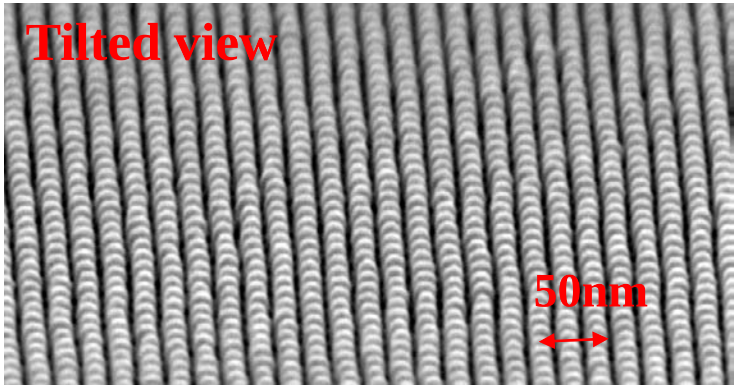
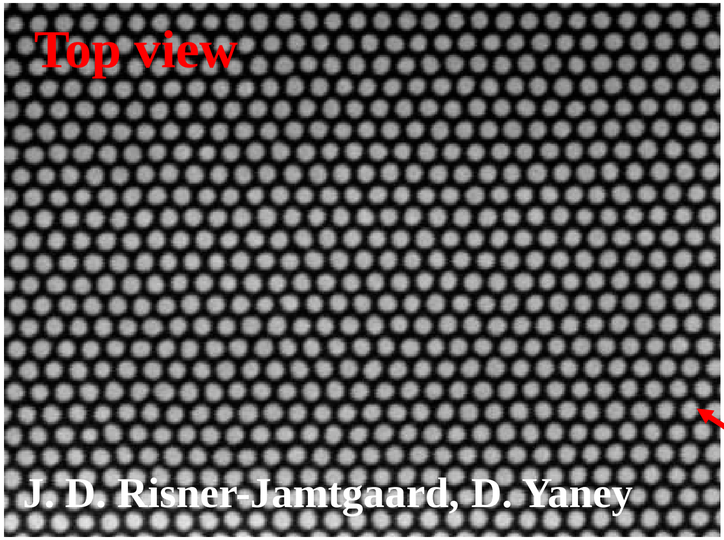
New schemes for bit pattern media recording





Magnetic bit

T. Hauet

Université de Lorraine, Institut Jean Lamour (Nancy)

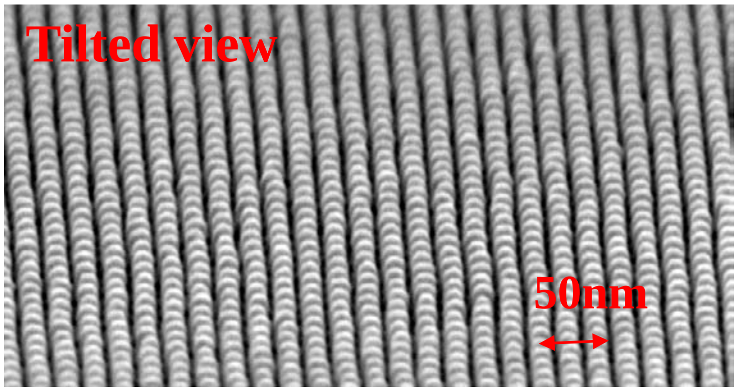
HGST-a western digital company (San Jose, USA)

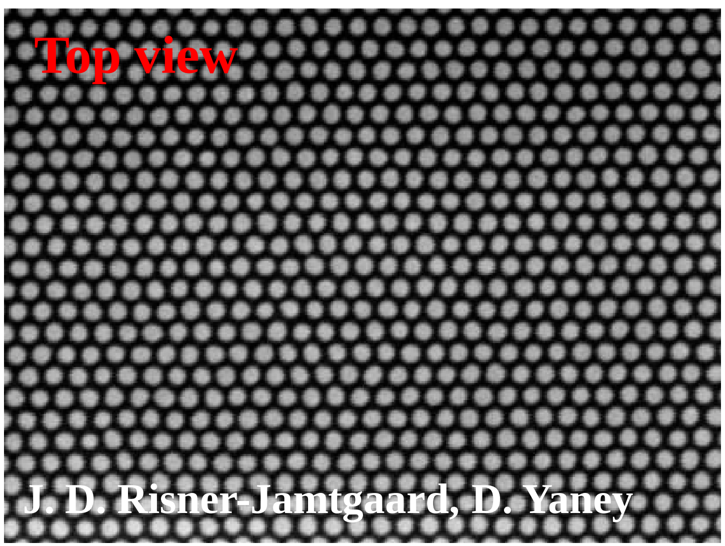
Outline :

- HDD Magnetic Recording
- Bit pattern media
- ECC media as a solution
- Auto-assembled nanobumps

New schemes for bit pattern media recording

T. Hauet

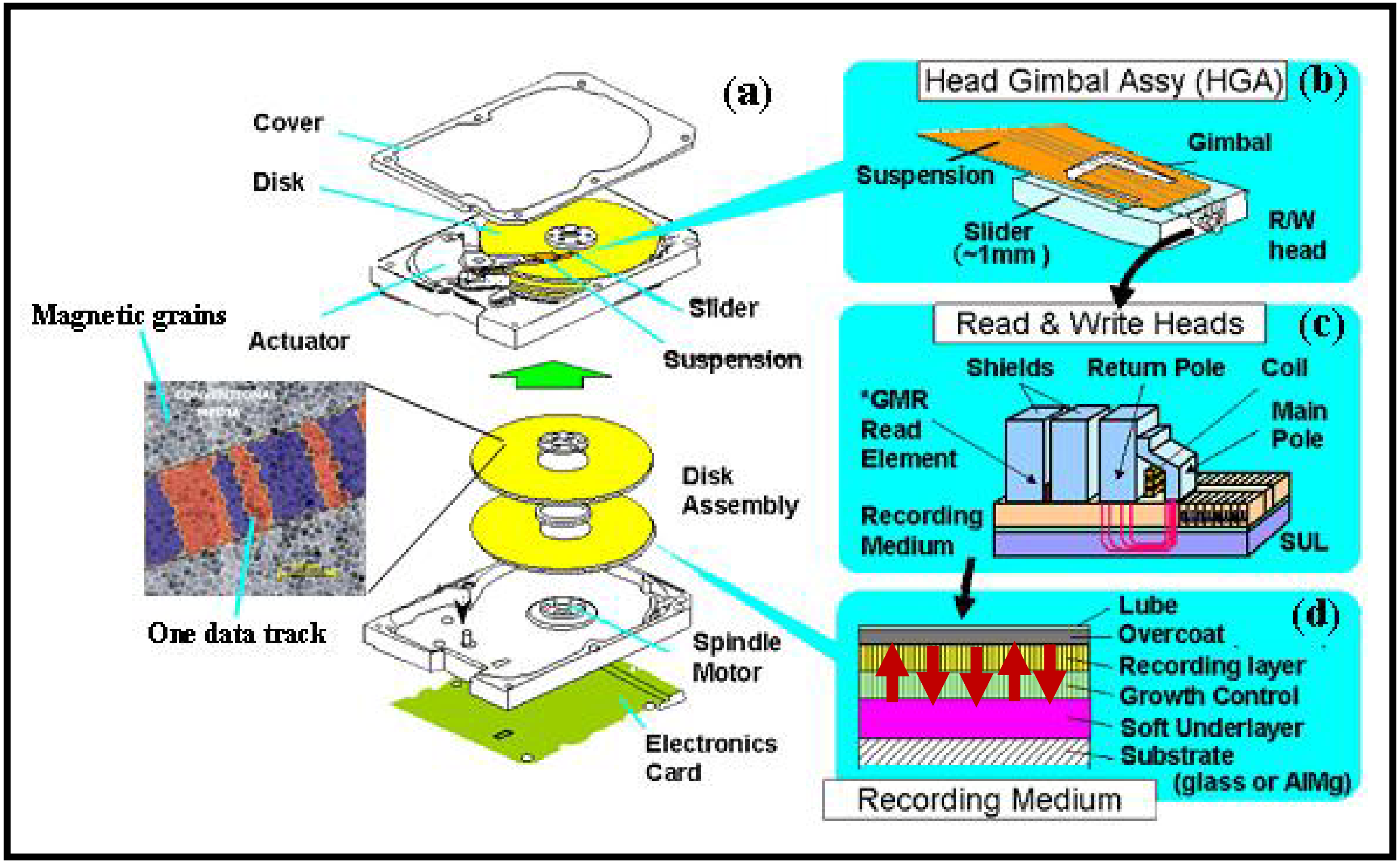




Outline :

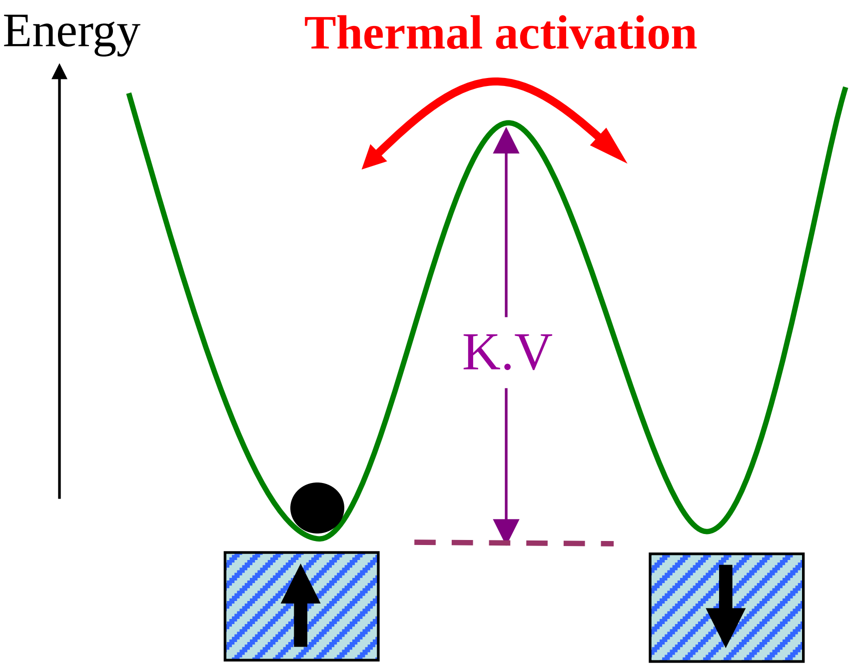
- **HDD magnetic recording**
- Bit pattern media
- ECC media
- Auto-assembled nanobumps

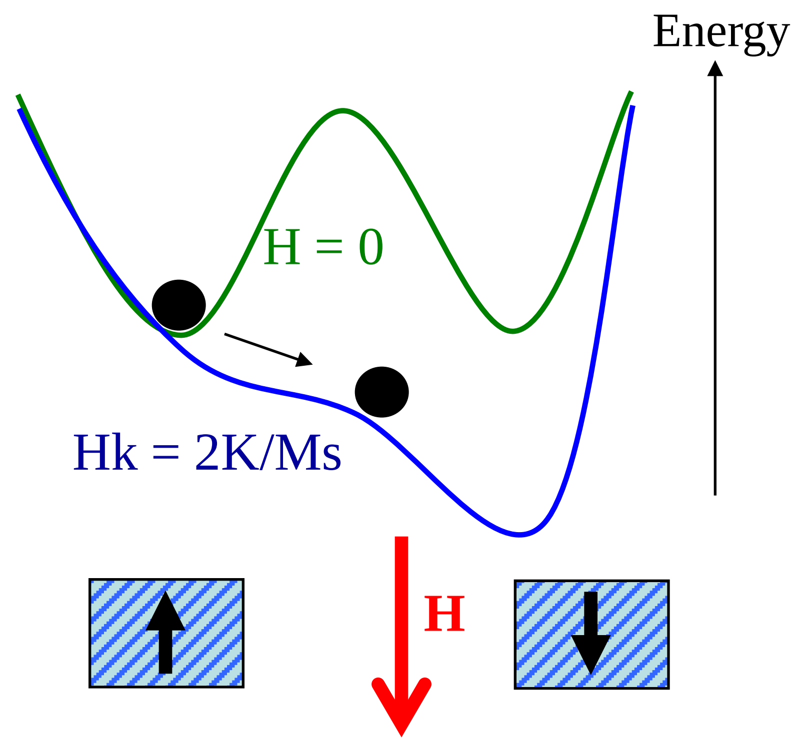
Magnetic recording : back to basics



"Spin-based data storage", O. Ozatay, T. Hauet et al., "Handbook of nanoscale optics and electronics" Elsevier B.V. (2009)

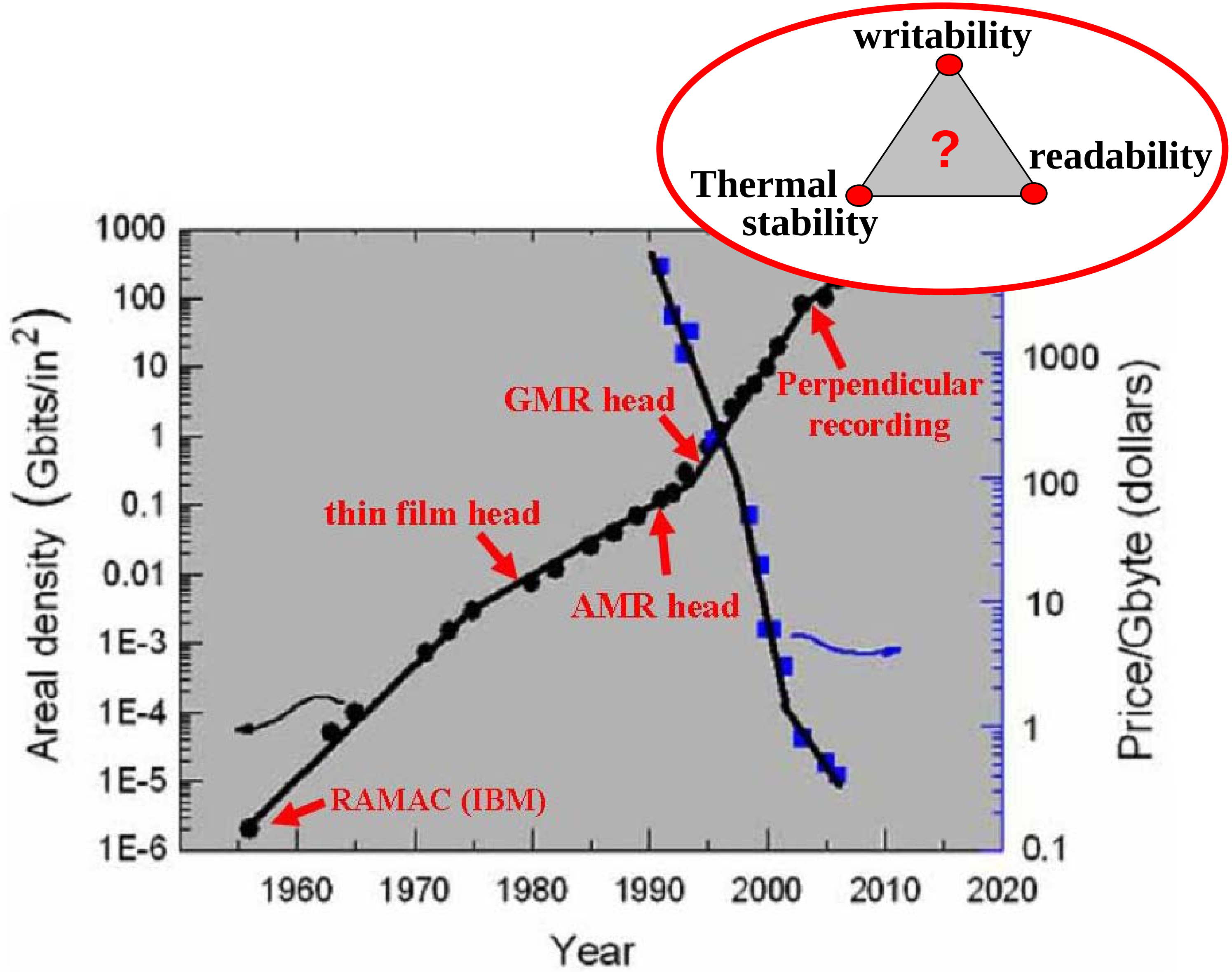
Magnetic recording : stability and writing process





