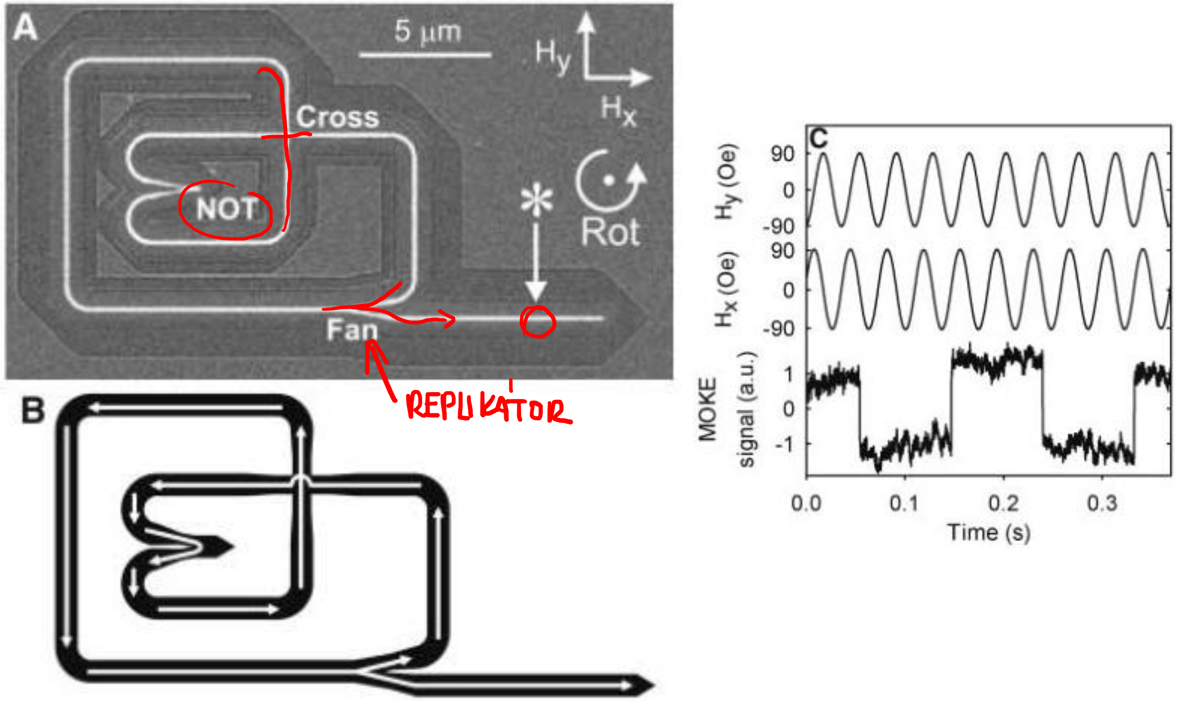




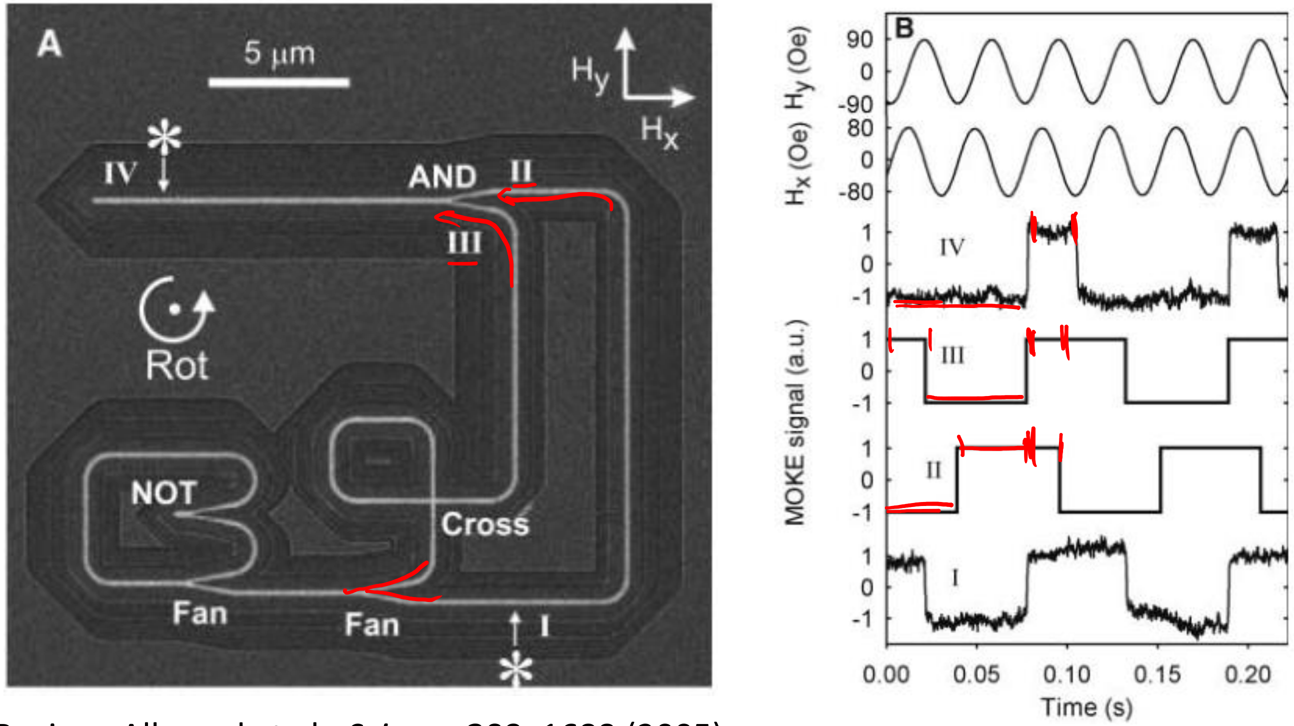




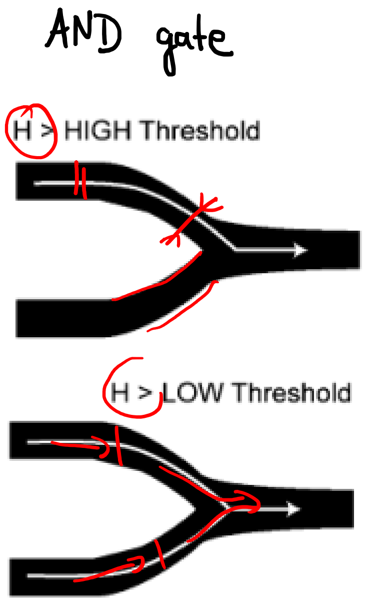
Review: Allwood et al., *Science* **309**, 1688 (2005).



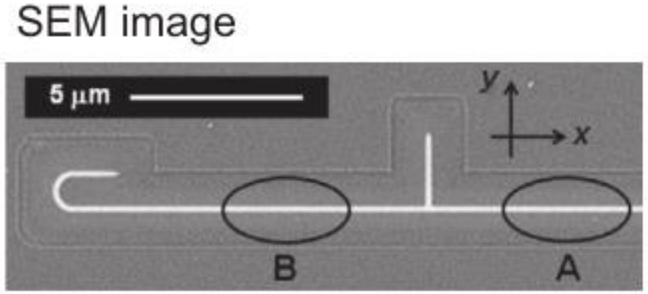
