Institute of Nuclear Physics Polish Academy of Sciences, Cracow, Poland

Direct laser interference patterning of magnetic films

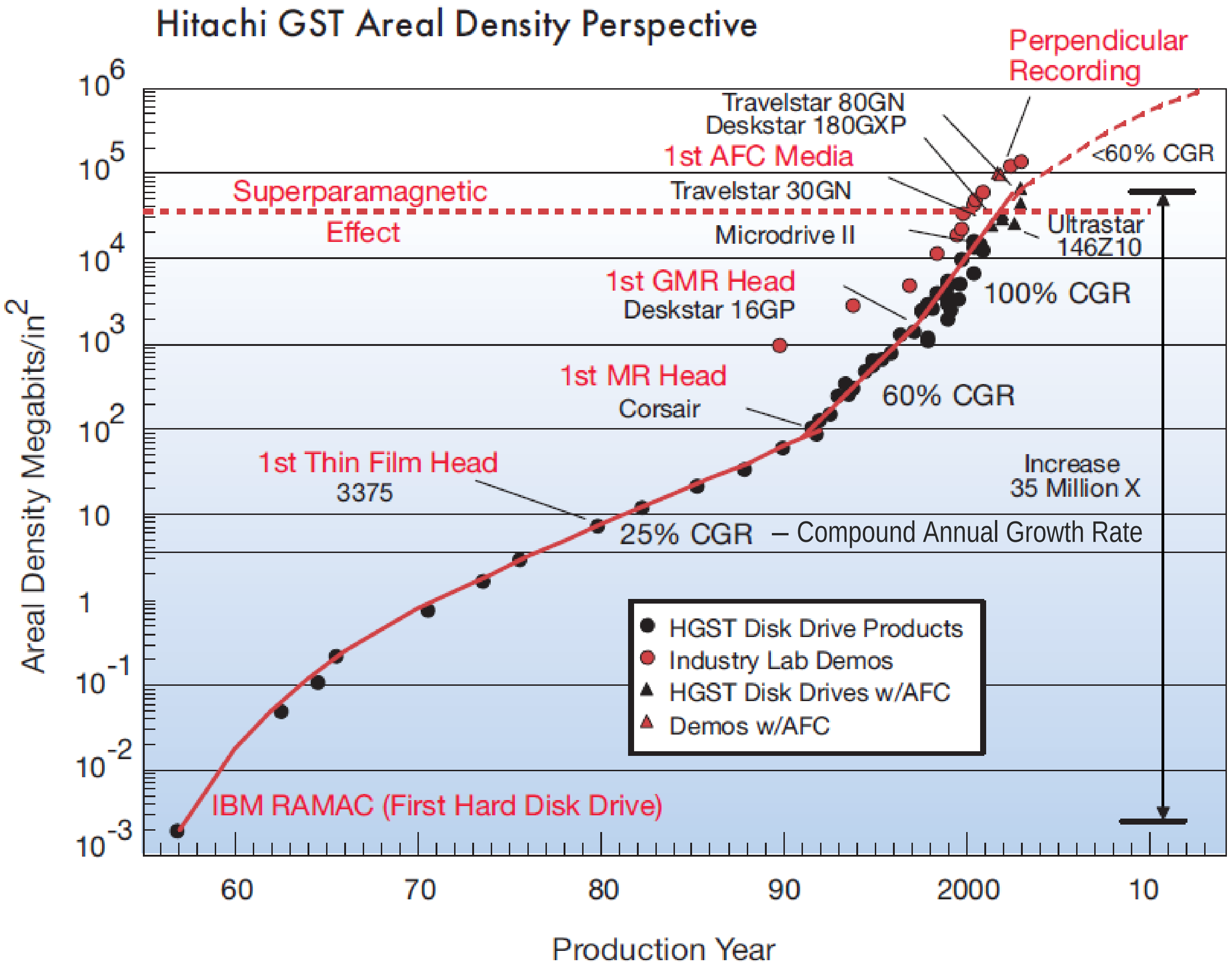
Y. Zabila, M. Perzanowski, A. Polit,

M. Krupiński and M. Marszałek

Outline

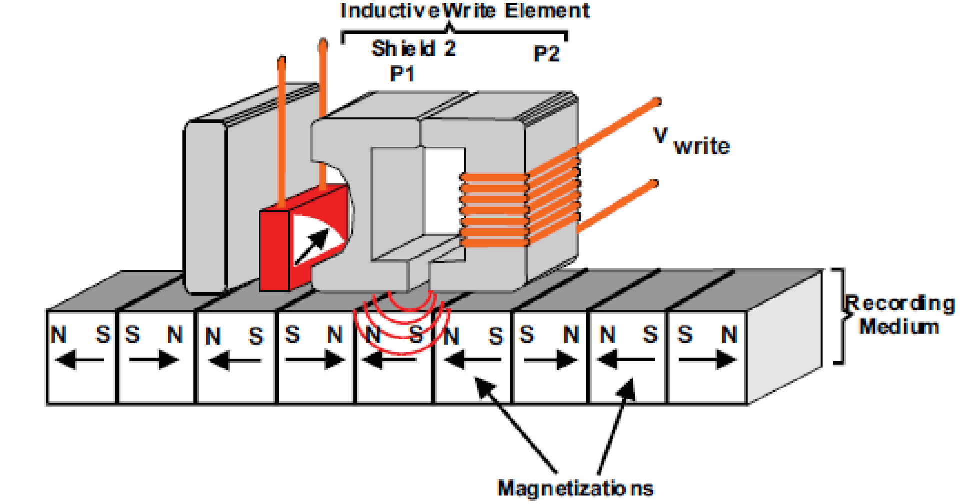
- Introduction: Magnetic recording and superparamagnetic limit
- Magnetic films for perpendicular magnetic recording
- Patterned magnetic arrays
- Conclusions