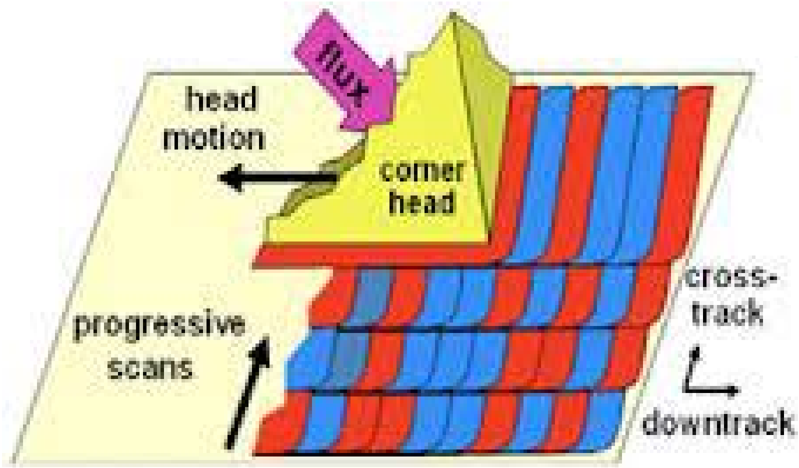
Goals : - **decrease the bit size to increase the areal density (1Tb/in^2)**
- **maintain thermal stability (= Anisotropy * Volume)**
- **decrease the noise related to the bits boundaries**

Magnetic recording : impact of new physics

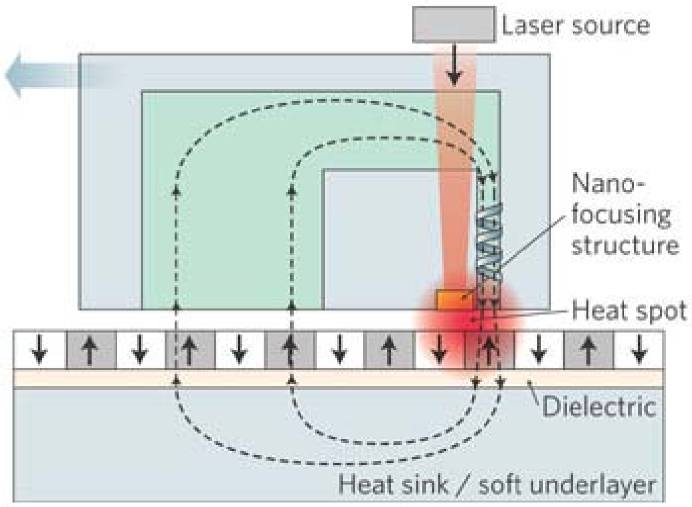


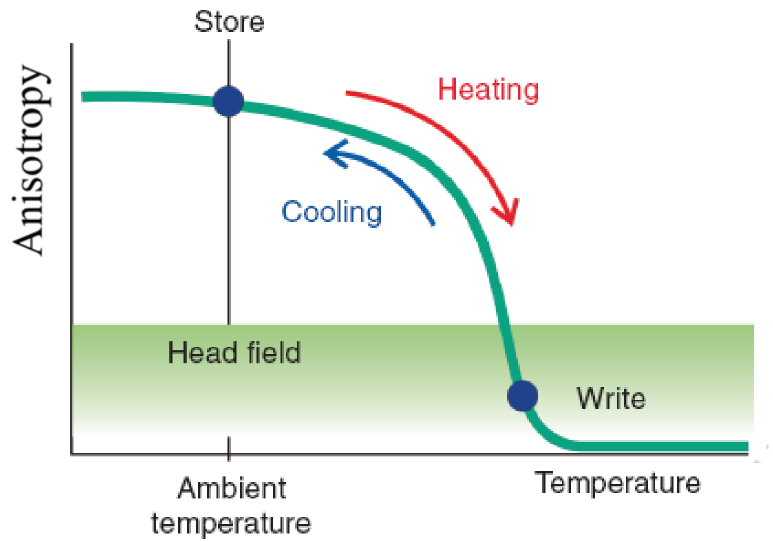
New schemes to improve density : Heat assisted recording

Shingle writing :



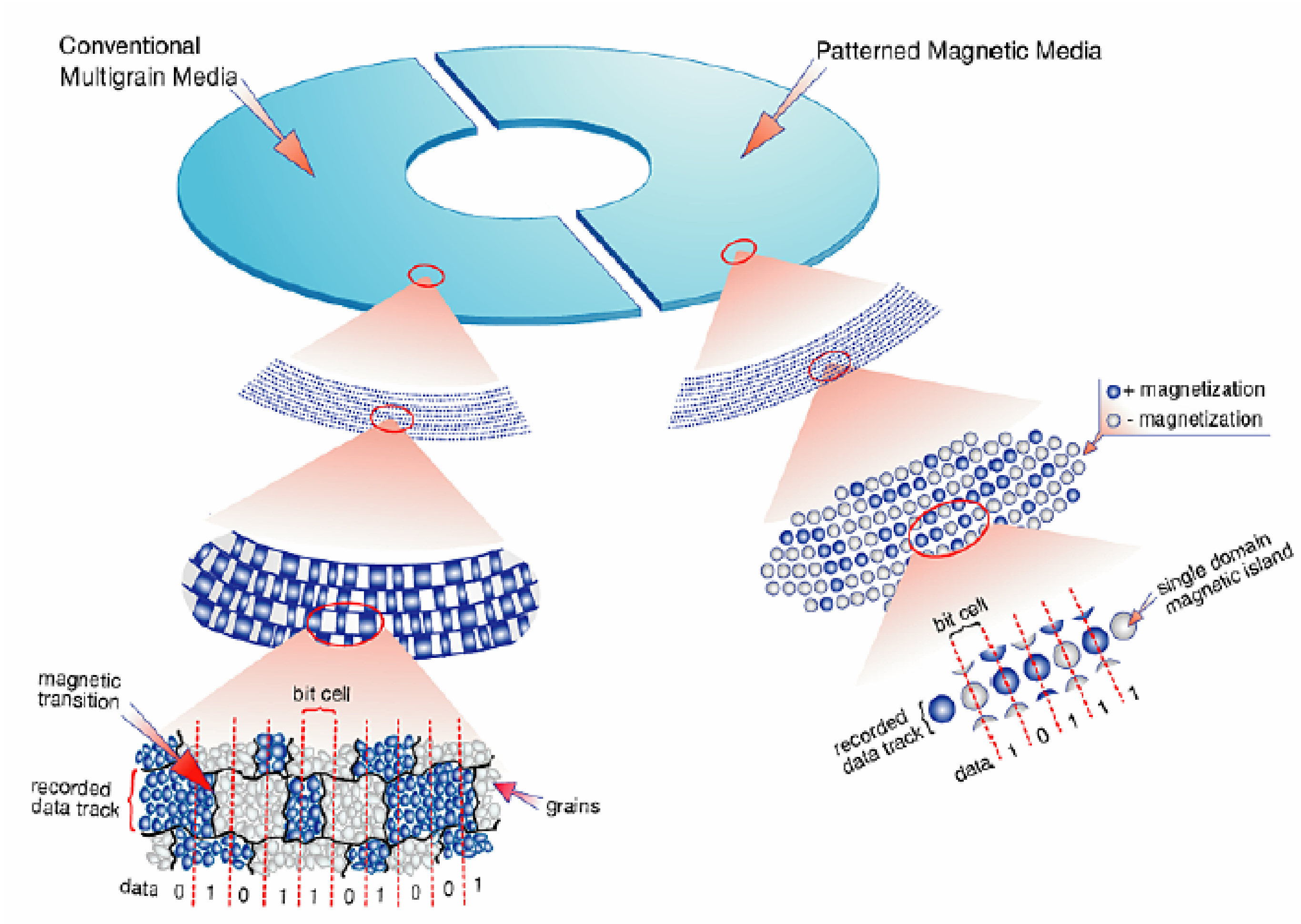
Heat assisted recording :





O. Ozatay et al. "Comprehensive Nanoscience and nanotechnology" Elsevier B.V. (2010)

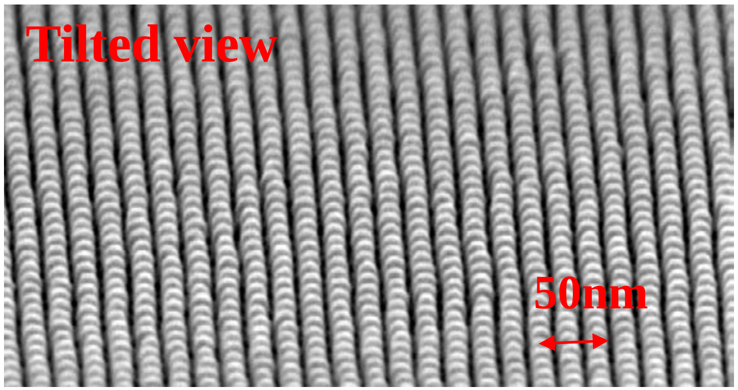
New schemes to improve density : Bit pattern Media (BPM)

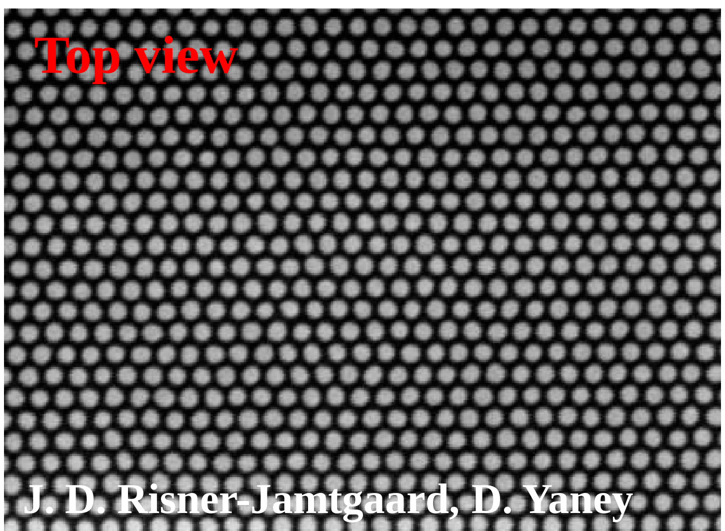


O. Ozatay et al. “Comprehensive Nanoscience and nanotechnology” Elsevier B.V. (2010)

New schemes for bit pattern media recording

T. Hauet

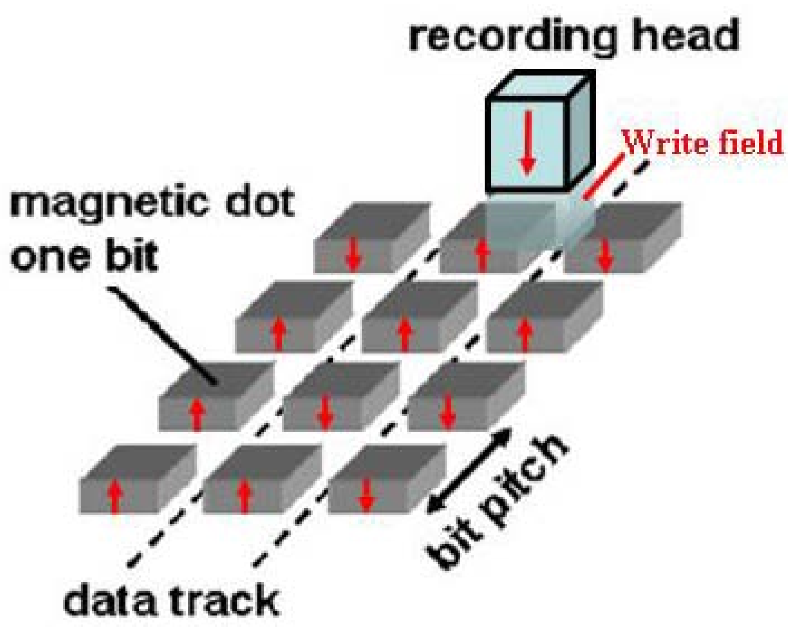




Outline :

- HDD magnetic recording
- **Bit pattern media**
- ECC media
- Auto-assembled nanobumps

Bit patterned media : A lot of technological issues

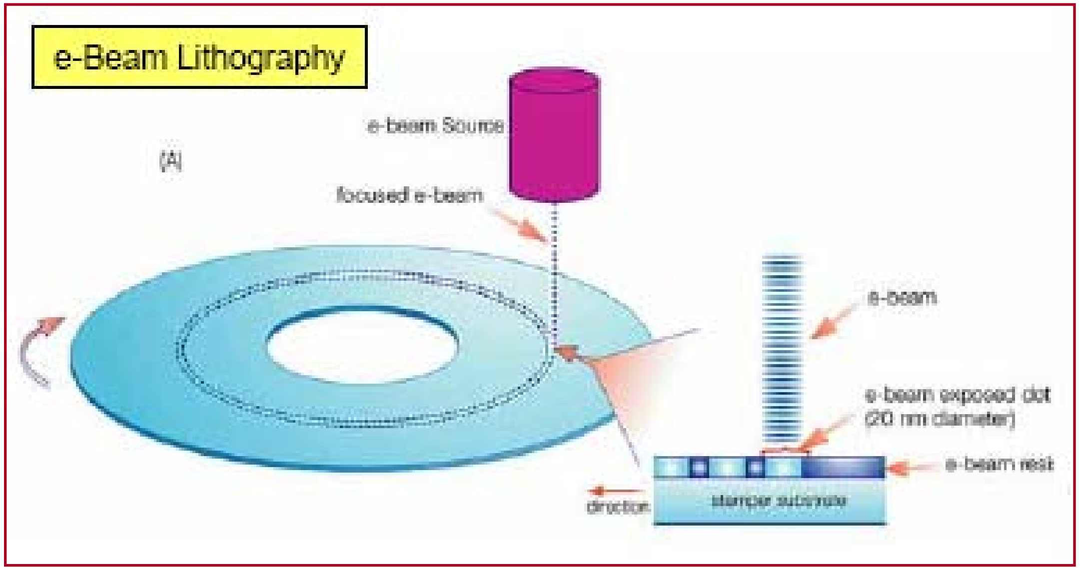


Pitch	Data density
100 nm	64 Gb/in2
45 nm	300 Gb/in2
35 nm	500 Gb/in2
25 nm	1 Tb/in2

Main issues :

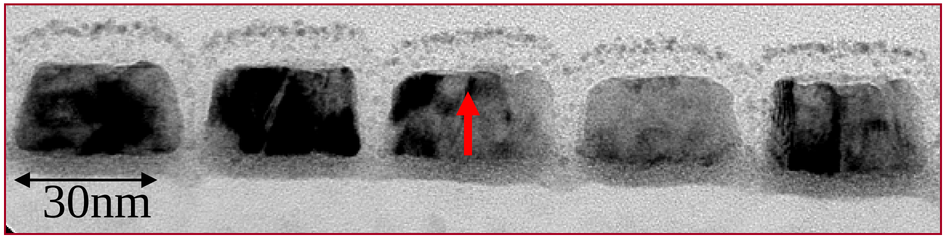
- Patterning of small, identical and well positioned islands
- Magnetics : stability, readability, writability
- Head must follow a pre-defined data track
- All the above in a cheap and fast mass production

Magnetic recording : lithography technique

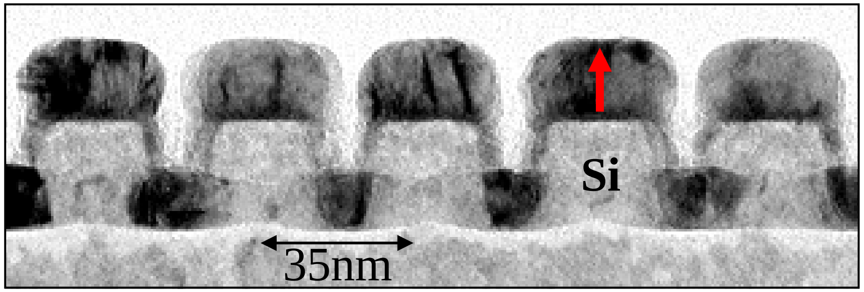


Pitch	Data density
100 nm	64 Gb/in2
45 nm	300 Gb/in2
35 nm	500 Gb/in2
25 nm	1 Tb/in2