PROCESOR NA DOMĒNOVÝCH STĚNÁCH

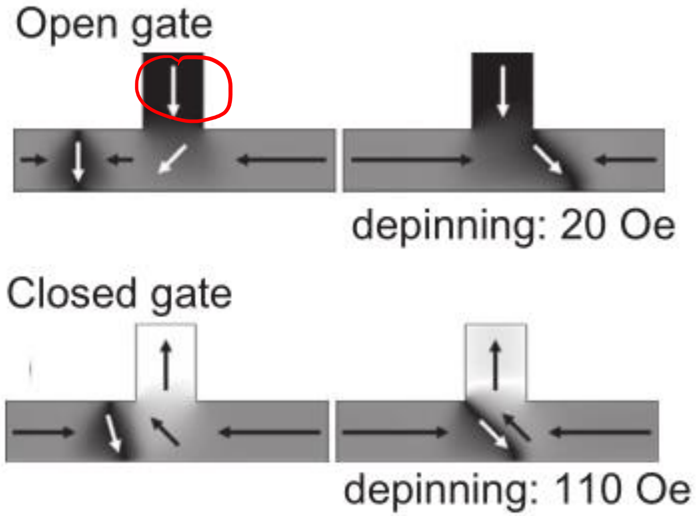


Review: Allwood et al., *Science* **309**, 1688 (2005).



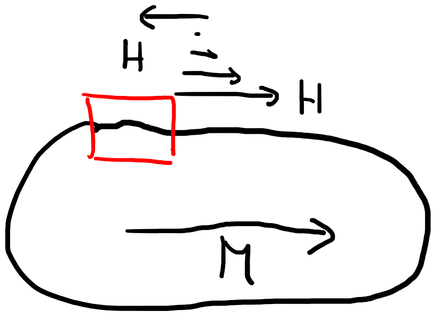
Klein et al., *IEEE* **42**, 2754 (2006).