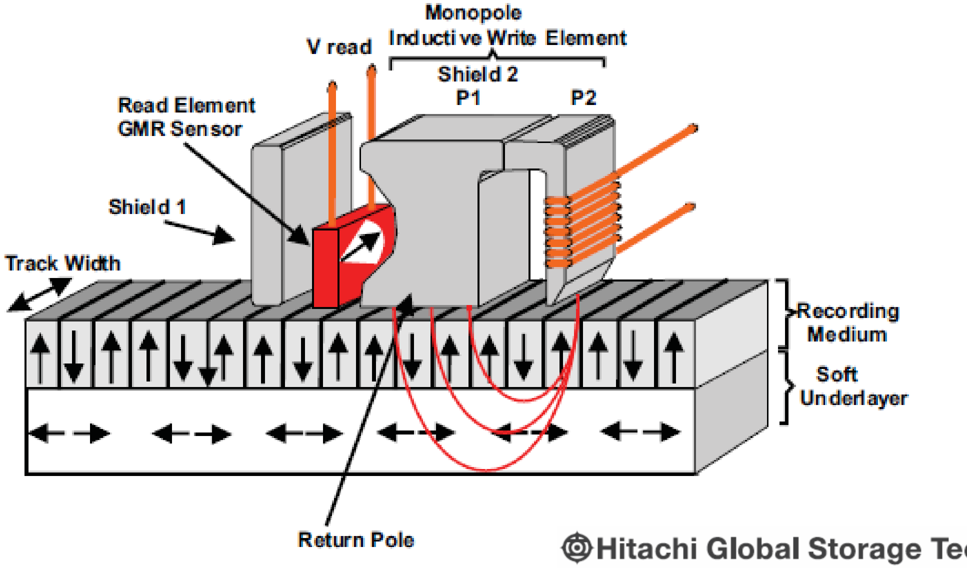
Magnetic recording perspective

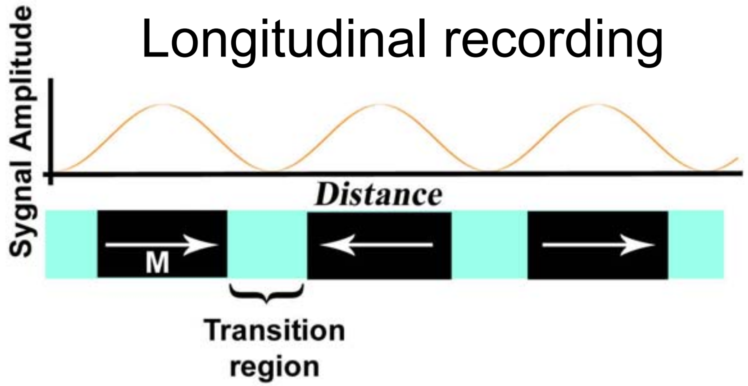


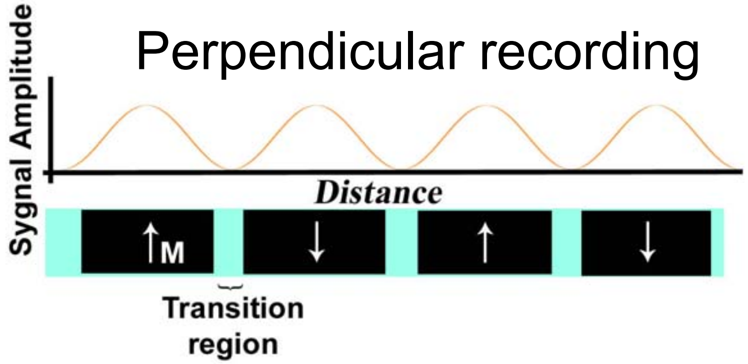
Hitachi Global Storage Technologies

Magnetic recording diagrams









Hitachi Global Storage Technologies

Superparamagnetic limit

To avoid thermal instabilities, a minimal stability ratio of stored magnetic energy, $K_u \cdot V$, to the thermal energy, $k_B \cdot T$,

$$\frac{K_u \cdot V}{k_B \cdot T} \cong 50 - 70$$

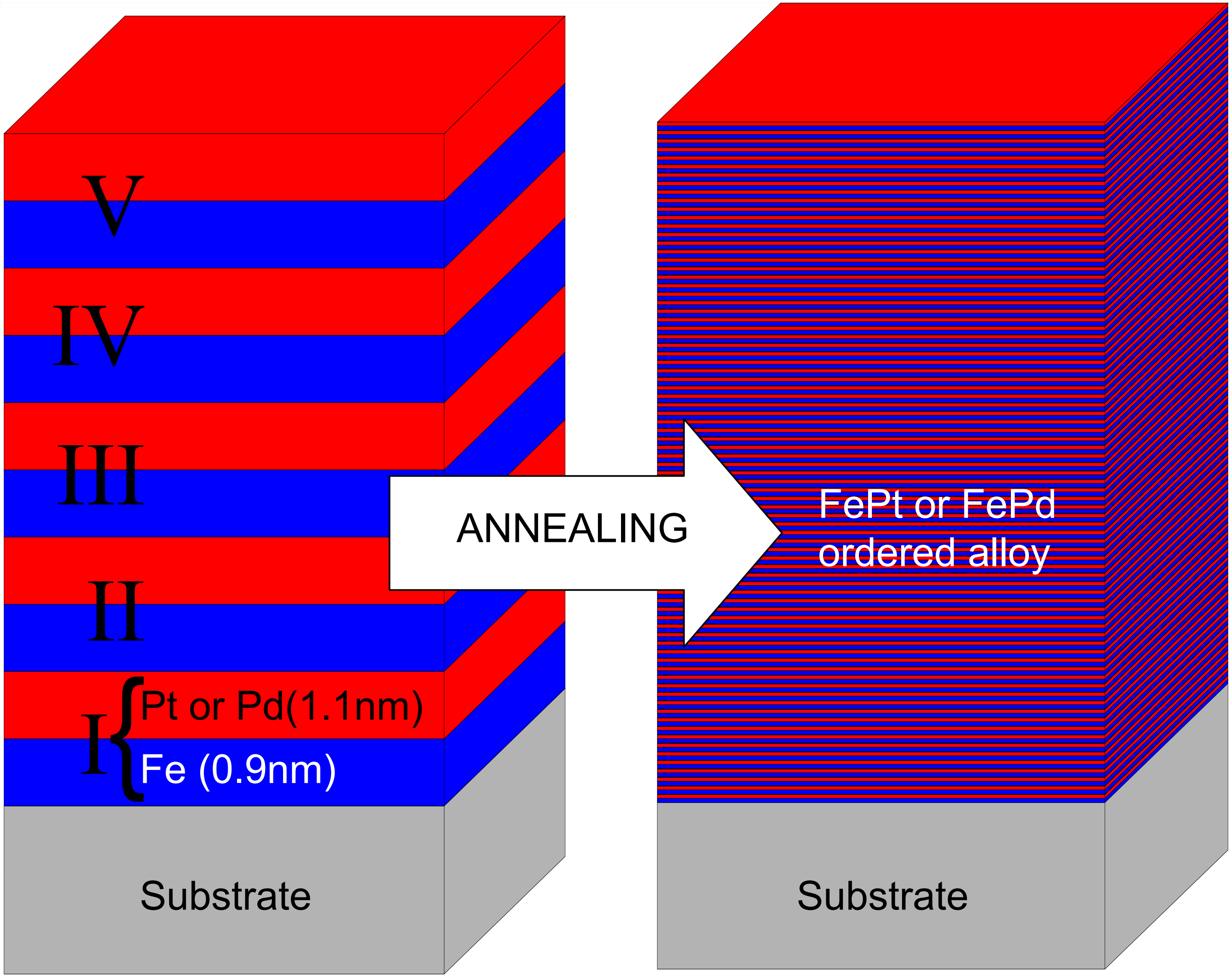
is required.

High K_u materials

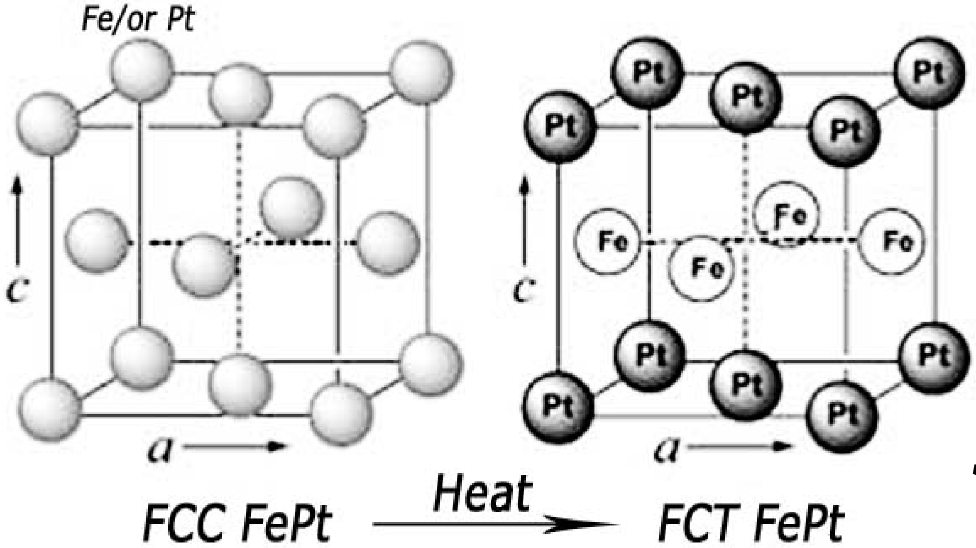
alloy system	material	K_u (10^7erg/cm^3)	M_S (emu/cm^3)	H_K (kOe)	T_C(K)
	CoPtCr	0.20	298	13.7	--
Co-alloys	Co	0.45	1400	6.4	1404
	Co_3Pt	2.0	1100	36	--
	FePd	1.8	1100	33	760
$L1_0$	FePt	6.6-10	1140	116	750
phases	CoPt	4.9	800	123	840
	MnAl	1.7	560	69	650
rare-earth	$Fe_{14}Nd_2B$	4.6	1270	73	585
transition metals	$SmCo_5$	11-20	910	240-400	1000