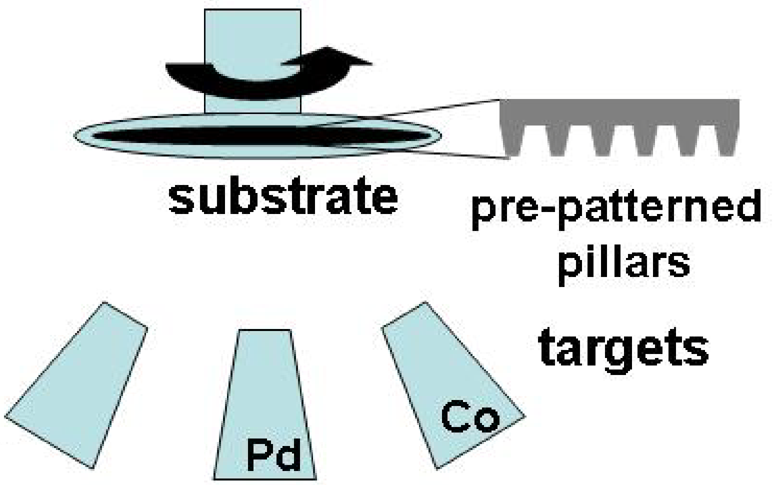
Post-patterning
(magnetic material is etched)

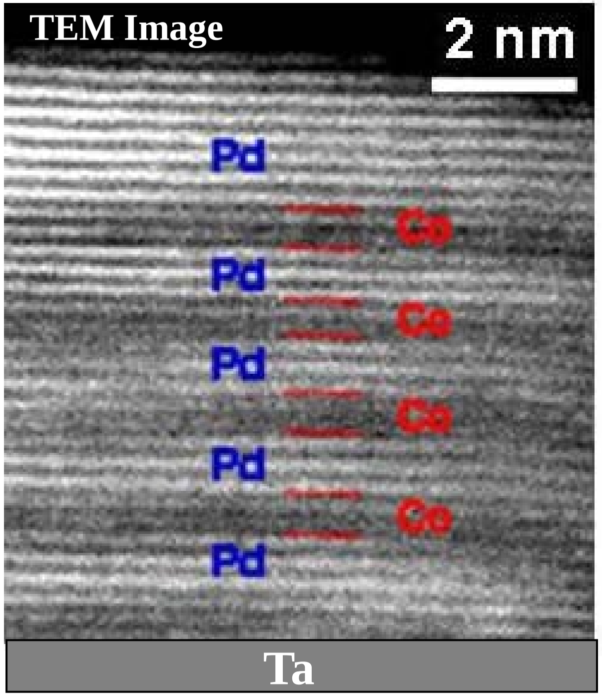


Pre-patterning
(substrate or underlayer is etched)



Co/Pd magnetic Media deposition by sputtering



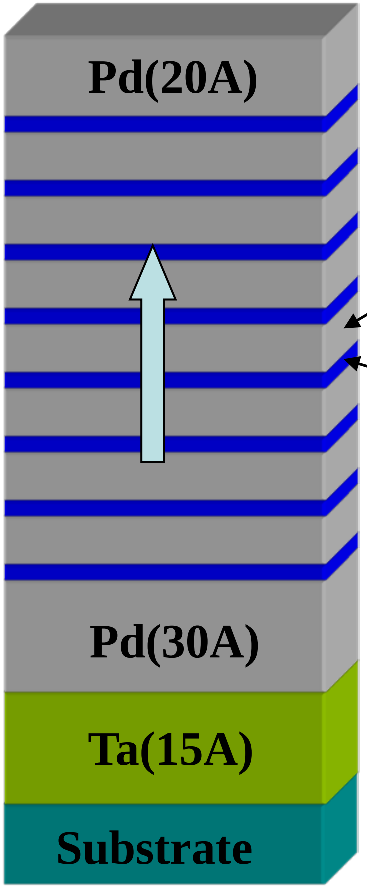


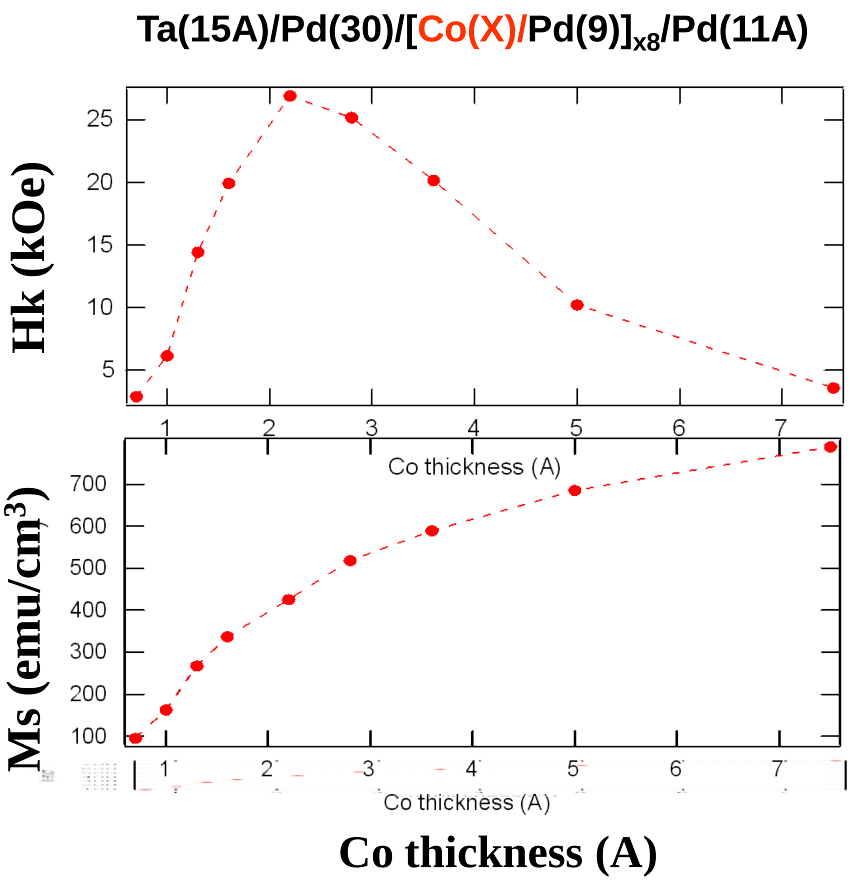
Full film Ta/Pd(20)/$[Co(4A)/Pd(8A)]_5$ /Pd(11A)

High quality of the multilayer interfaces

O. Hellwig, et al. Appl. Phys. Lett. 95, 232505 (2009)

Co/Pd magnetic Media with out-of-plane anisotropy

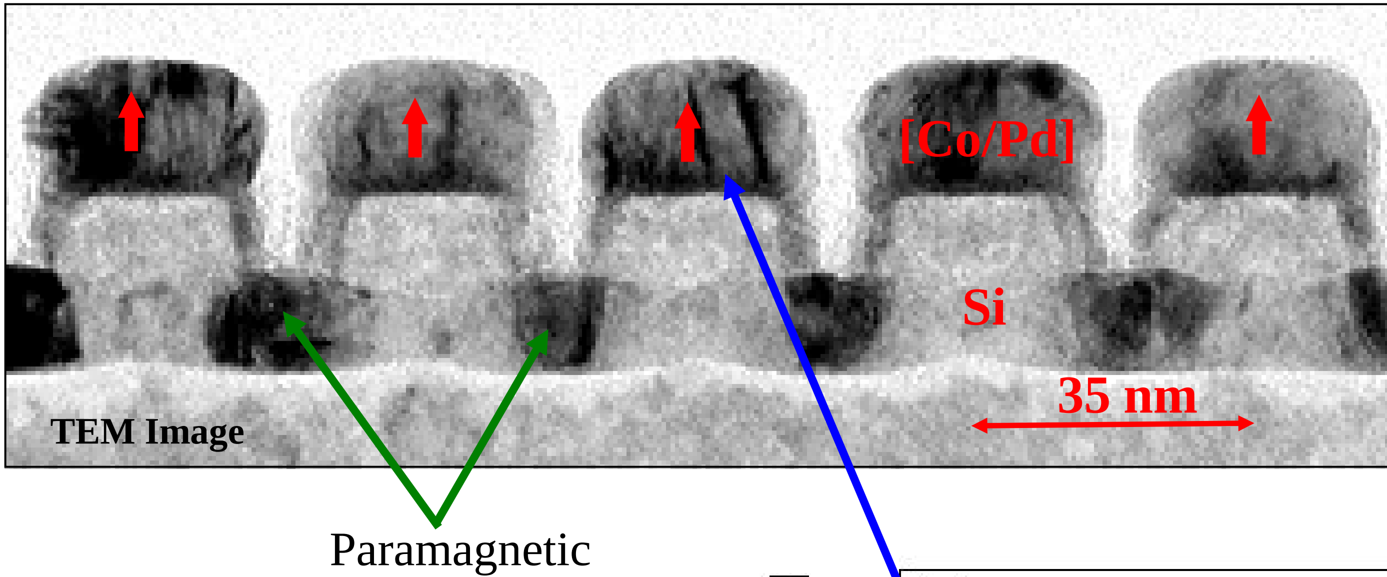




[Co/Pd] multilayer

- **Magnetization perpendicular to the Co/Pd interfaces**
- **Anisotropy (Hk) / Magnetization (M) can be tuned**
- **High Anisotropy (Hk) = high thermal stability**

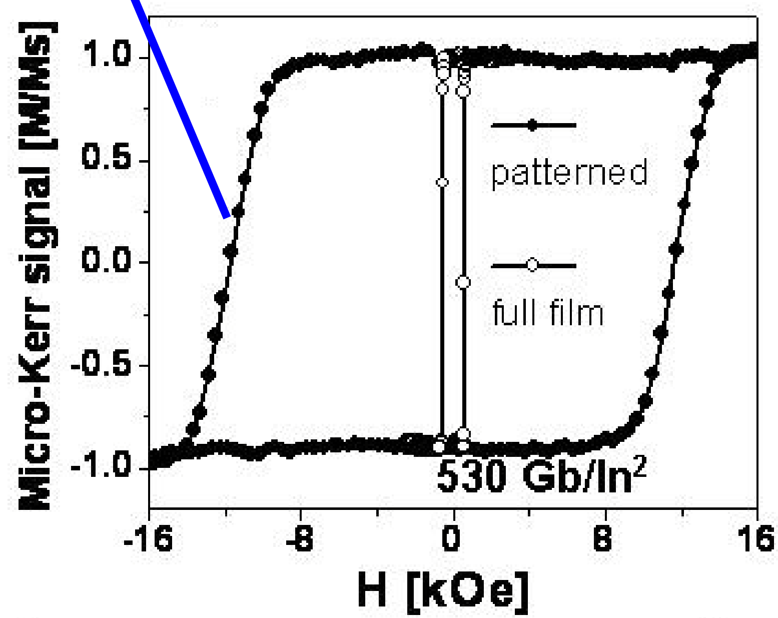
Co/Pd deposited on Si prepatterned substrates



2 problems to solve on magnetics:

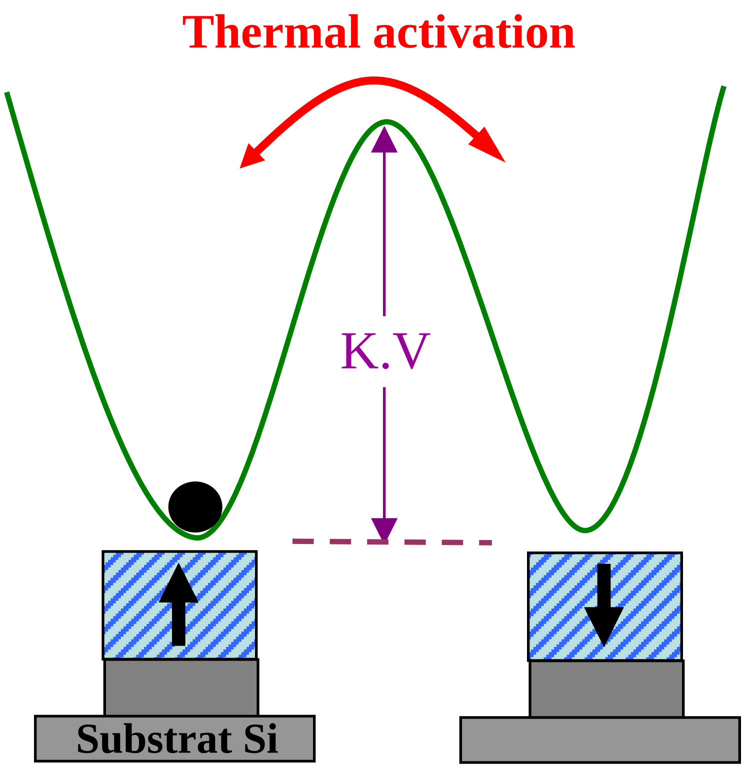
— Hk (dots) is too high because high K

— Large distribution of switching field Hc

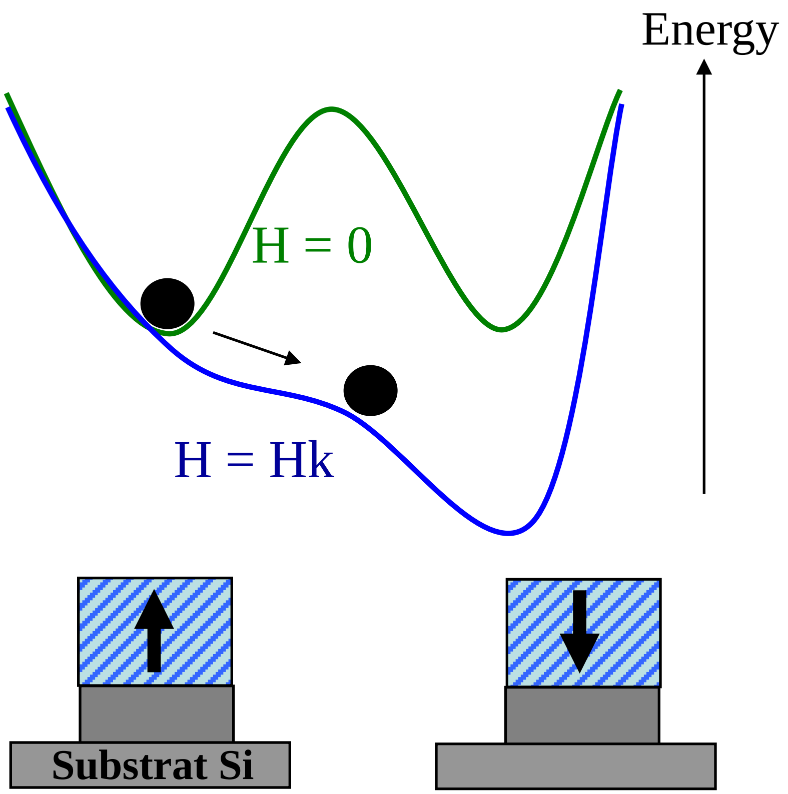


Problem 1 : Swithing field Hc vs thermal stability

Under zero external magnetic field



Under external magnetic field H

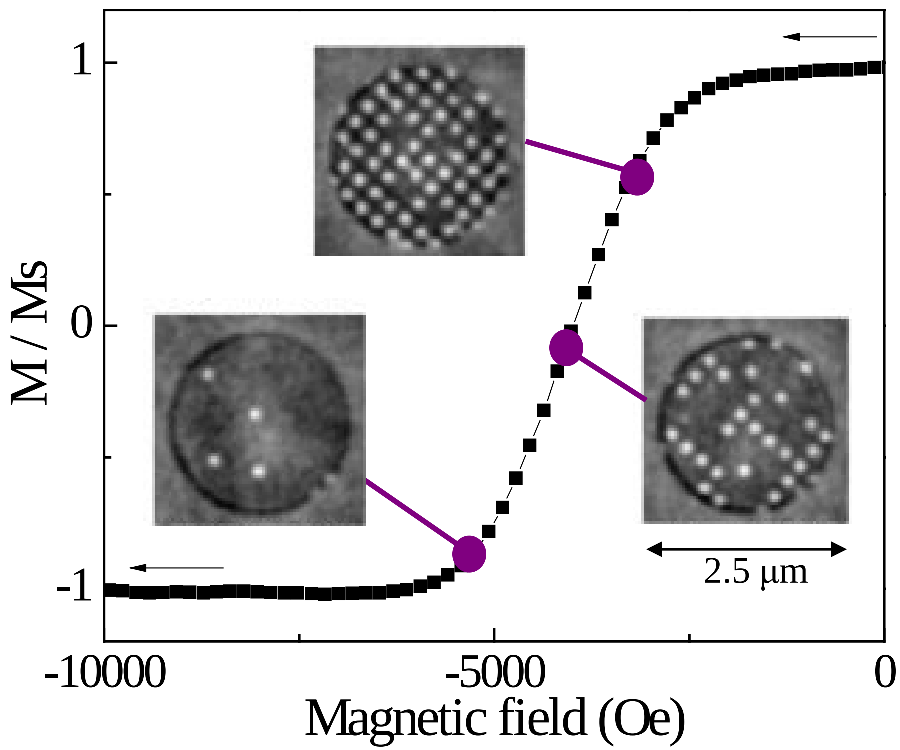


High anisotropy K = high termal stability

High anisotropy K = high switching field Hk

BUT Field created by the Hard disk drive head is limited around 8kOe !