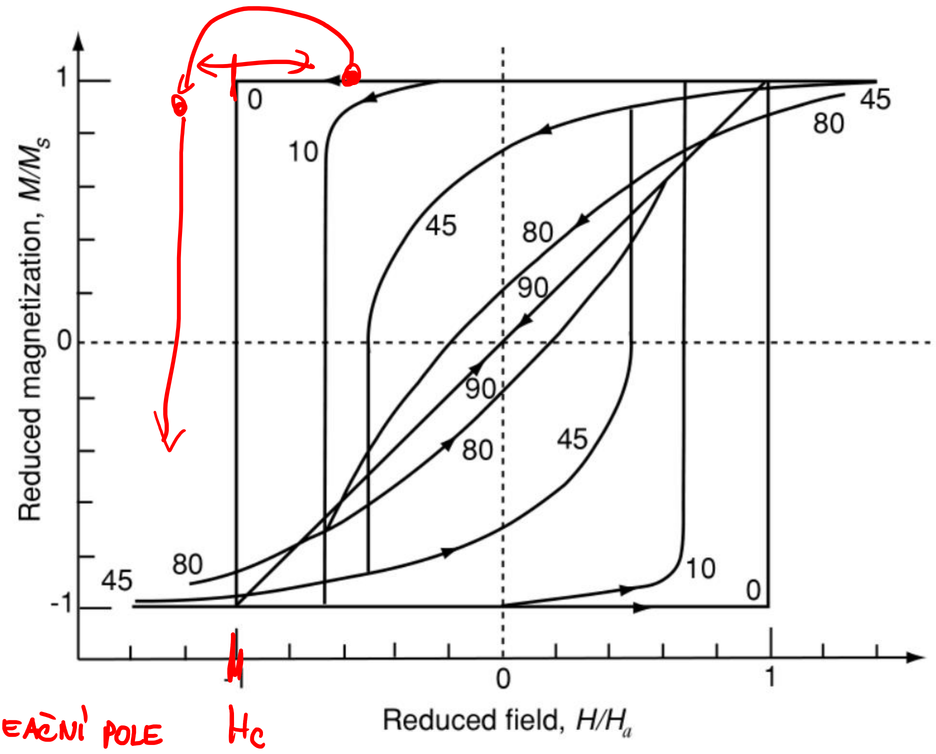
Petit et al., *APL* **93**, 163108 (2008).

NUKLEACE DOMĚN

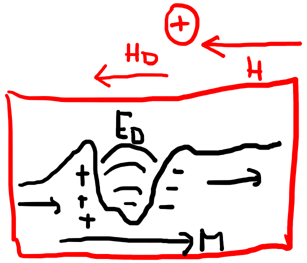


$K_1 \sin^2\theta$ kryst. shape

$$H_c = \frac{2K_u}{\mu_0 M_s} \qquad K_u = \underbrace{K_1}_{} - \frac{1}{2}\mu_0 M_s \underbrace{N}_{}$$