D. Weller et al. IEEE TRANSACTIONS ON MAGNETICS, Vol. 36, No. 1, (2000)

Samples preparation



Ordering parameter



The degree of ordering in the alloy is

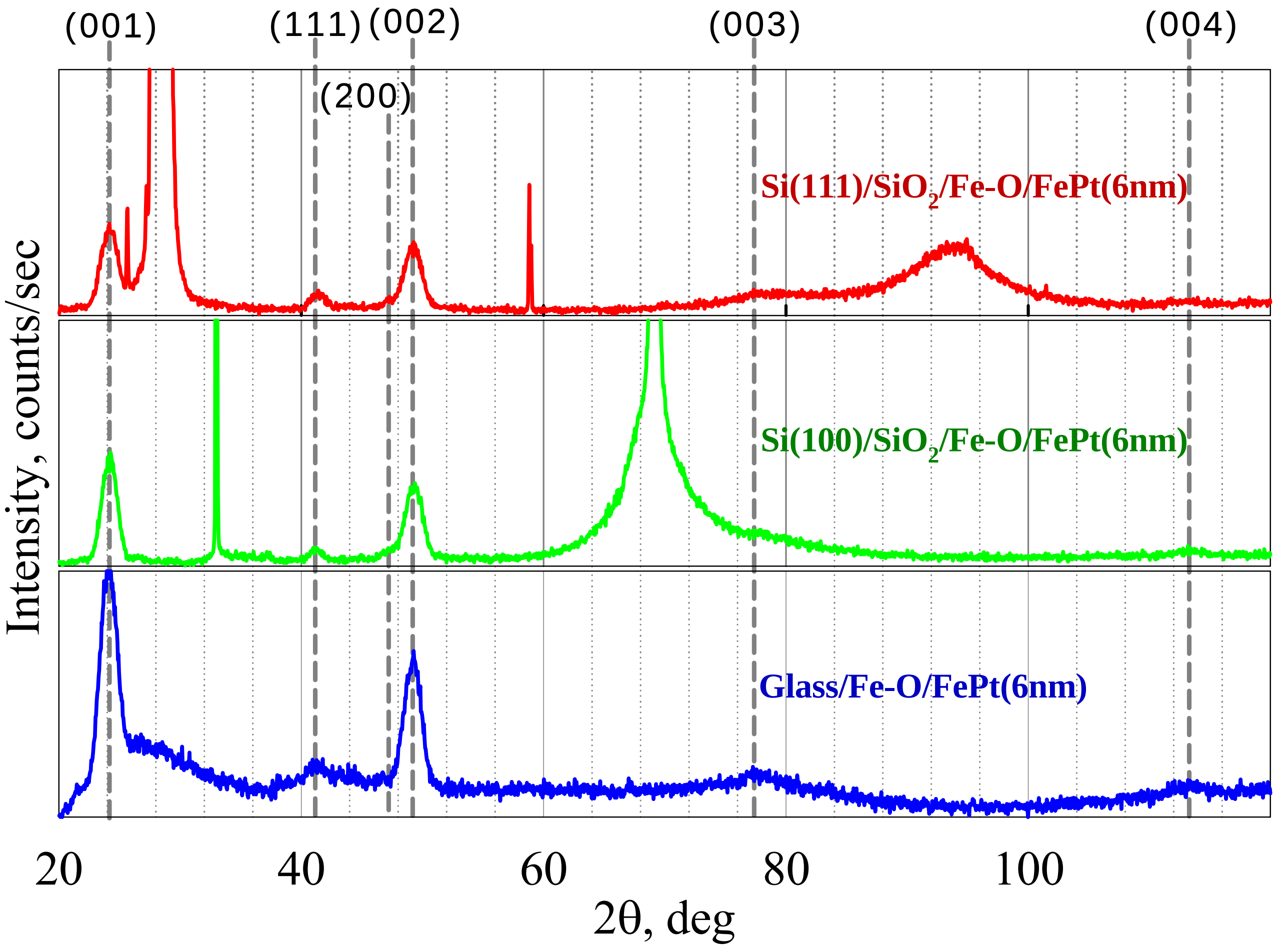
$$S = \frac{r_{Fe} - x_{Fe}}{1 - x_{Fe}} = \frac{r_{Pt} - x_{Pt}}{1 - x_{Pt}}$$

S – ordering parameter;

x_{Fe}, (x_{Pt}) – is the mole fraction of Fe (Pt) in the alloy;

r_{Fe}, (r_{Pt}) – is the probability that an Fe (Pt) sublattice site is occupied by an Fe (Pt) atom