Problem 2 : Switching field distribution

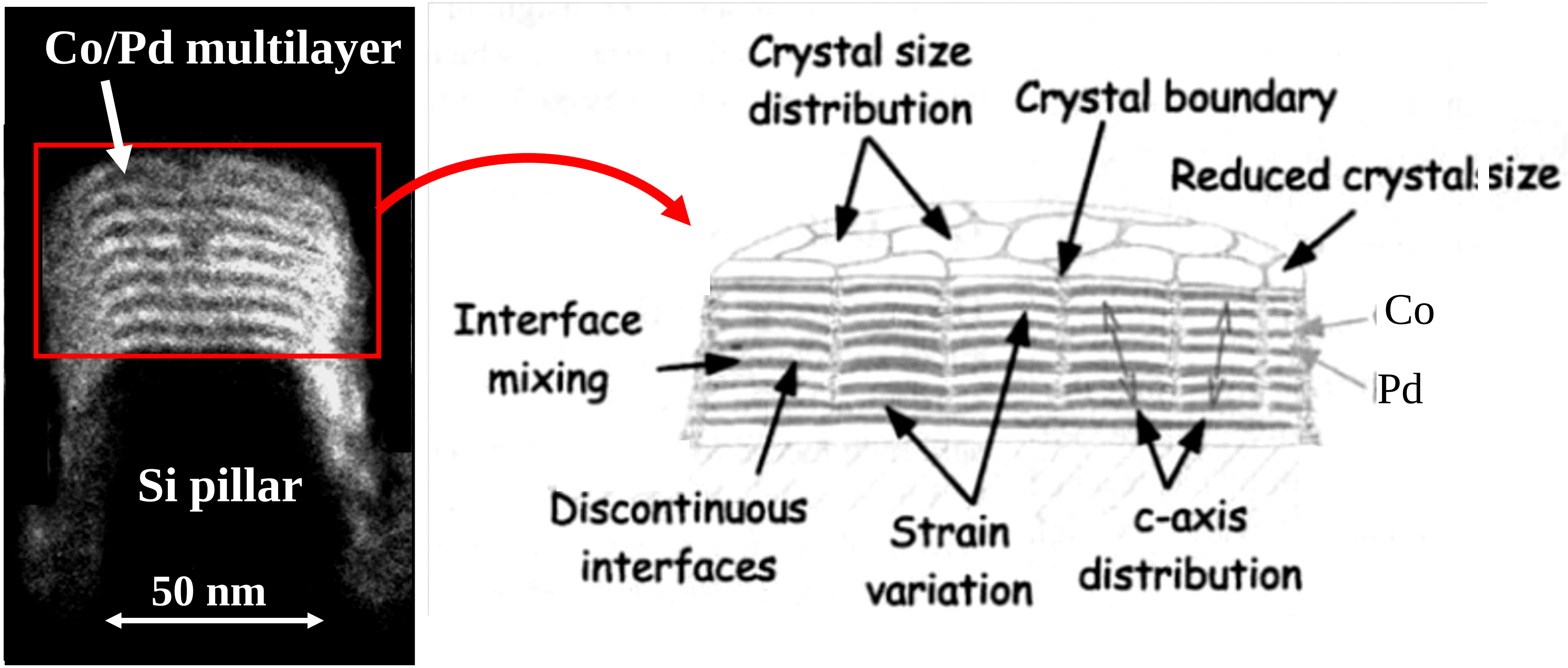


X-ray Holography (Berlin)

All the bit (dots) magnetizations do not reverse at the same field

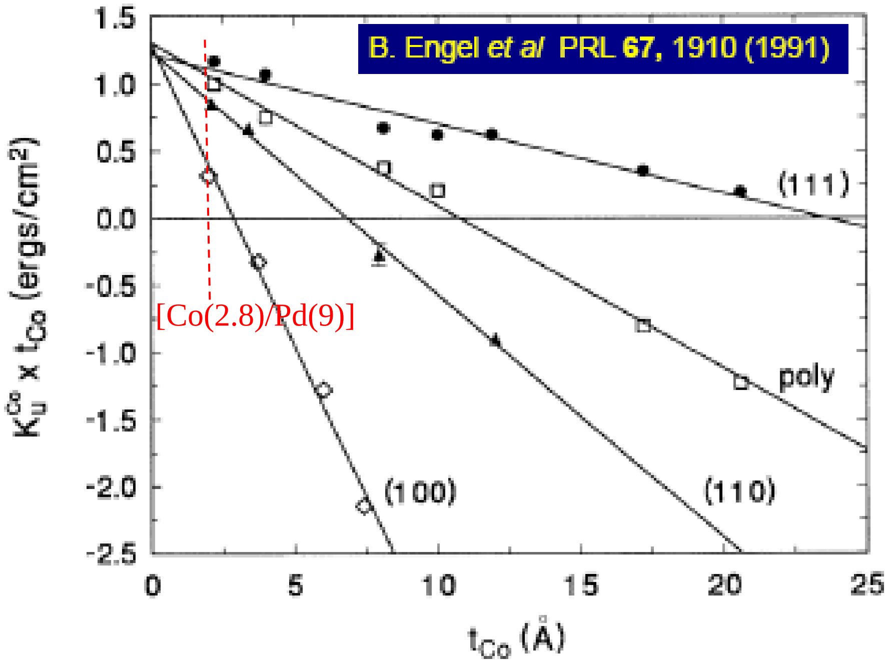
=> Writing errors or data erasure in hard disk drive

Some origins of the dot-to-dot distribution (SFD)

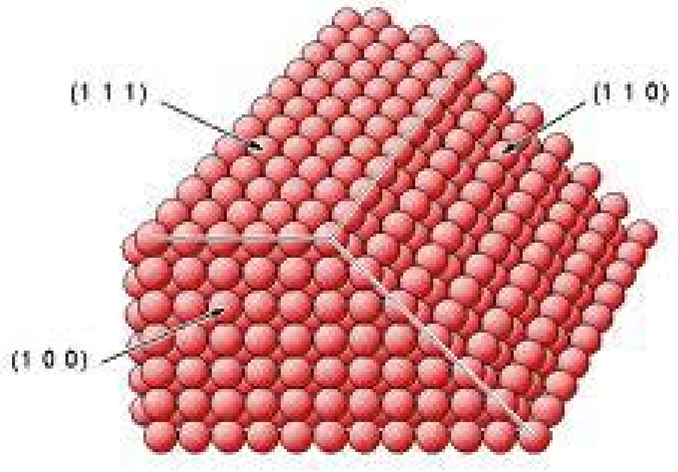


We found that misorientated grains seem to have the largest impact

Crystalline structure is the most important origin of SFD



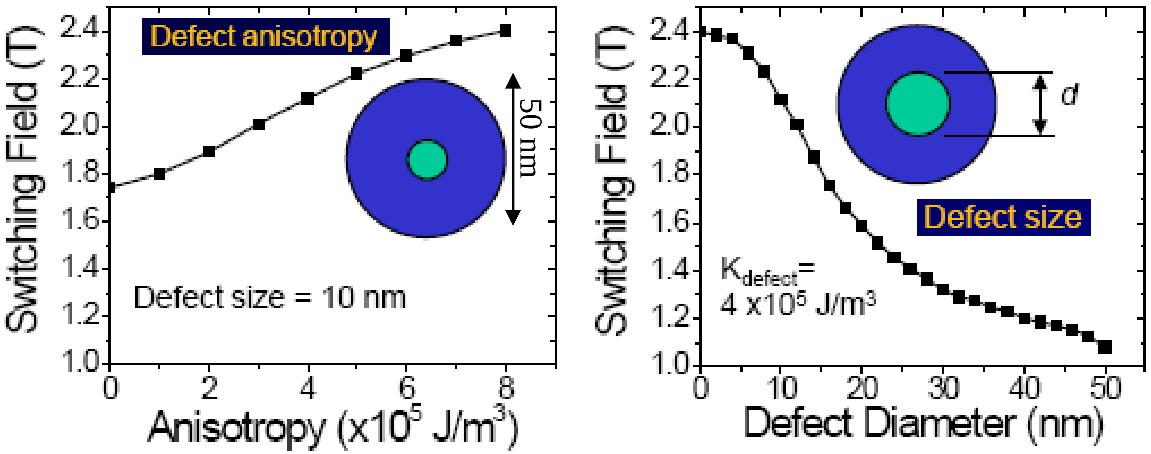
What direction is perpendicular to the media ?



<u>**Simulations**</u>

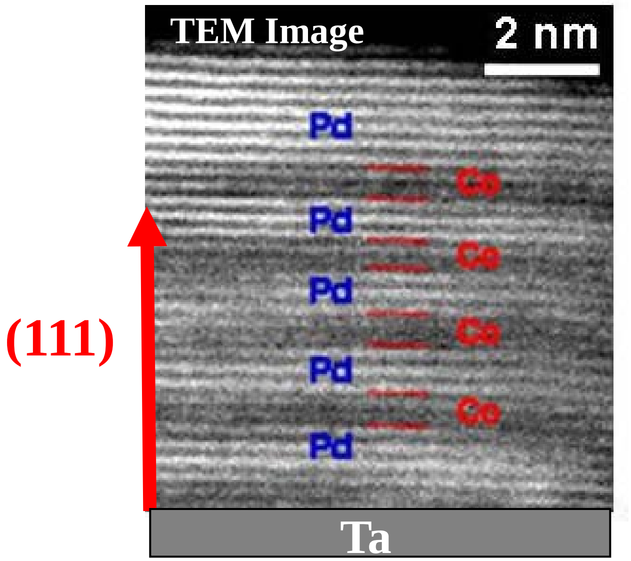
<u>**(J. Shaw et al. PRB 2008) :**</u>

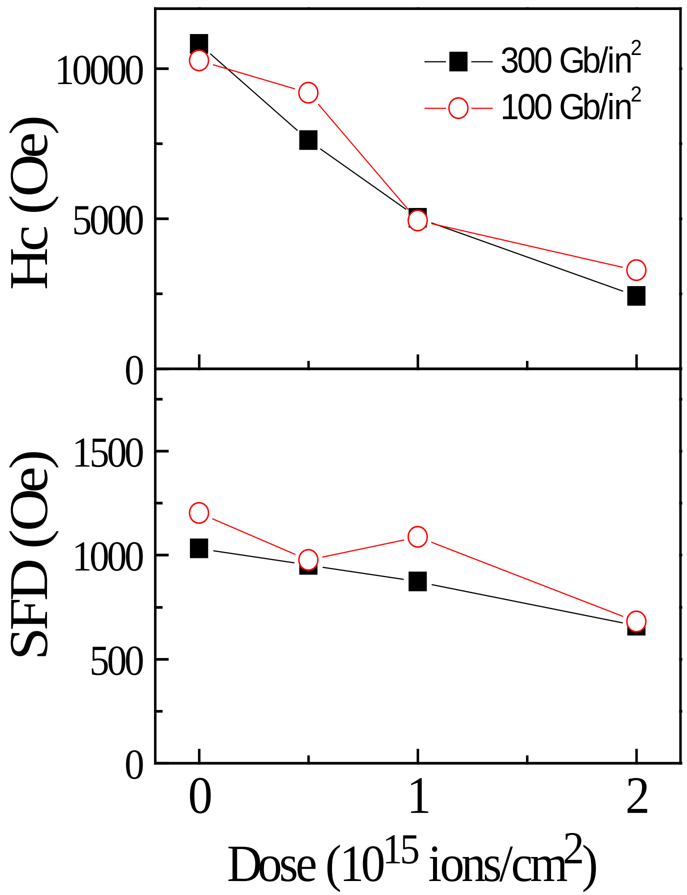
If 10nm wide defect in 50nm dot, Hc can decrease by 6 kOe



Ion irradiation on Co/Pd Bit pattern media

20keV He^+ ion irradiation suppresses interfaces but maintains crystallinity



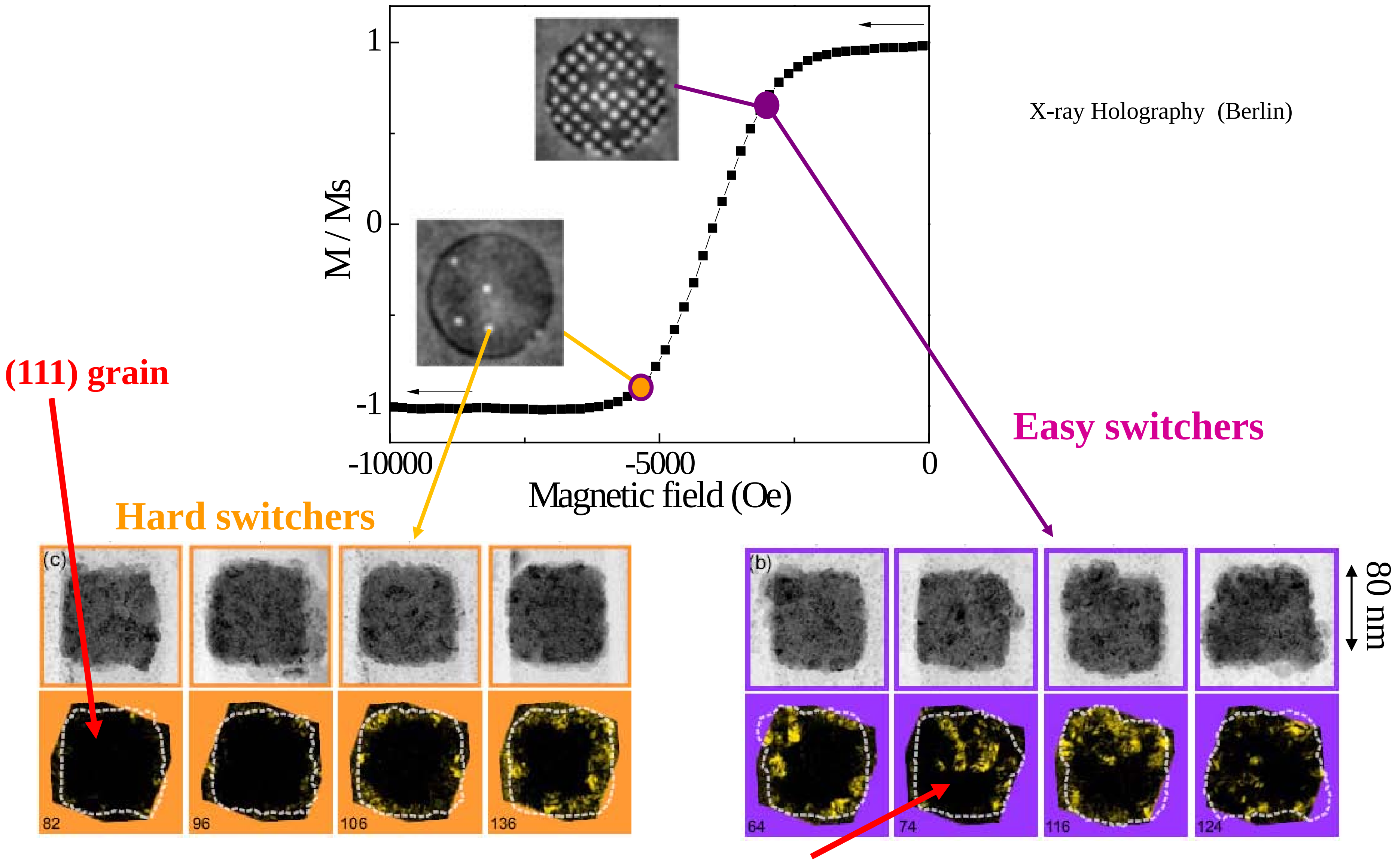


Interfaces provides the leading contribution to K, but only the second order term to the SFD

Crystalline structure is the leading contribution to the SFD but second order to Hc and anisotropy.