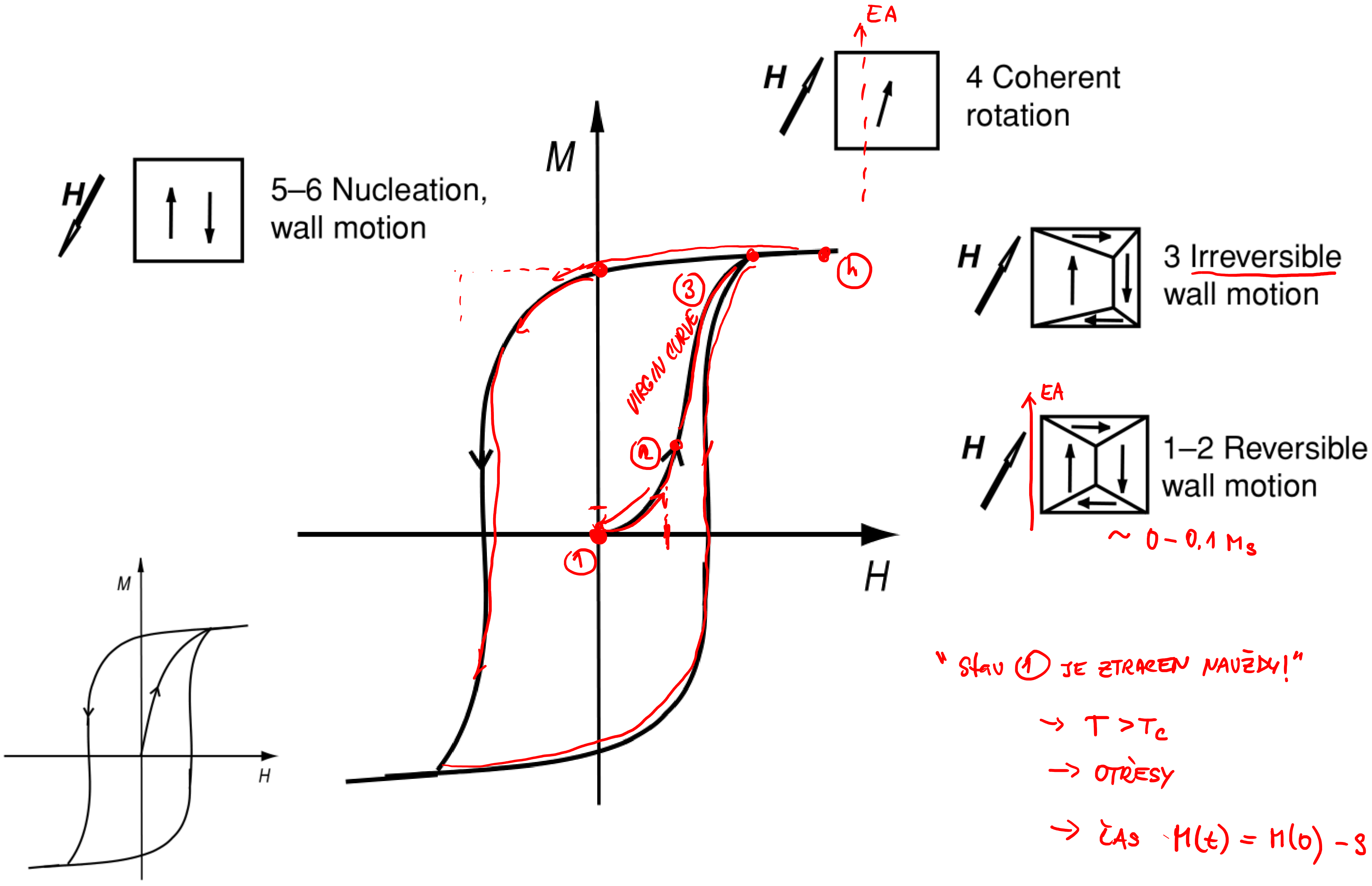


NUKLEAČNÍ POLE



tato část se přepne při $H_N < H_c$

REÁLNÉ HYSTEREZNÍ KŘIVKY



4 Coherent rotation

5–6 Nucleation, wall motion

3 Irreversible wall motion

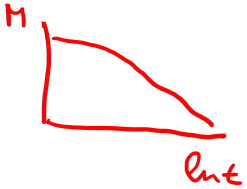
1–2 Reversible wall motion

„STAV ① JE ZTRACEN NAVŽDY!“

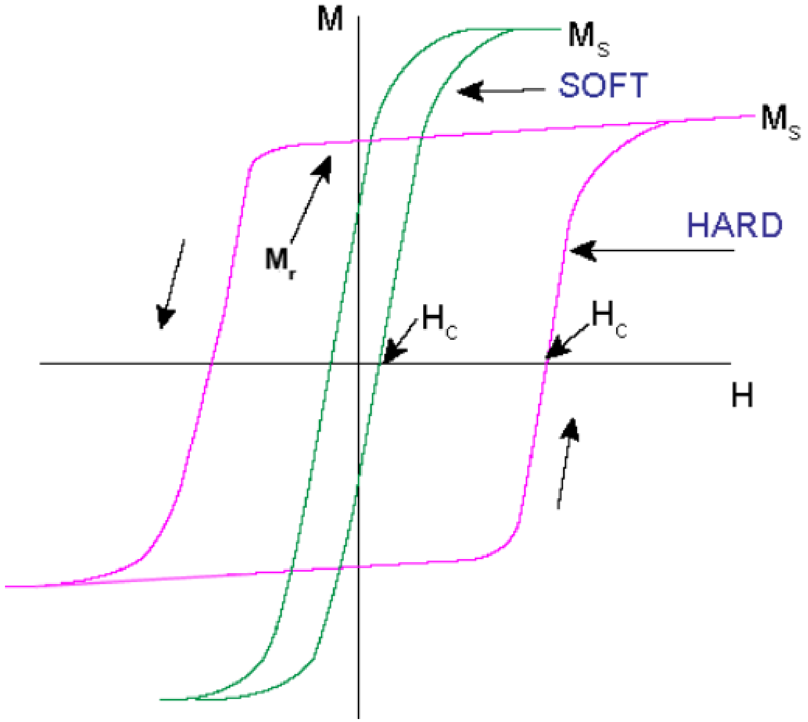
→ $T > T_c$

→ OTŘESY

→ ČAS $M(t) = M(0) - S \ln \frac{t}{\tau}$



REÁLNÉ HYSTEREZNÍ KŘIVKY



MĚKKÉ : MG. STÍNĚNÍ
Trafa
SENSORY

TVRDÉ : HARD DISKY
MOTORY
PERM. MAGNETY