XRD measurements

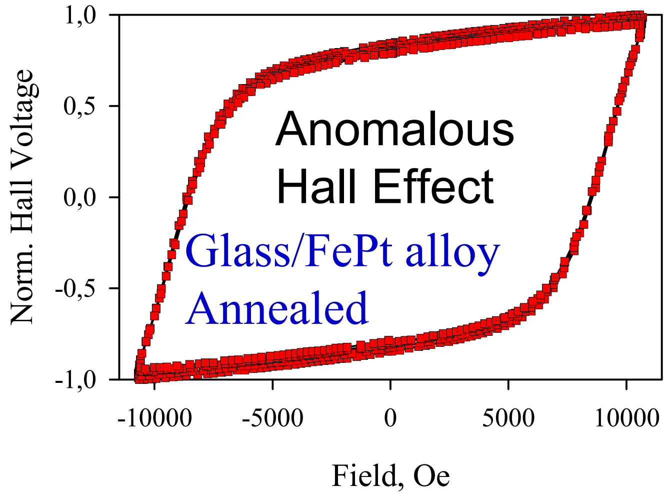


$S_{001}=0.79$

$S_{001}=0.79$

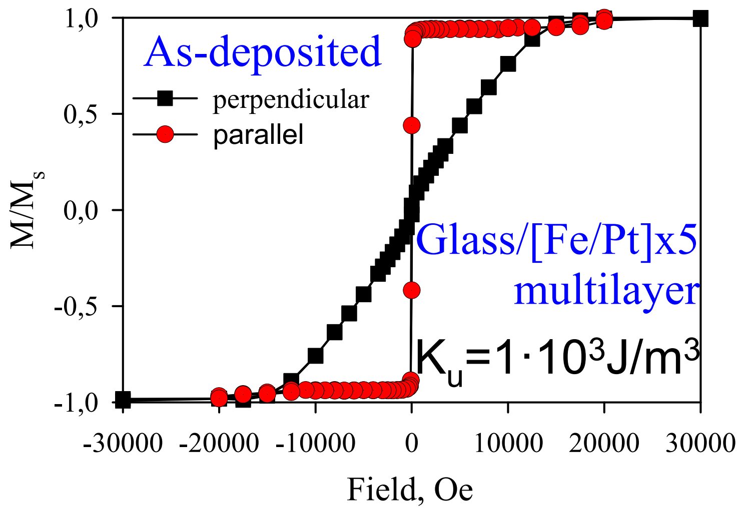
$S_{001}=0.94$

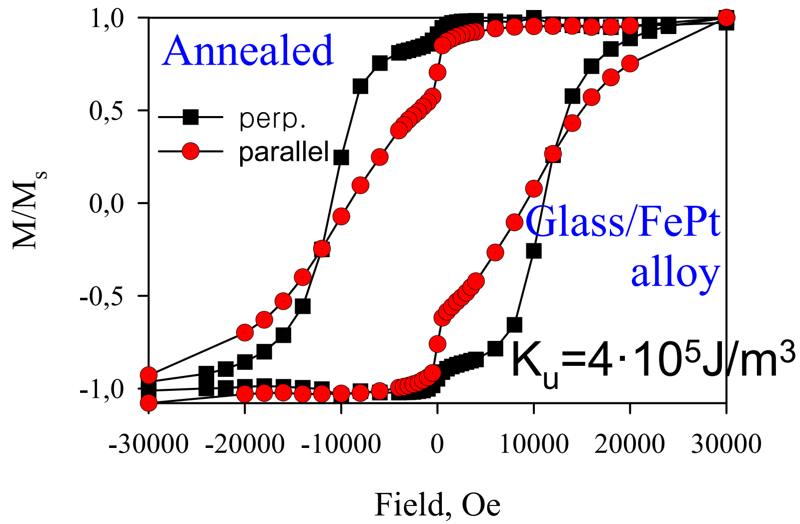
Magnetic properties



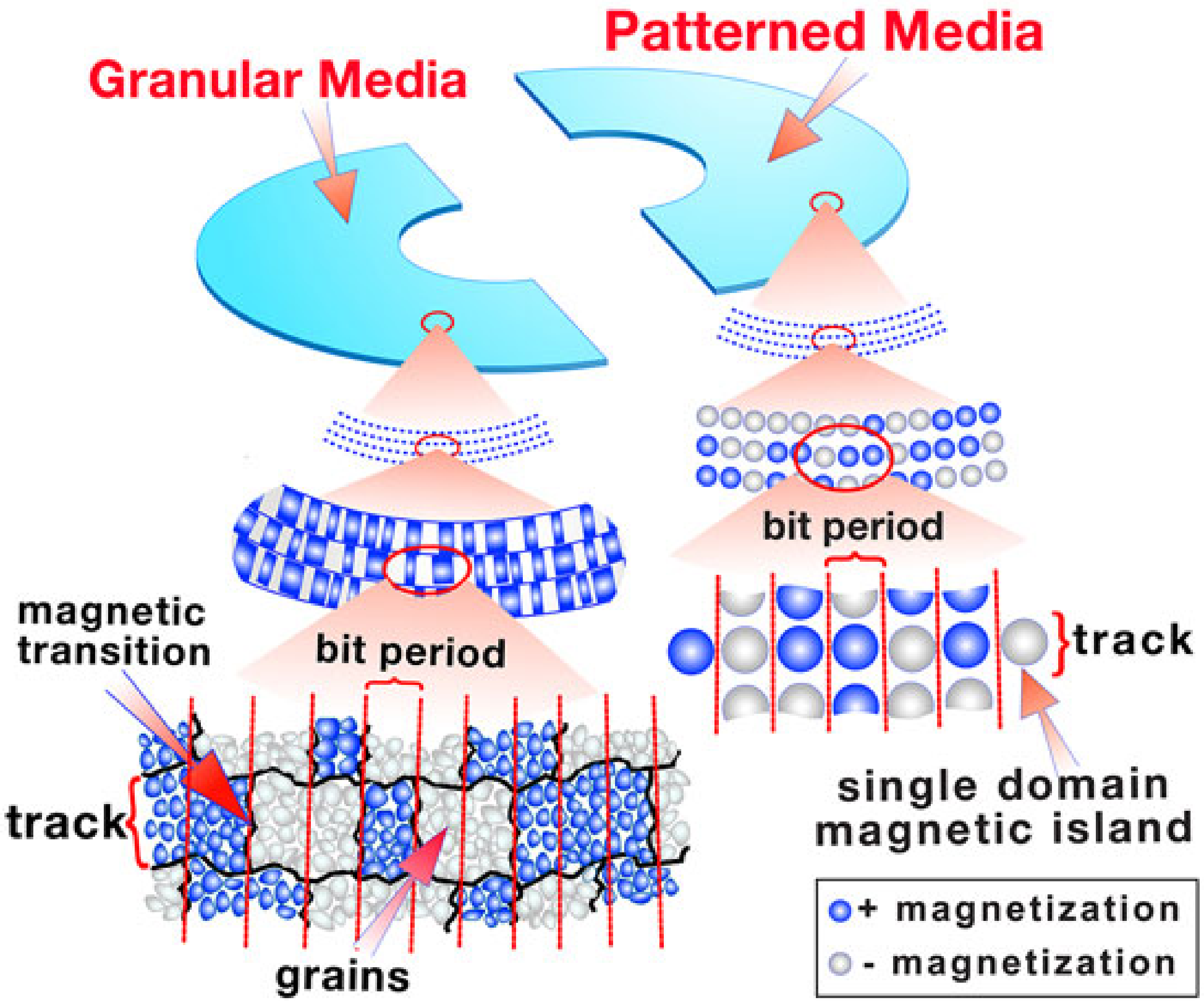
$$\rho = R_0 \cdot B + 4 \cdot \pi \cdot R_s \cdot M$$

ρ – transverse resistivity;
R_0 – usual Hall coefficient;
B – magnetic field;
R_s – anomalous Hall coefficient;
M – magnetization.