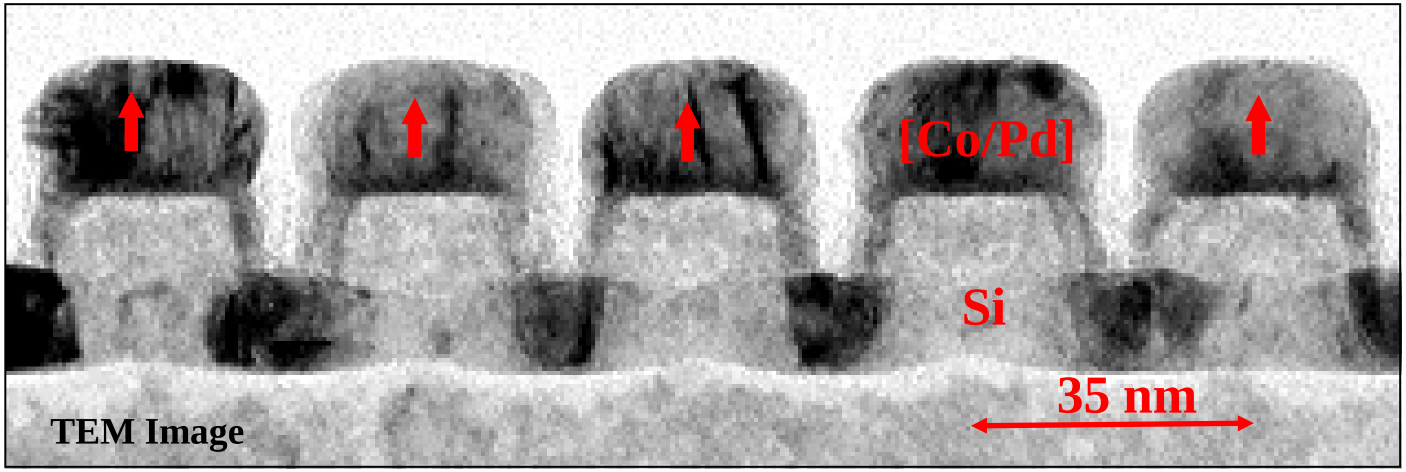
T. Hauet et al. Appl. Phys. Lett. 98, 172506 (2011)

Major Switching field distribution origin : granularity



B. Pfau et al., Appl. Phys. Lett. **99** 062502 (2011)

How to control Hc and SFD ?



2 problems to solve on magnetics:

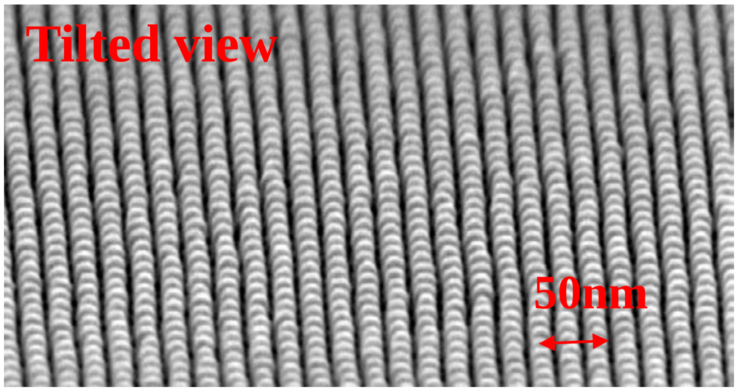
— Hc (dots) / Hk dilemma ⟷ Intrinsic to the material

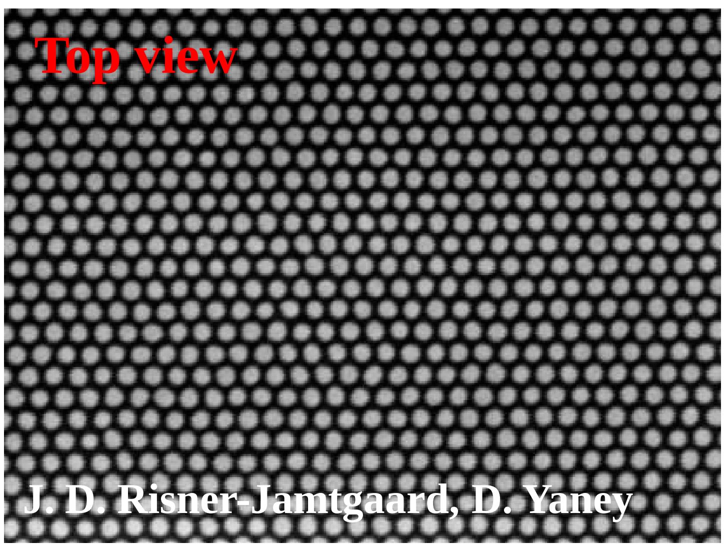
— Large SFD ⟷ mostly unavoidable because of structural defects

Can we find some magnetic tricks to overpass the material related issues ?

New schemes for bit pattern media recording

T. Hauet



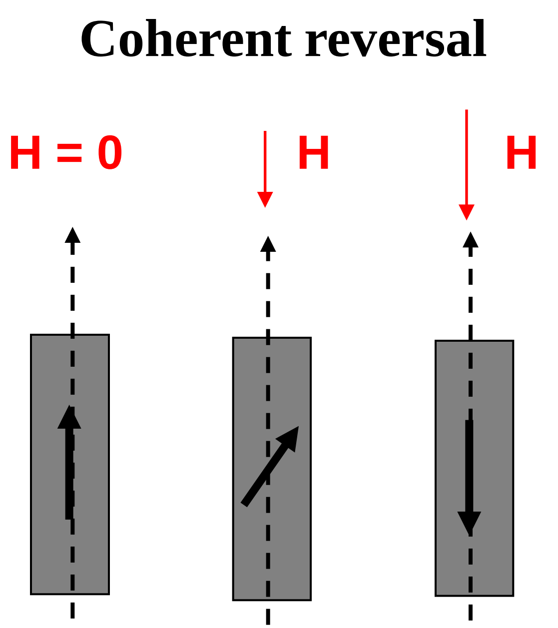


<u>Outline :</u>

- HDD magnetic recording
- Bit pattern media
- **ECC media**
- Auto-assembled nanobumps

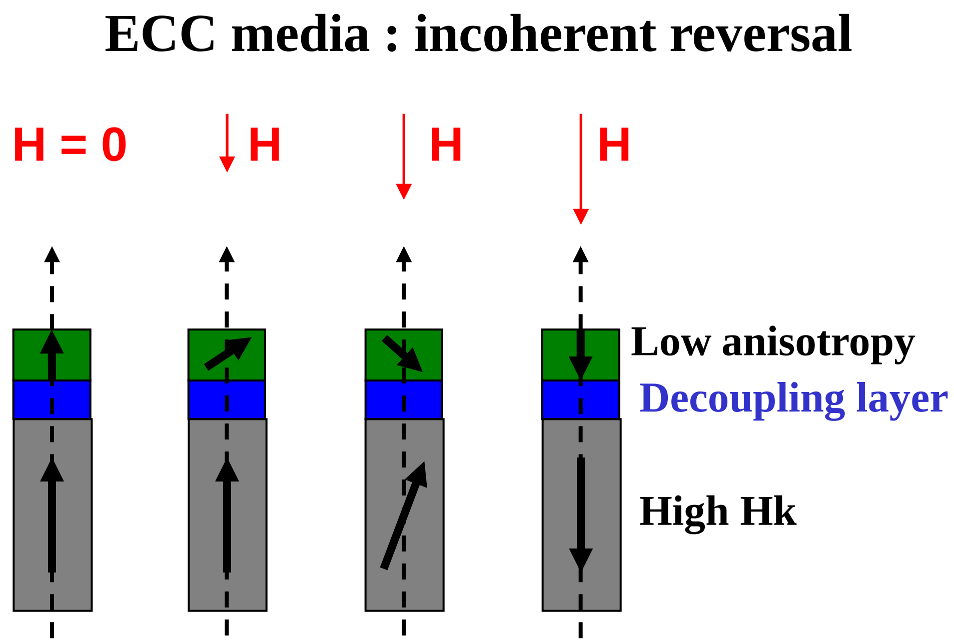
How to lower Hc while keeping high thermal stability ?

Possible solution : Modify the magnetization reversal mechanism



Hc =Hk

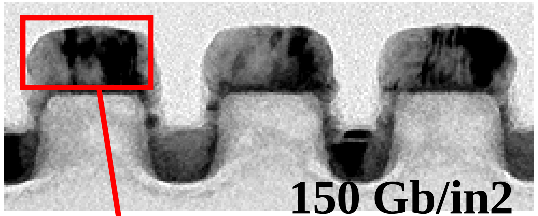
monospin



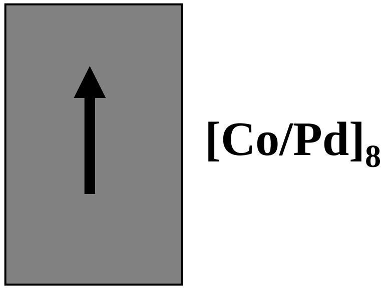
- **Hc << Hk + same Hk as coherent case**
- **Gain in Hc** depends on **Hk(high)-Hk(low)**

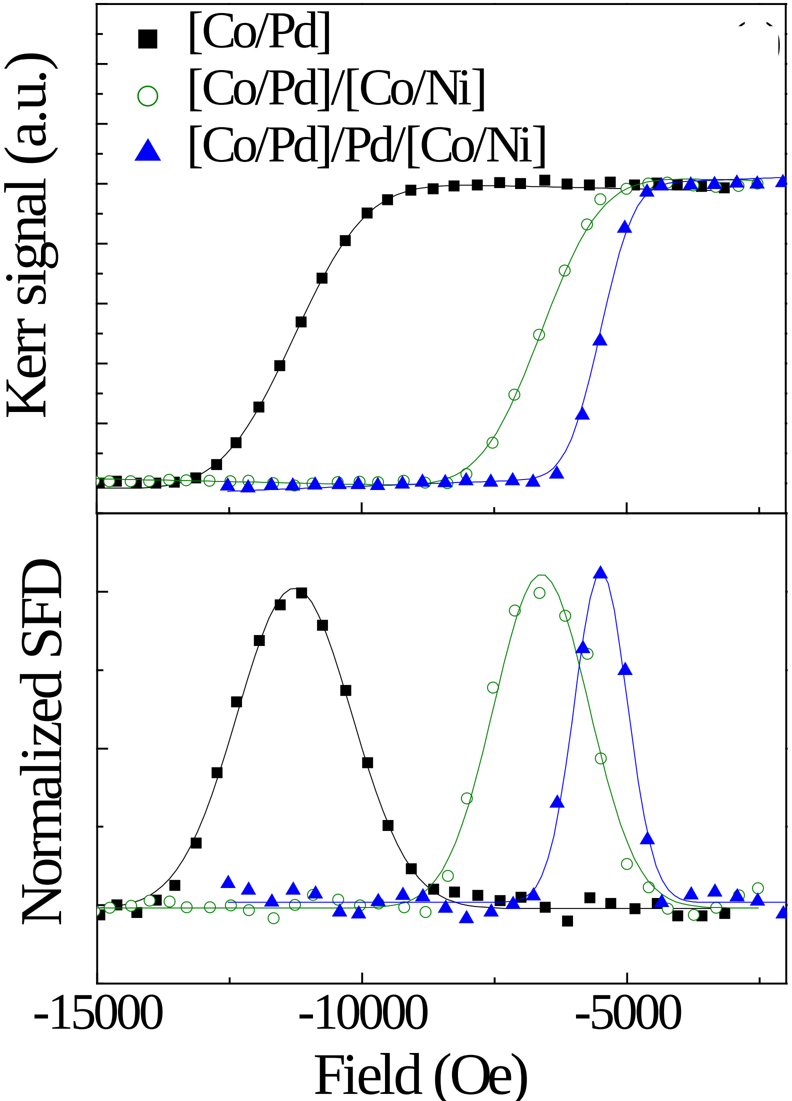
D. Suess et al., J. Magn. Magn. Mater. 321, 545 (2009); A. Berger et al., Appl. Phys. Lett. 93, 122502 (2008)

ECC media : Pd interlayer to tune the magnetic coupling

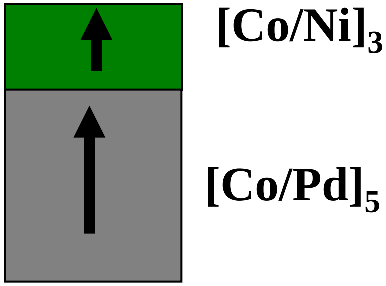


High Hk [Co/Pd]

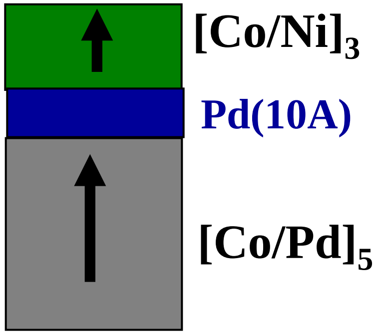




Low/high Hk



ECC media



ECC media

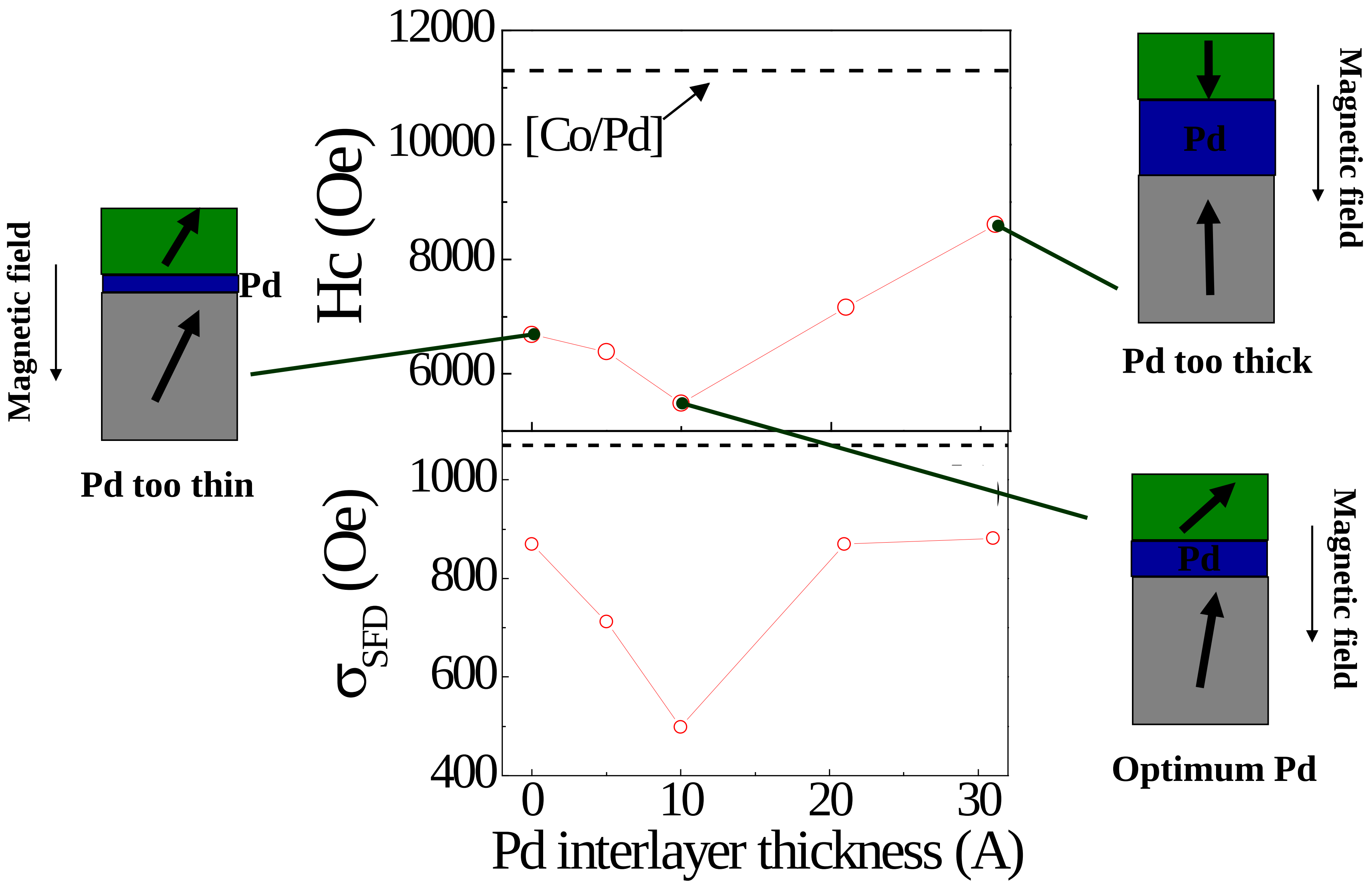
Large Hc decrease

Limited Hk decrease

Gain in SFD

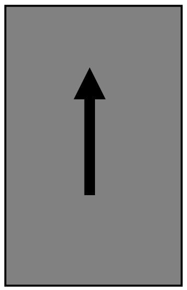
T. Hauet et al.,APL 95, 262504 (2009)