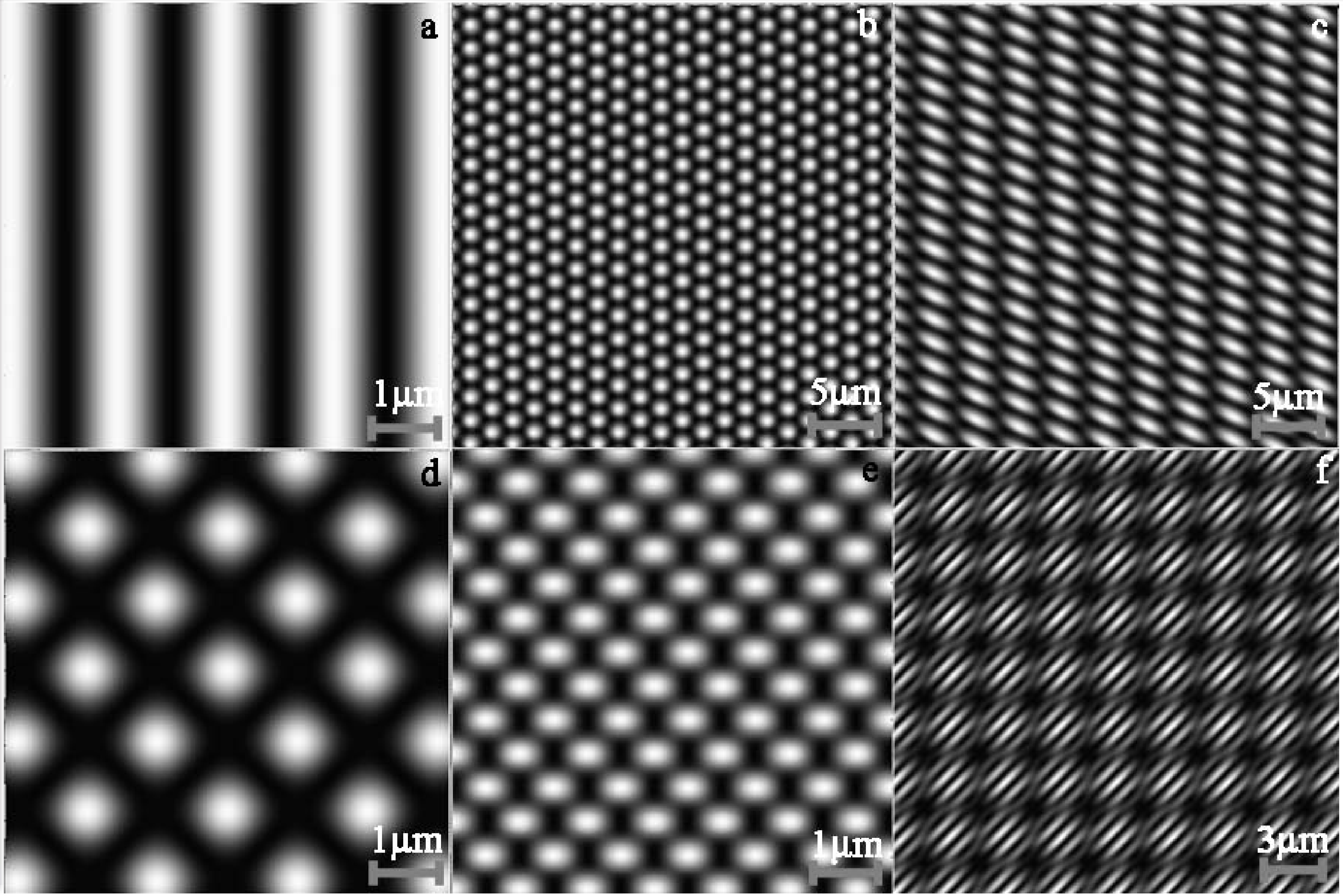




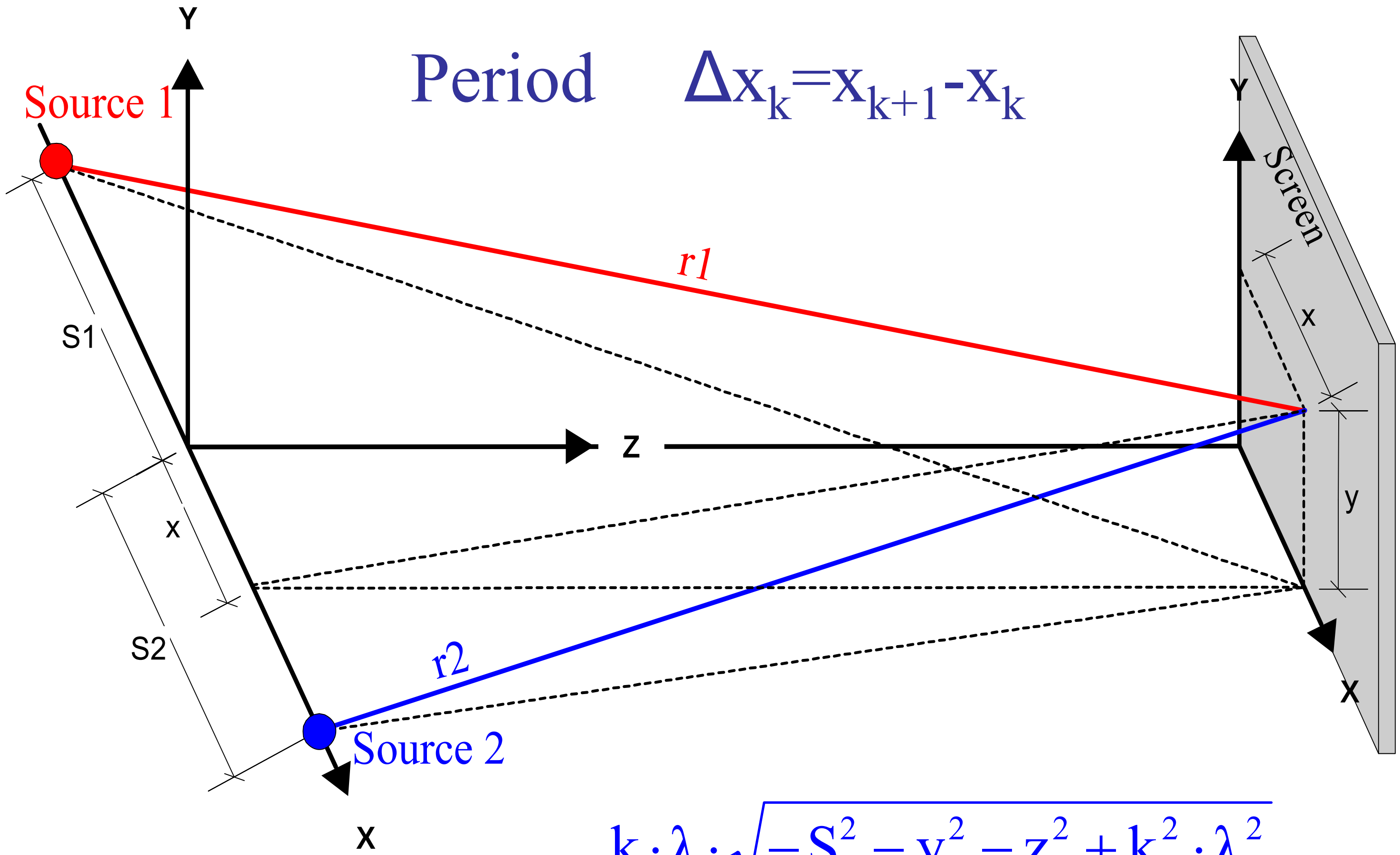
Bit Patterned Media



2, 3 and 4 beam interference

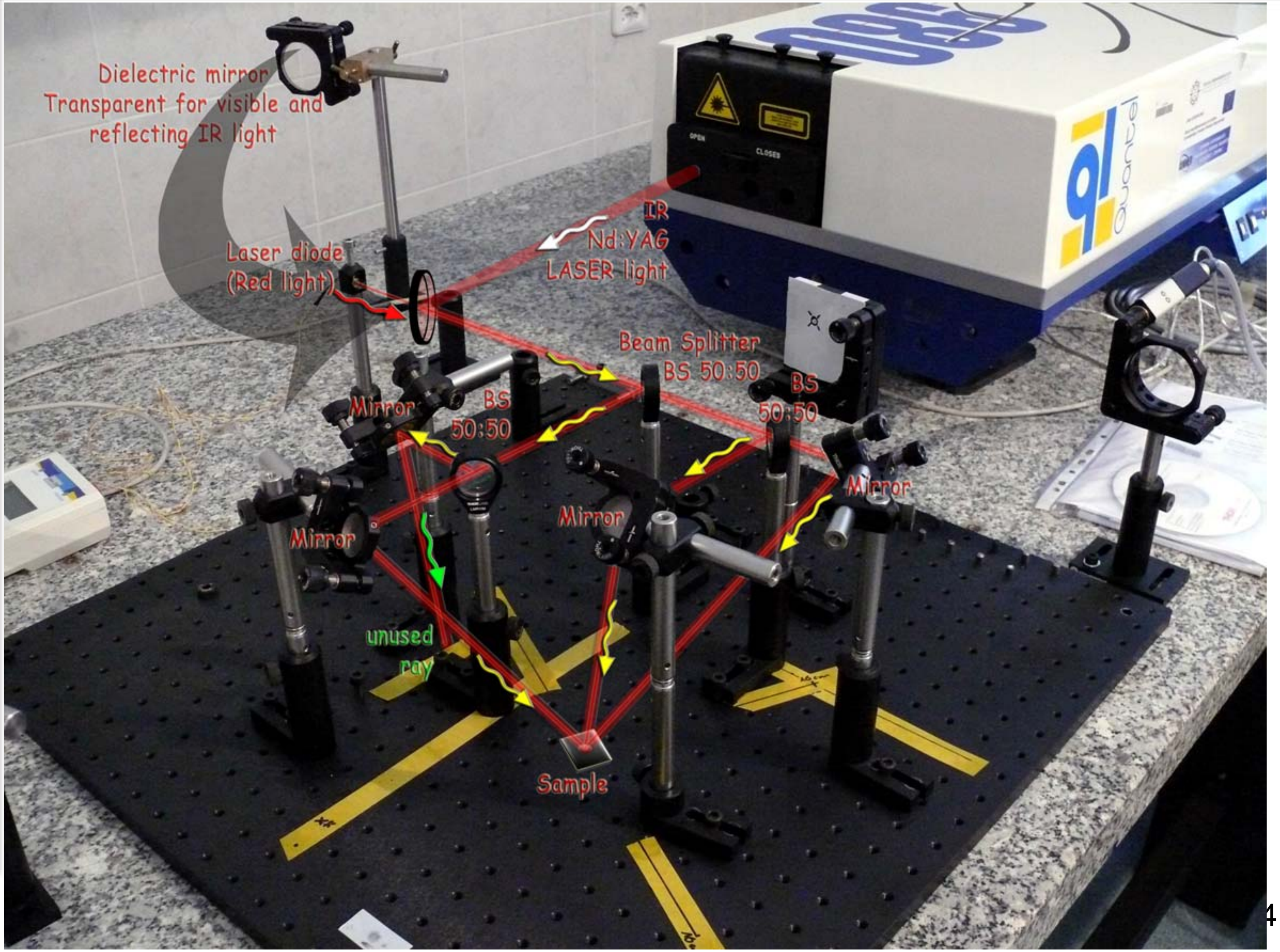


Experimental setup

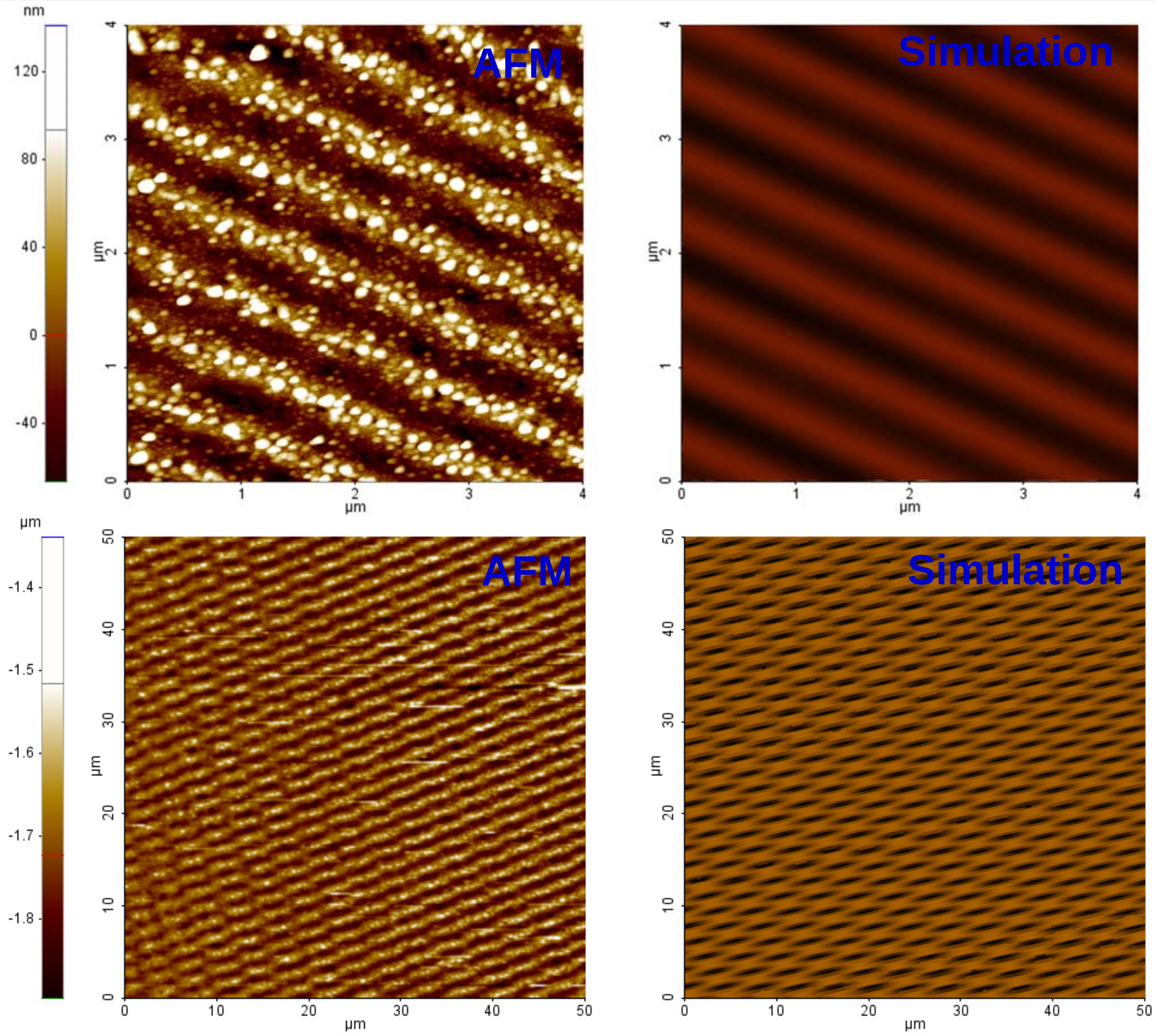


$$x_k = \frac{k \cdot \lambda \cdot \sqrt{-S^2 - y^2 - z^2 + k^2 \cdot \lambda^2}}{\sqrt{k^2 \cdot \lambda^2 - S^2}}$$

Experimental setup



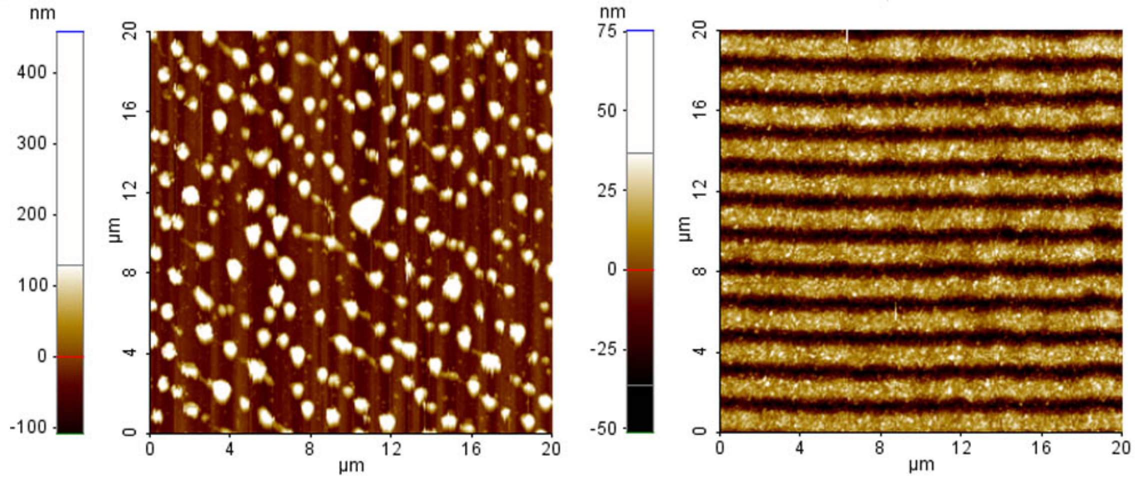
Patterning


nm
120
80
40
0
-40
AFM
Simulation
µm
µm
-1.4
-1.5
-1.6
-1.7
-1.8
AFM
Simulation
µm
µm