Influence of Pd interlayer thickness in ECC media



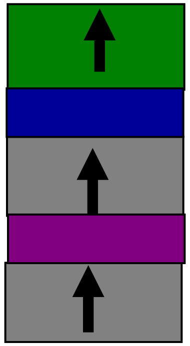
Influence of a 2nd Pd interlayer : additional gain

High Hk [Co/Pd]



[Co/Pd]$_8$

2 Pd interlayer



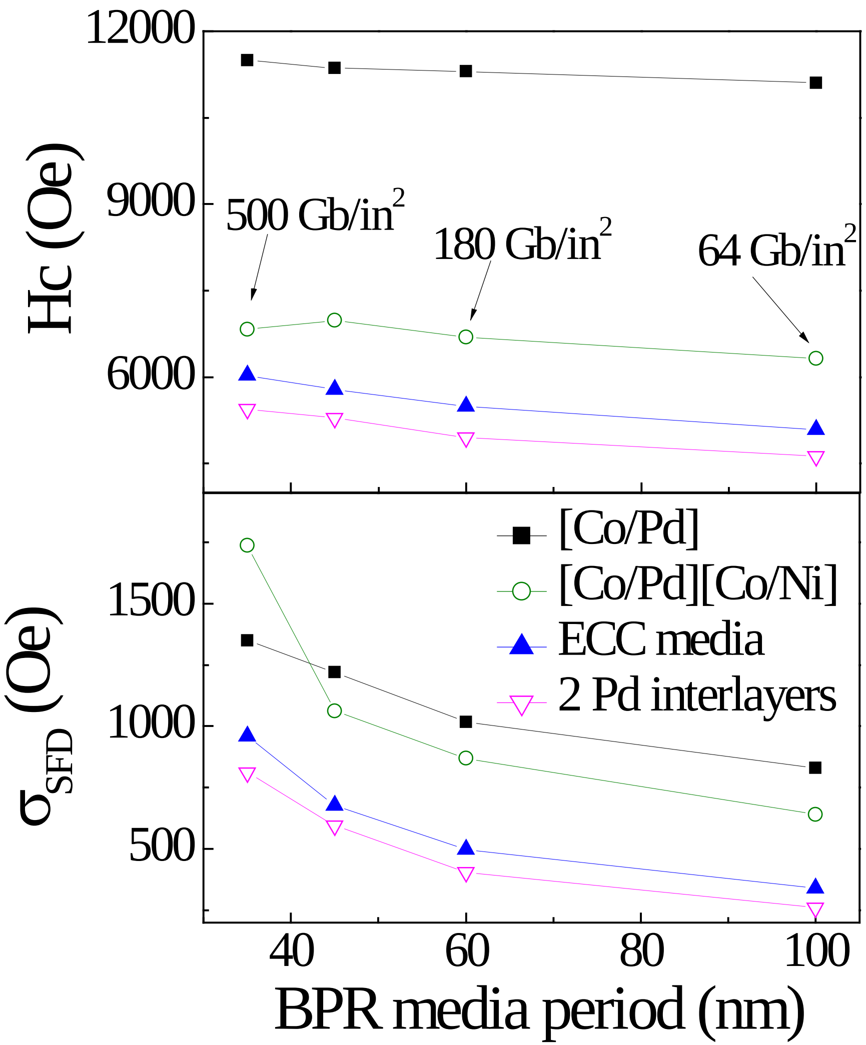
[Co/Ni]$_3$

Pd(10A)

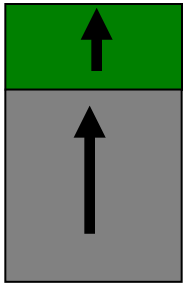
[Co/Pd]$_2$

Pd(10A)

[Co/Pd]$_2$



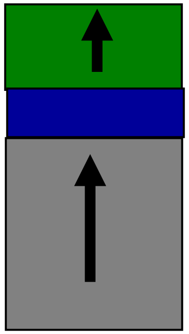
Low/high Hk



[Co/Ni]$_3$

[Co/Pd]$_5$

ECC media



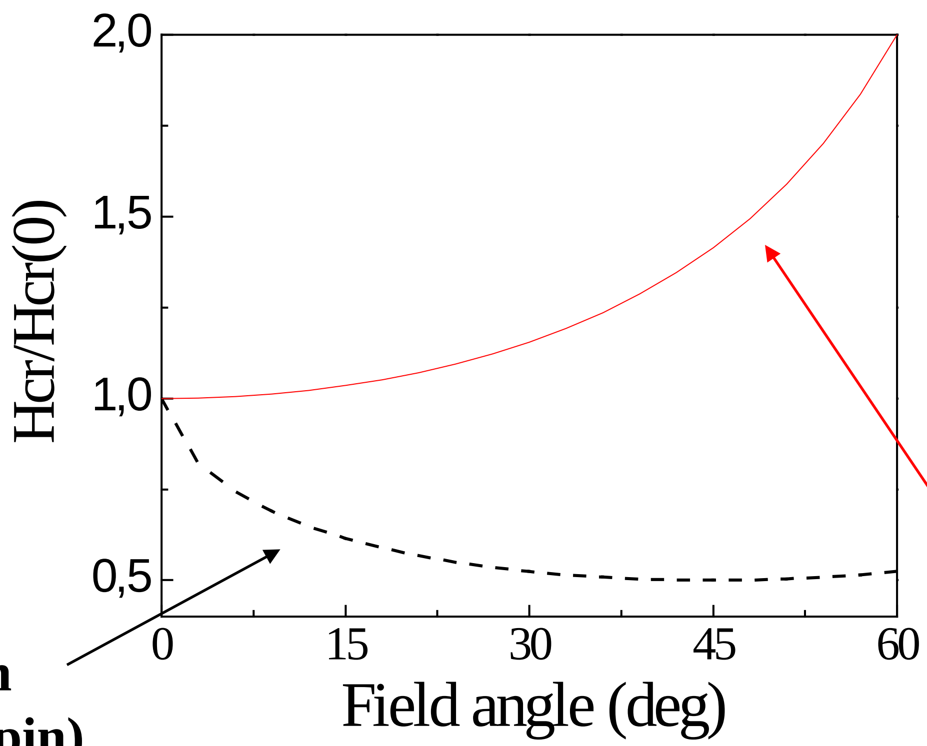
[Co/Ni]$_3$

Pd(10A)

[Co/Pd]$_5$

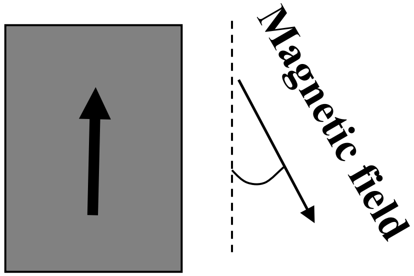
T. Hauet et al., Appl. Phys. Lett. 95, 262504 (2009)

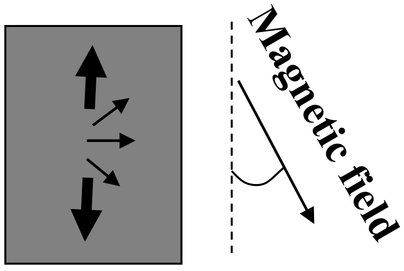
Angular dependance : proof of reversal incoherency



Stoner-Wohlfarth reversal (Macrospin)

Kondorsky reversal (Domain wall depinning)

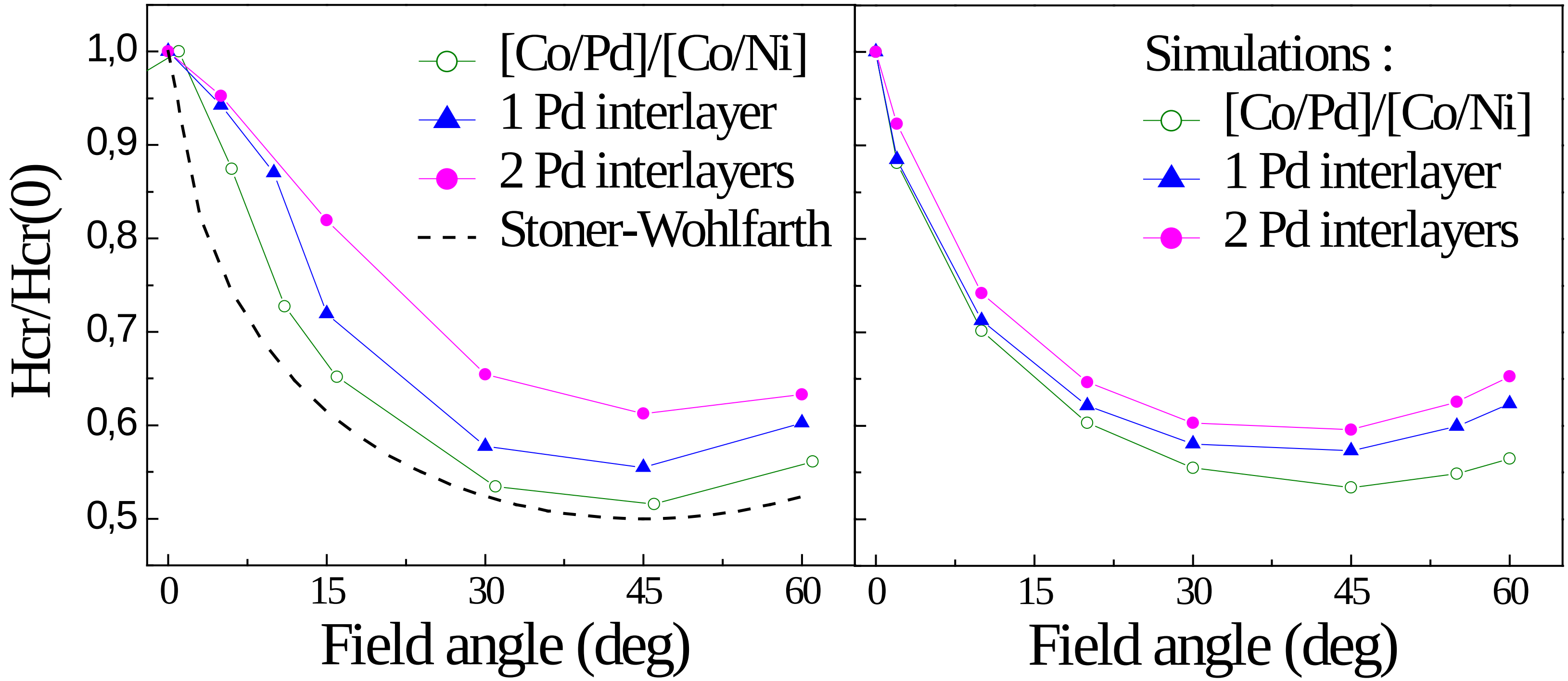


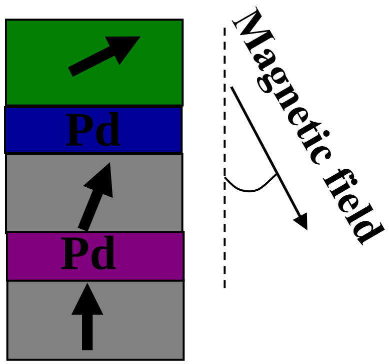


$$E_{mag} = KV\sin^2(\varphi - \theta) - M_s HV\cos(\varphi)$$

$$E = -M\,VH\cos(\theta) + E_{pinning}$$

Angular dependance : proof of reversal incoherency



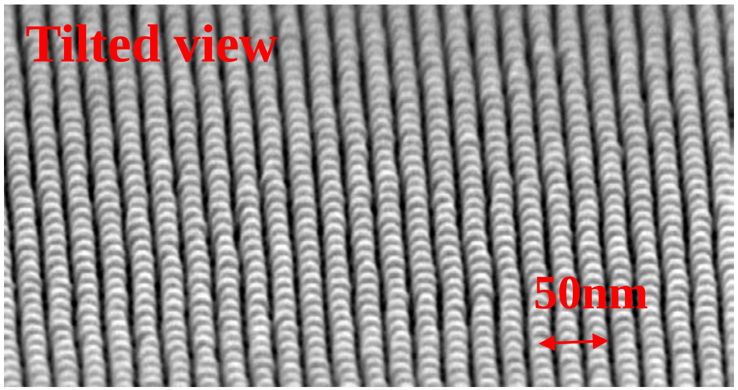


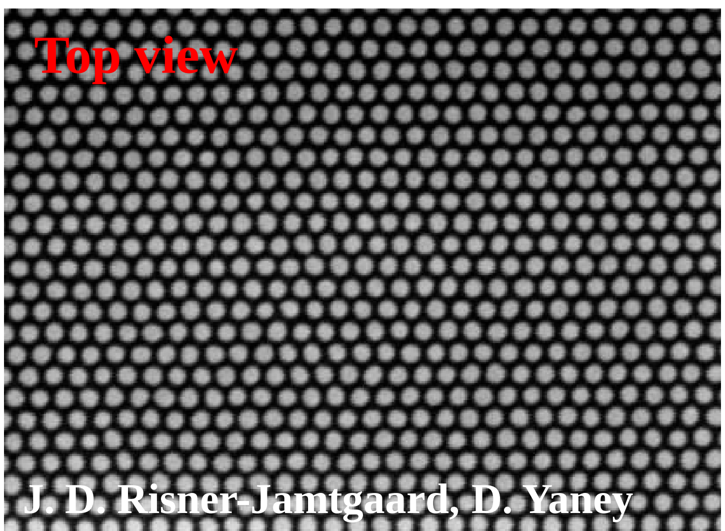
Incoherency in the magnetization reversal increases as the Pd interlayers are added

Simulations : J. Park, B. Lengsfield (H.N. Bertram and B. Lengsfield, IEEE Trans. Magn. 43, 2145 (2007))

New schemes for bit pattern media recording

T. Hauet





Outline :

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- ECC media
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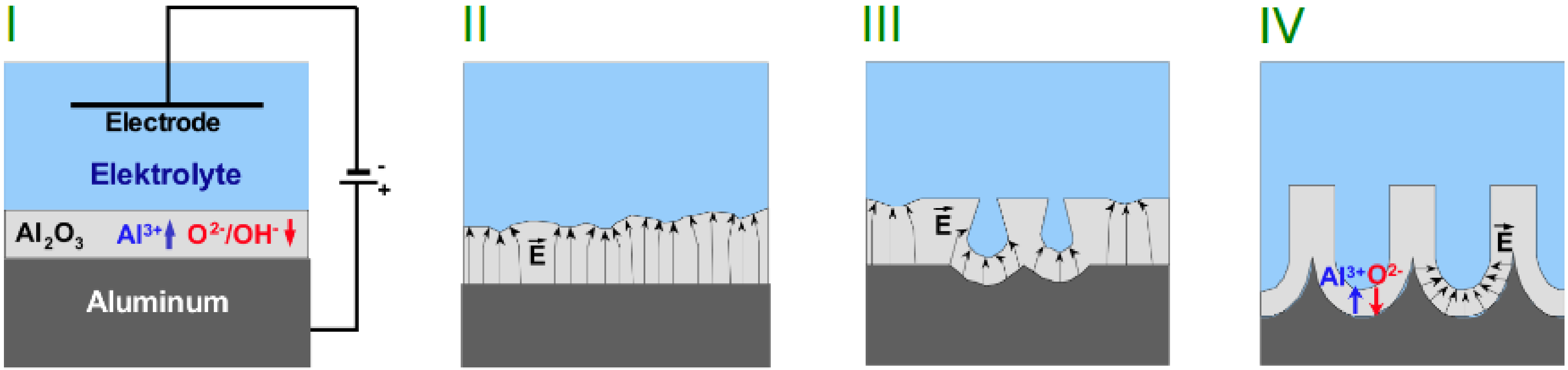
A new method to form assembly of nanodots

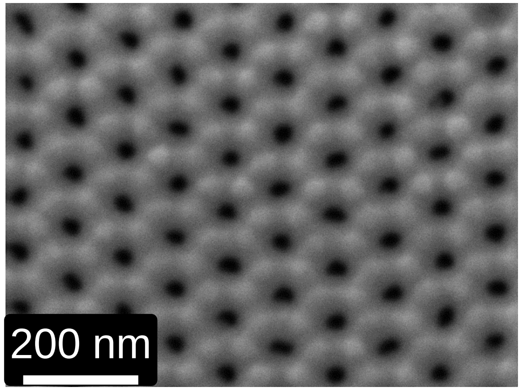


Oxide Barrier Layer Growth

Pore Creation

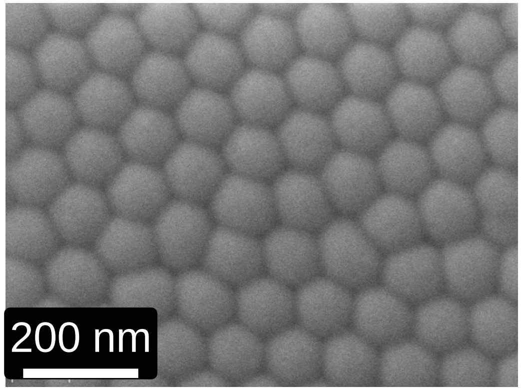
Pore Development

Steady State



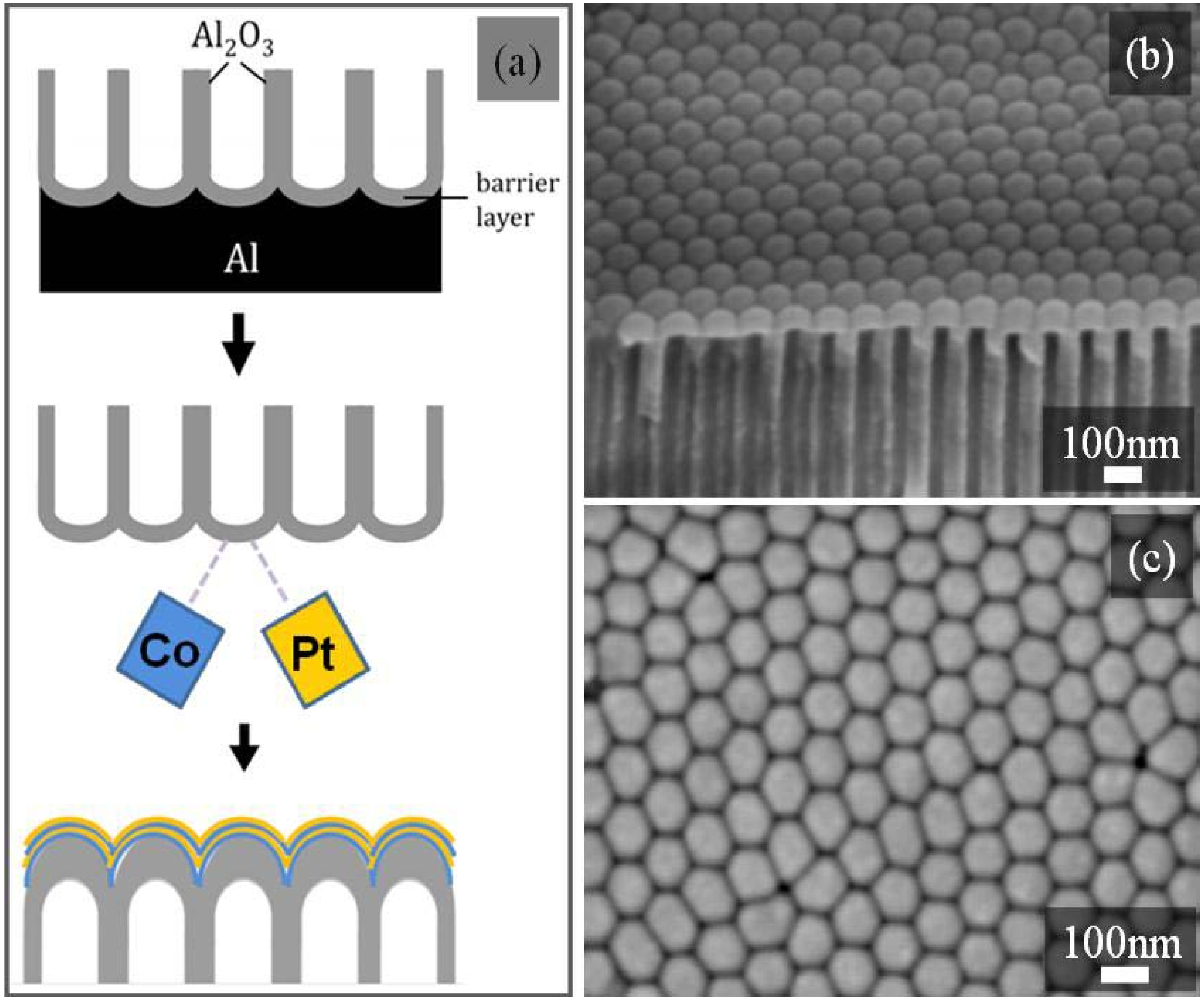
TOP View

BOTTOM View



S. Matefi-Tempfli et al., Thin Solid Films 516, 3735 (2008)

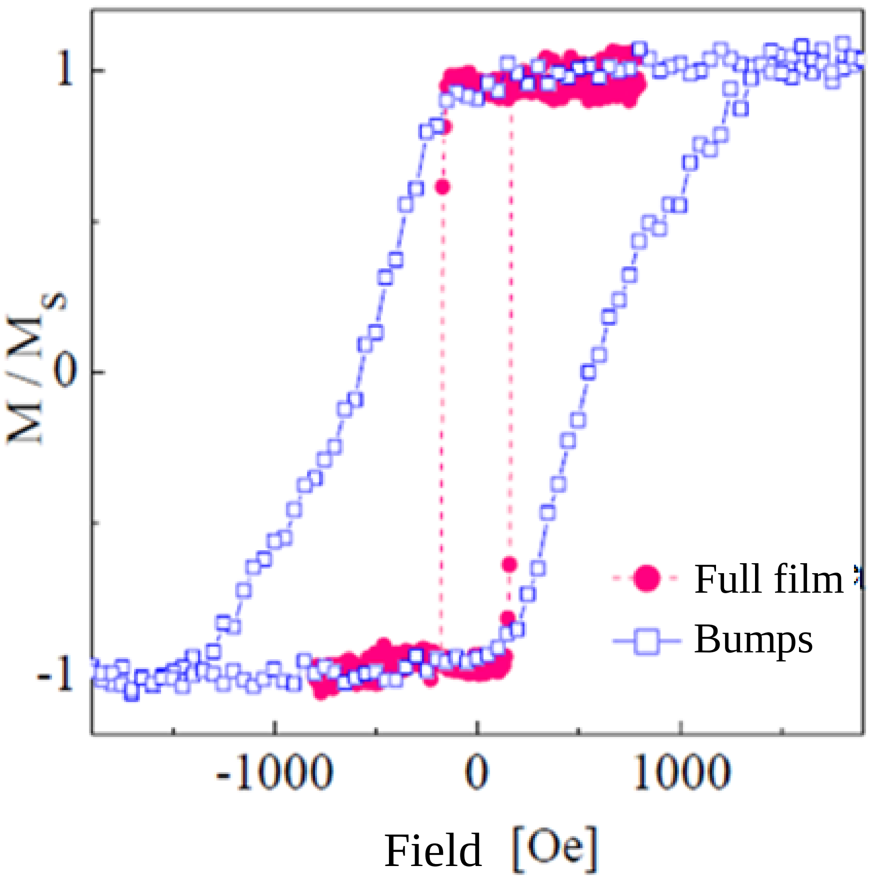
Bit pattern media on the back of AAO template

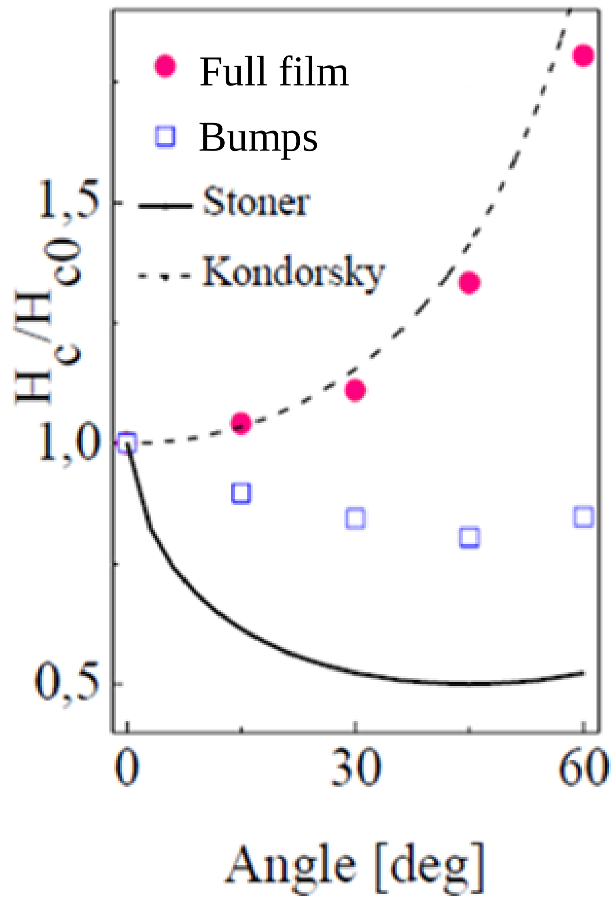


L. Piraux et al., Appl. Phys. Lett. 101, 013110 (2012)

Macroscopic magnetic characterizations

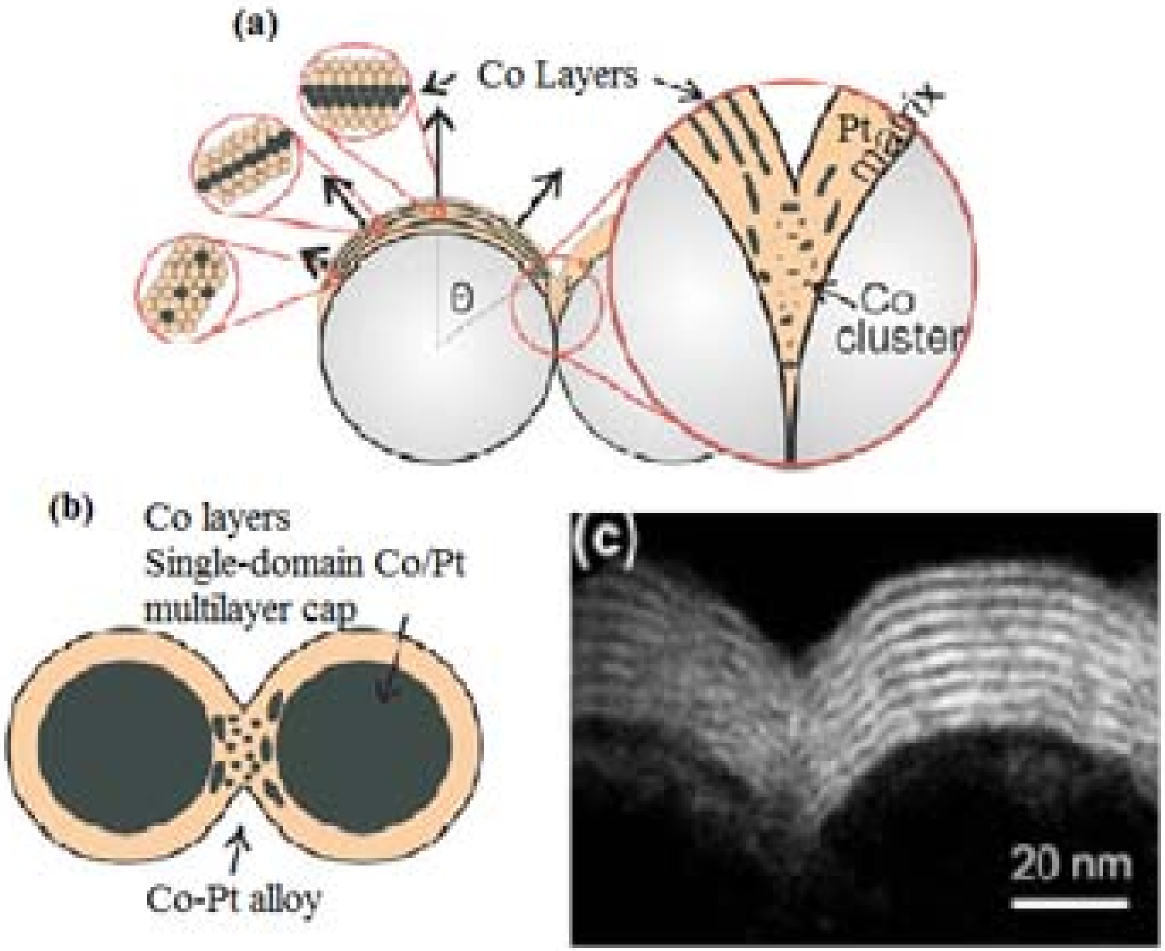
Full film vs nanobumps





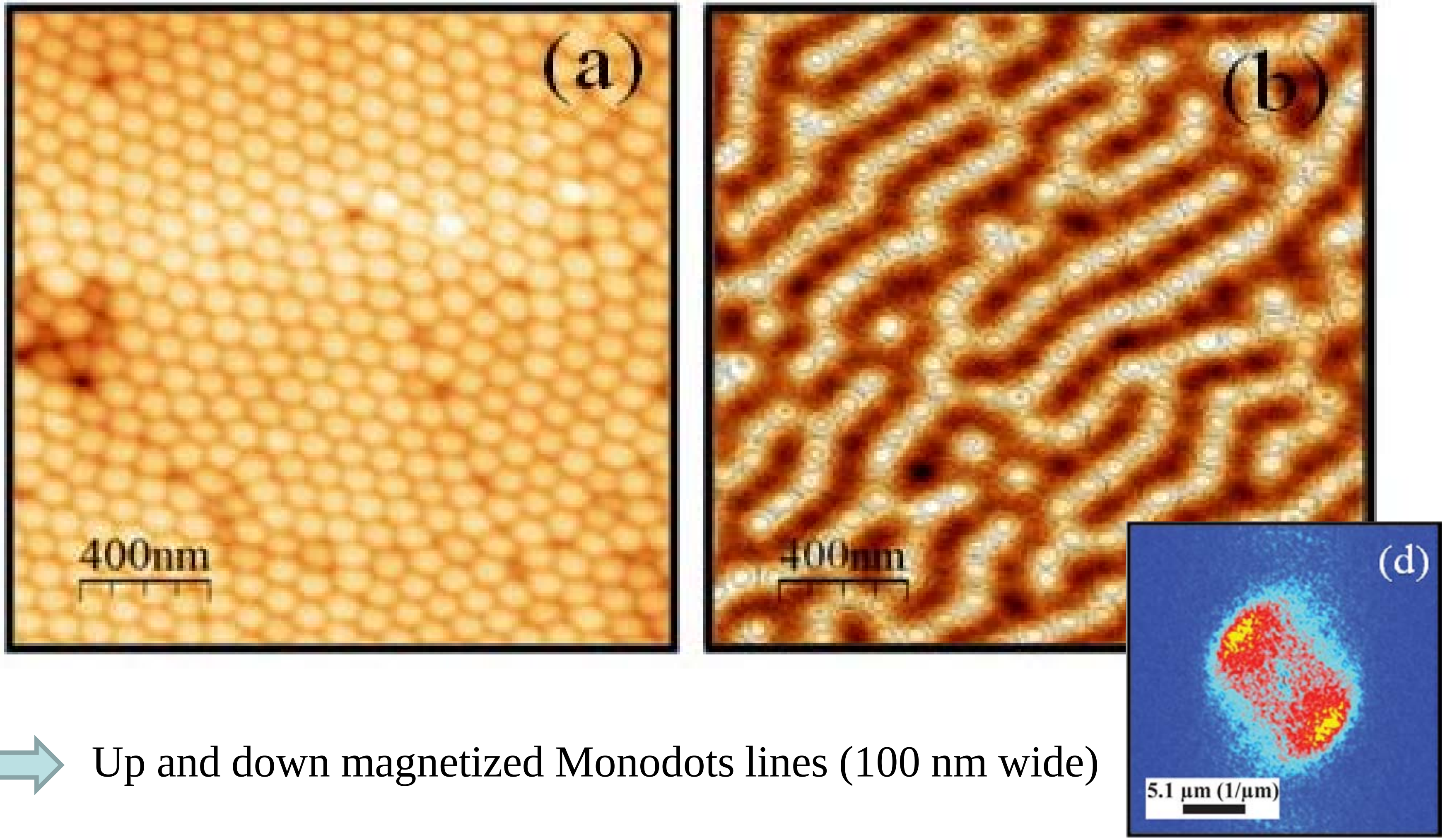
L. Piraux et al., Appl. Phys. Lett. 101, 013110 (2012)