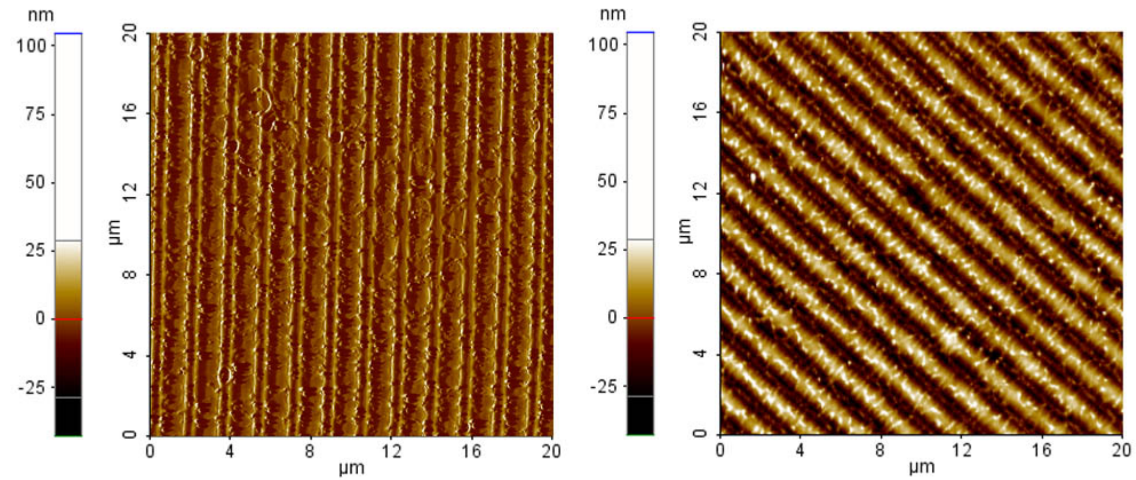
Energy fluence variations

QSD 350µs

QSD 330µs



$Si(100)/SiO_{2\,(100nm)}/Pt_{(5nm)}/[Co_{(0.3nm)}/Pt_{(0.8nm)}]x10/Pt_{(2nm)}$

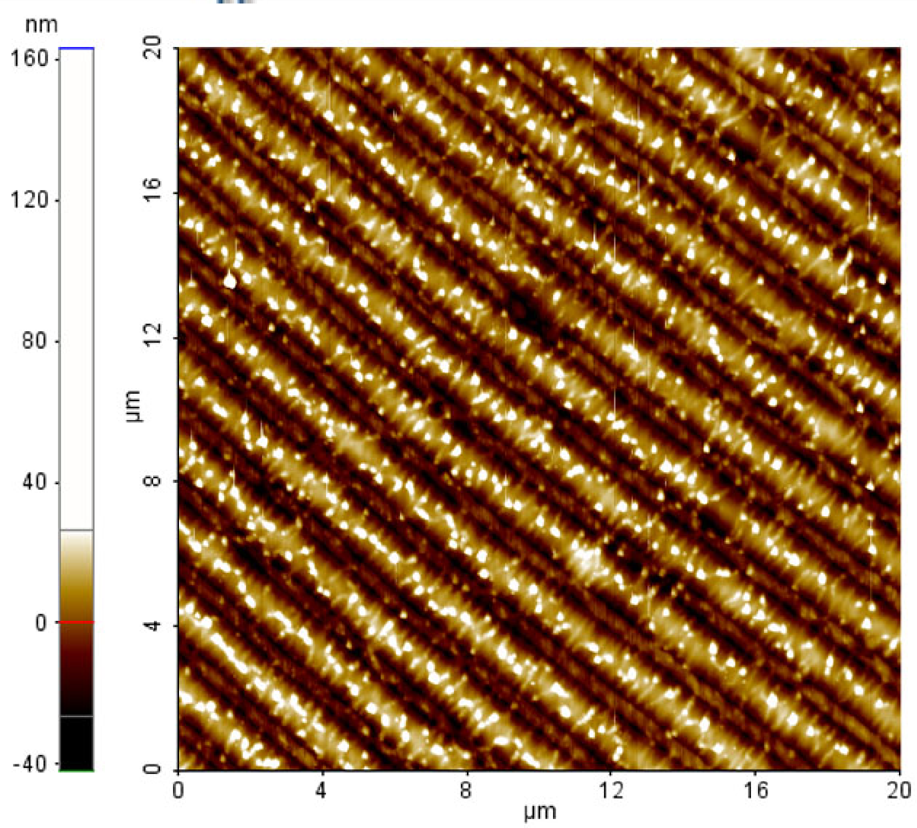


QSD 325µs

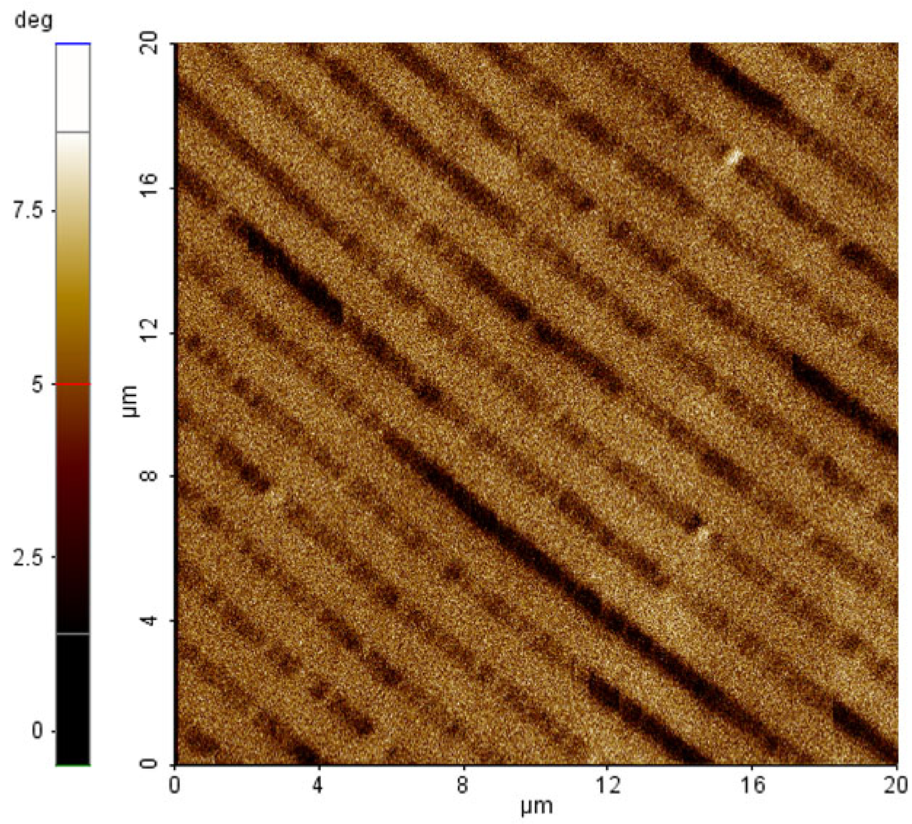
QSD 310µs

$Si(100)/[Fe_{(0.9nm)}/Pd_{(1.1nm)}]x5$

The FePd magnetic wires array



AFM - Topography

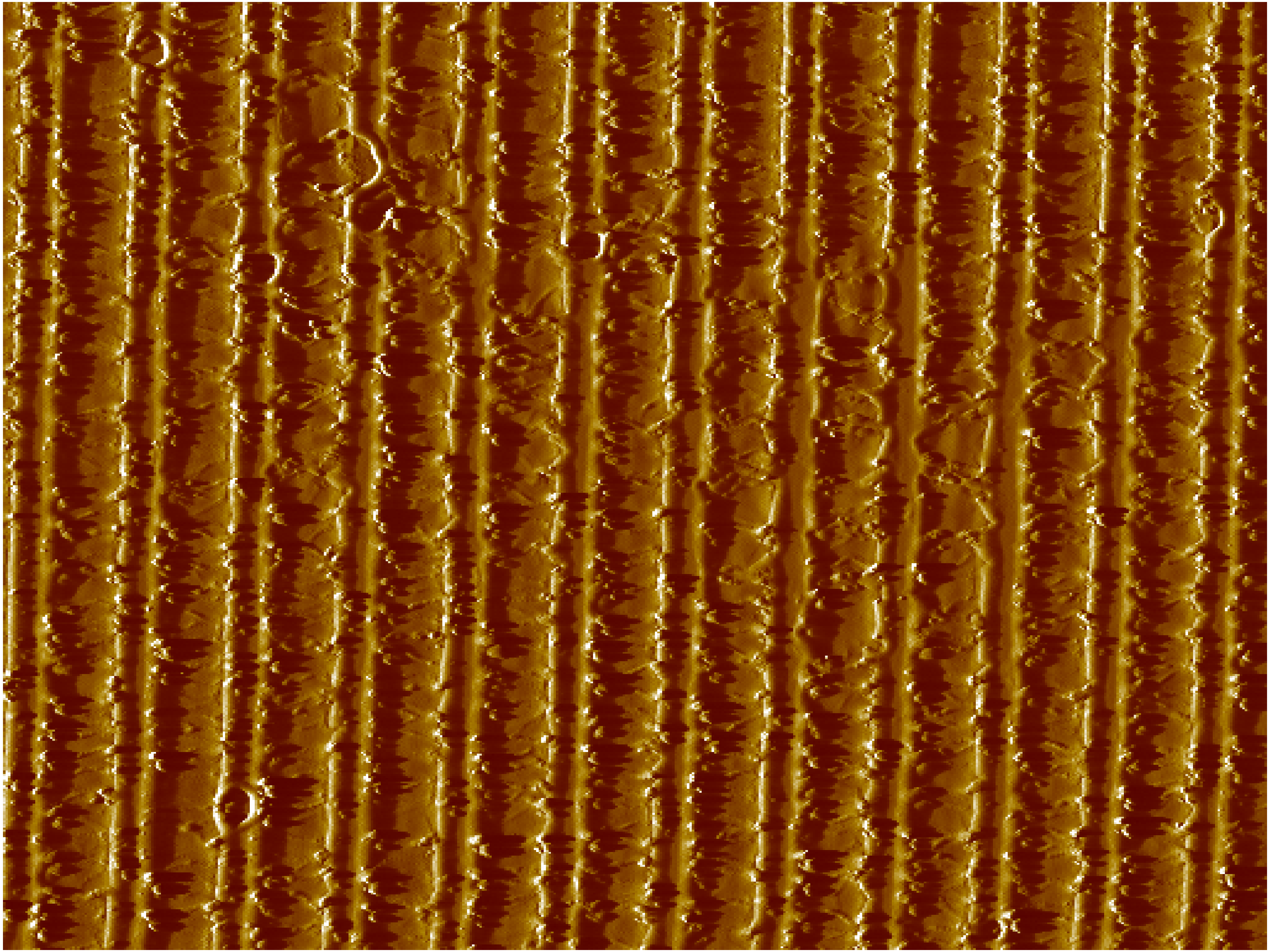


MFM - Phase

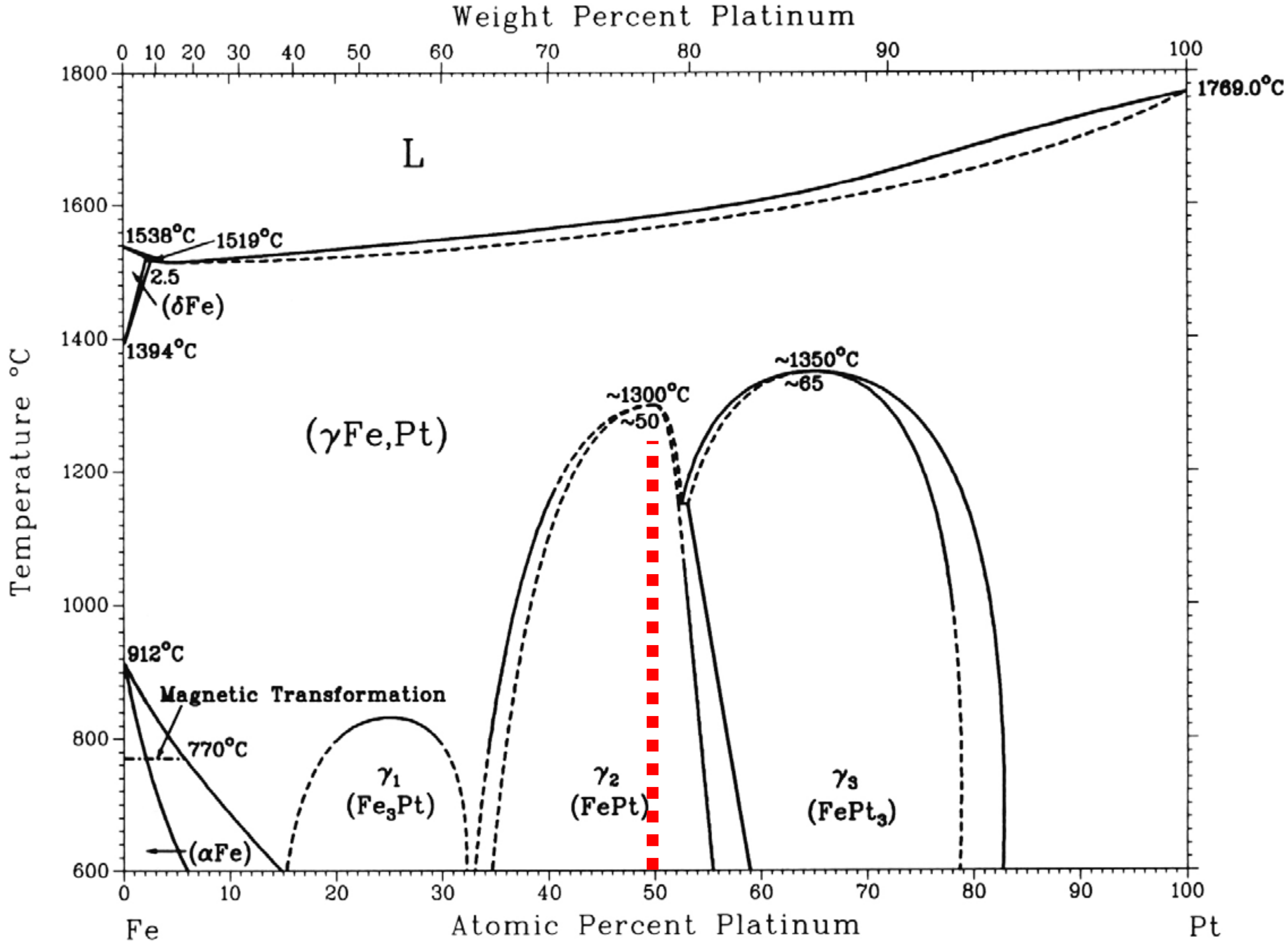
Conclusions

- Direct Laser Interference Patterning is a fast and one of the cheapest way of submicron sructures production.
- Along with short-wave coherent light sources improvement it can be considered as a new litography tool.
- In addition the annealeng stage of magnetic alloy fabrication can be coupled with interference litography process.

Thank you

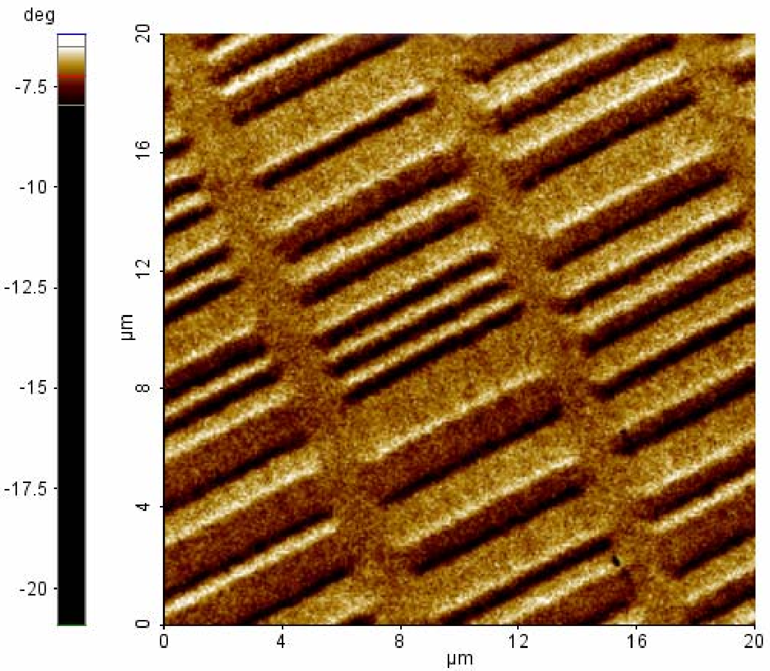


FePt magnetic alloy

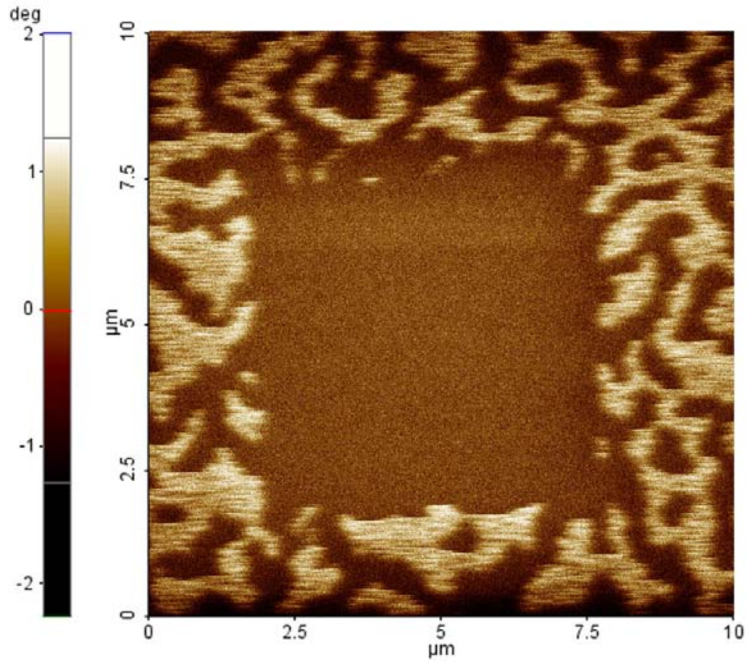


Magnetic recording medium

MFM images taken at



a logitidinal medium surface



a perpendicular medium surface with square region magnetized by MFM tip

XRD measurements