Origin of the inter-bumps magnetic decoupling



J. Kimling et al. J. Appl. Phys. (2010)

Magnetic force microscopy on the demagnetized state

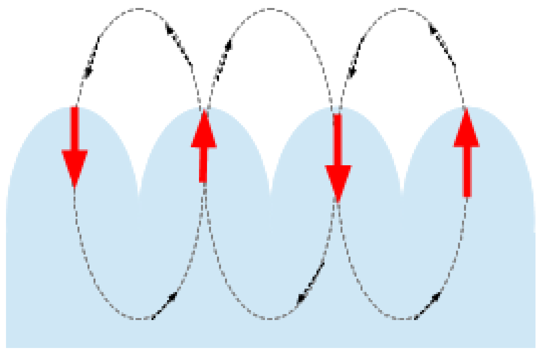


➡ Up and down magnetized Monodots lines (100 nm wide)

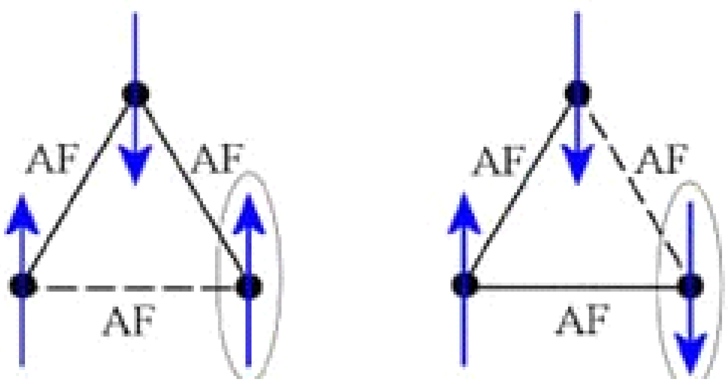
L. Piraux et al., Appl. Phys. Lett. 101, 013110 (2012)

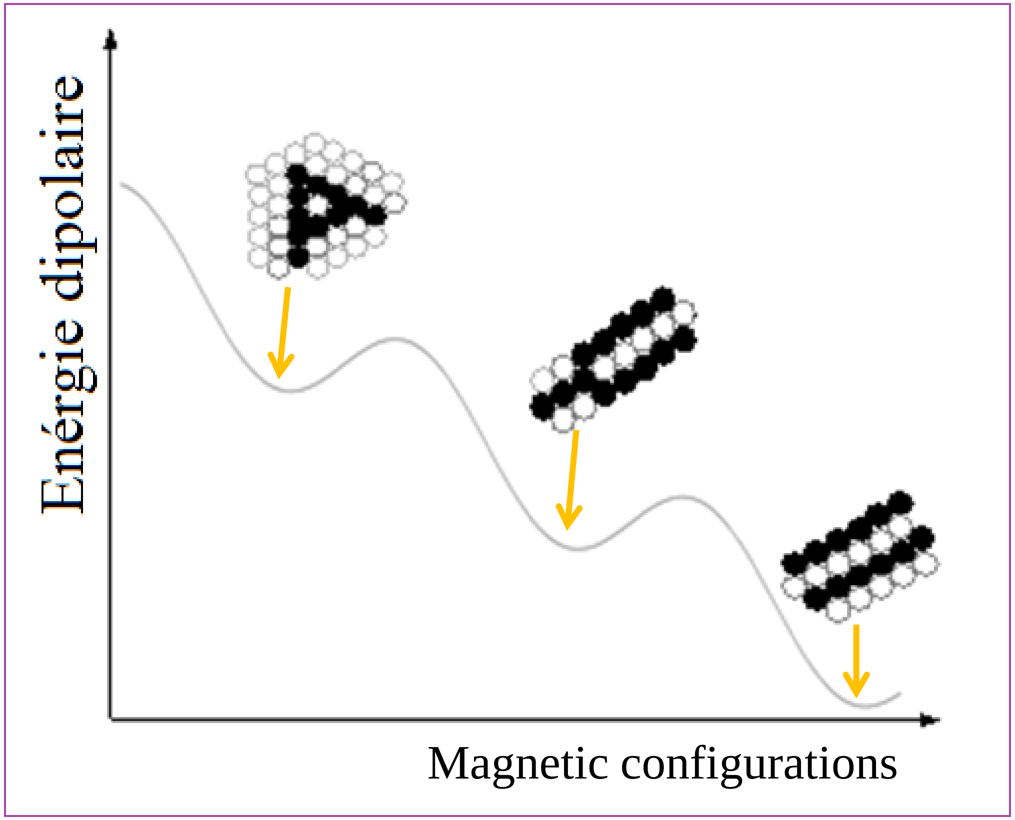
Demagnetized state due to hexagonal lattice frustrations

✓ Dipolar fields

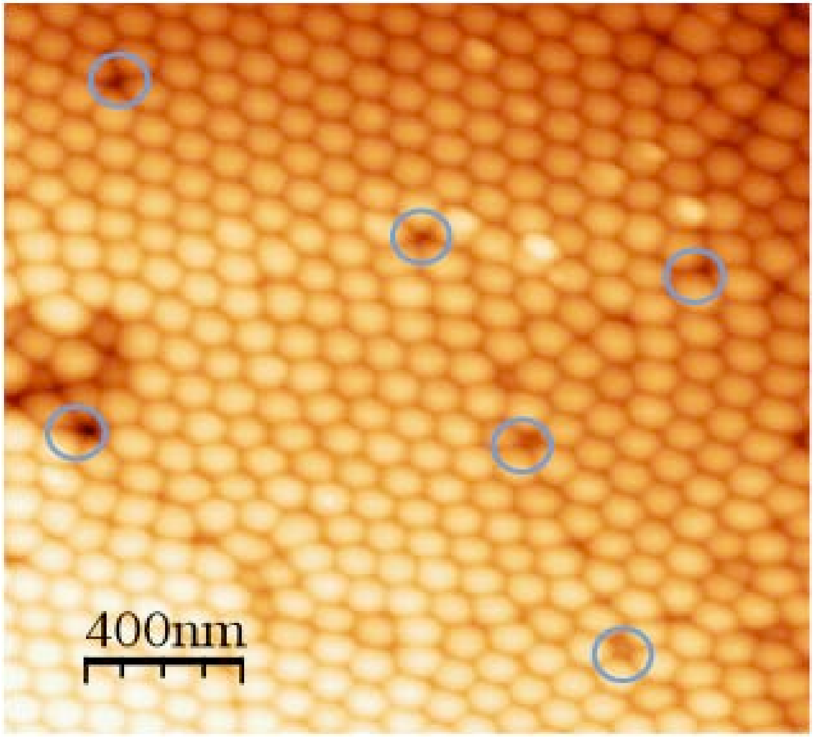


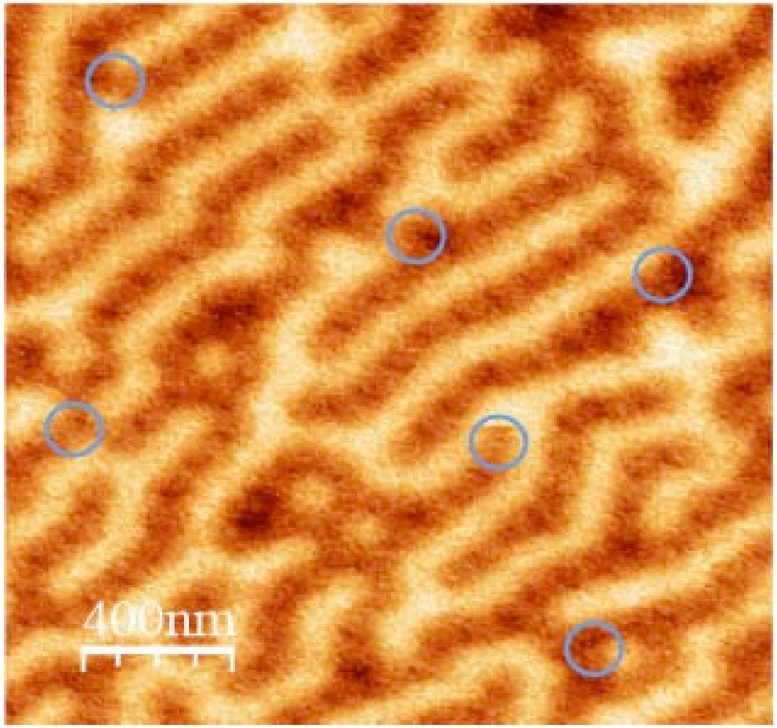
✓ Magnetic frustrations





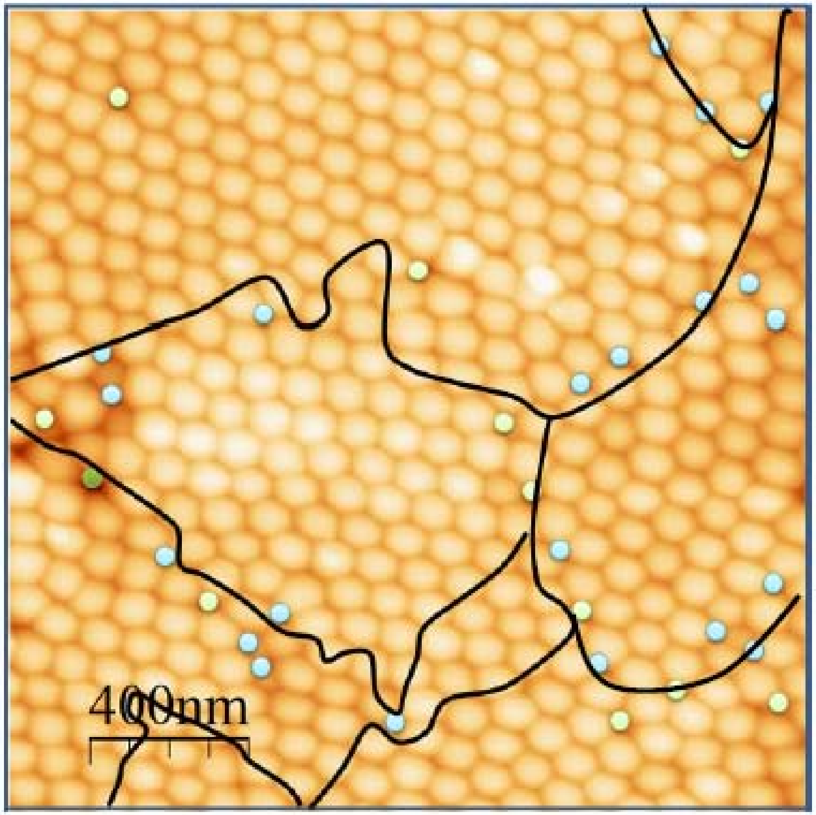
Origin of disorder in the demagnetized state

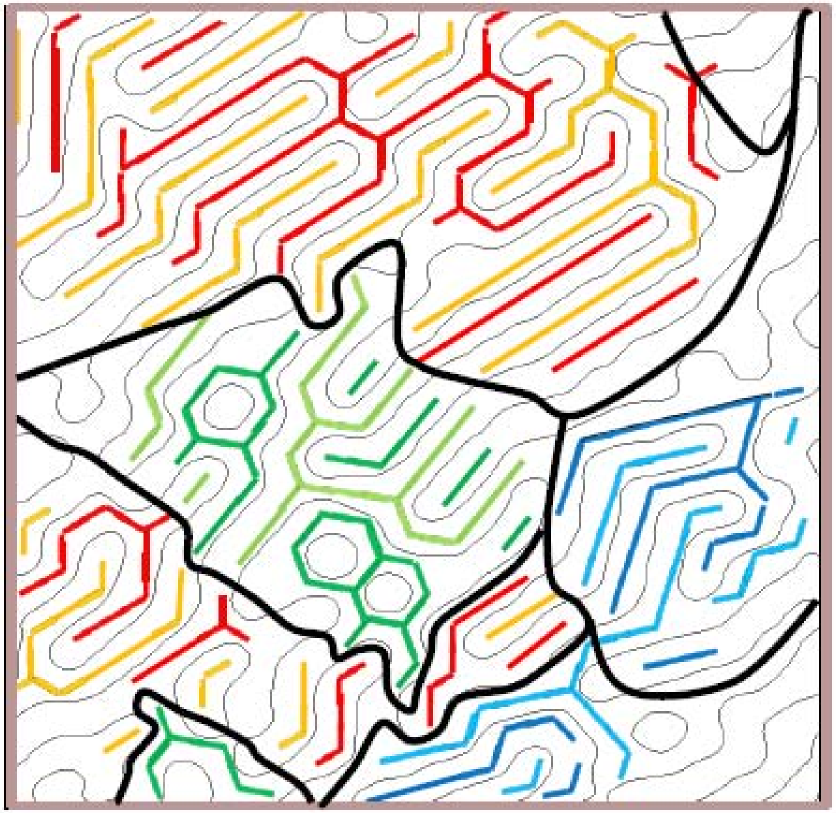




- Topological defects
- « Anisotropy and Ms » dot-to-dot distribution

Origin of disorder in the demagnetized state





Long range influence of the structural order

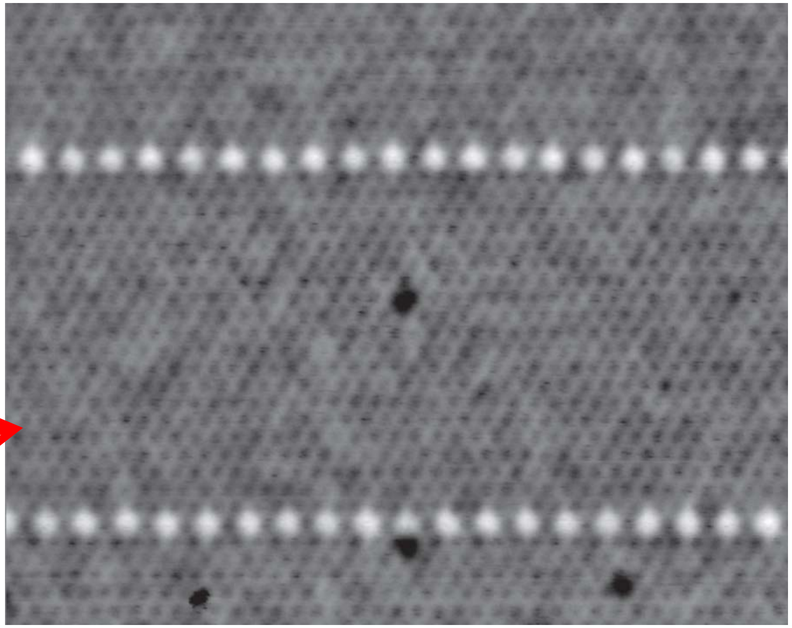
New schemes for Bit patterned media : summary

- Bit patterned media : [Co/Pd]x deposited on pre-patterned substrate
- 2 problems : | decrease Hc while maintaining thermal stability
  | decrease the switching field distribution
- ECC type media (incoherent reversal) is a solution to both problems
- Auto-assembled nanobumps system

<u>Coming next :</u>

Heat assited recording
+ Bit pattern media

1 Tb/inch^2



B.C. Stipe et al., Nature Photonics 4, 484 (2010)

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E.E. Fullerton

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