MODIFICATION OF MULTILAYERED STRUCTURES WITH PERPENDICULAR MAGNETIC ANISOTROPY

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Motivation

FePt, CoPt and FePd fct ordered alloy thin films with the perpendicular magnetic anisotropy are promising materials for the future high density magnetic recording. In order to apply such films as a perpendicular magnetic recording medium, it is necessary to control the orientation of the c-axis, which is the magnetization easy axis. For this purpose we use deposition of multilayered films on the silicon covered by native oxide or on the glass with subsequent rapid thermal annealing (RTA). The ordering of FePt alloy and the preferred orientation of grains depend on annealing temperature and time.

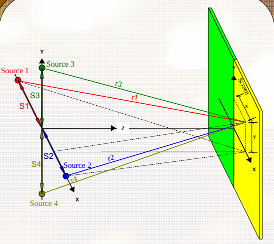
The investigation of the FePt ordered alloy showed the strong positive correlation between the SQUID and magnetoresistance measurements. This conformity allows us to use magnetoresistance measurement as a tool for fast determination of annealing conditions.

In this work we have focused attention on modification of the FePt multilayer magnetic properties by pulsed laser annealing and patterning. The direct laser interference patterning (DLIP) is a rapid and economical way to fabricate nanostructures with periods of a few hundreds nanometers. Each magnetic nanodot of such structures can be used to store a single bit of information in a bit-patterned media.

This poster presents the calculations of laser light intensity coming from the interference of 2, 3 and 4 coherent light beams used for the direct laser interference patterning. We have calculated the influence of the optical system geometry on periodicity, linearity and contrast of the interference images. Basing on the results of these calculations the optimal configuration of optics for laser patterning has been chosen, and the experimental setup was developed.

The setup has been used for patterning with Nd:YAG laser of ordered FePt alloy annealed by RTA method. The pattern images obtained with atomic force microscope (AFM) are compared with theoretical images. The magnetic properties of sample are also shown.

Theory



Scheme of direct laser patterning setup.

2 beam interference

In case of two-beam interference sources 3 and 4 are absent. Under the assumption of $S_1=S_2=S$ the solution for the amplitude of the resultant wave has the form:

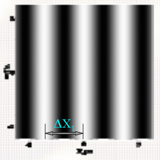
$$A = 2\cdot A_0\cdot\cos\left(\frac{\pi}{\lambda}\cdot\left(\sqrt{(S-x)^2+y^2+z^2}-\sqrt{(S-x)^2+y^2+z^2}\right)\right)$$

where A_0 – amplitude of interfering beams; λ – laser beam wavelength.

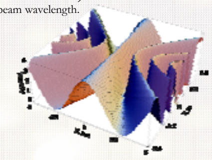
The fringe period defined as:

$$\Delta x_k = \frac{(k+1)\cdot\lambda\cdot\sqrt{-S^2-y^2-z^2+(k+1)^2\cdot\lambda^2}}{\sqrt{(k+1)^2\cdot\lambda^2-S^2}} - \frac{k\cdot\lambda\cdot\sqrt{-S^2-y^2-z^2+k^2\cdot\lambda^2}}{\sqrt{k^2\cdot\lambda^2-S^2}}$$

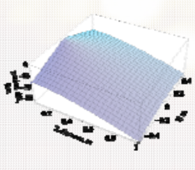
The dependence of the fringe period on the experimental setup geometry



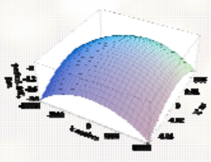
Two beam interference image.



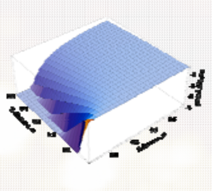
The dependence of the interference pattern intensity on the position on the screen. Large scale along the y-axis allow us to illustrate a quasi-periodicity of the fringe pattern.



The dependence of fringe period on Z distance and Y-axis position (λ=700 nm, S=0.025 m, k=0).

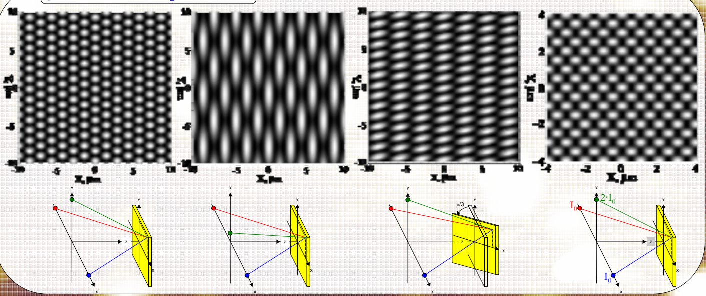


Interference fringe intensity dependence on the position on the screen (λ=700 nm, S=0.025 m, k=0).

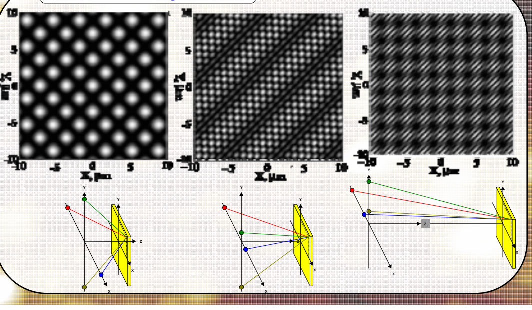


Fringe period versus the S and Z distances (λ=700 nm, S=0.025 m, k=0).

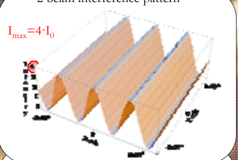
3 beam interference



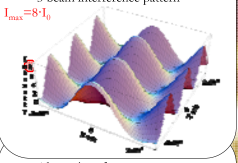
4 beam interference



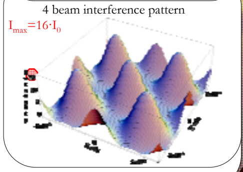
2 beam interference pattern



3 beam interference pattern



4 beam interference pattern



Contrast

The relation for the resulting amplitude for 2-, 3- and 4-beam interference:

for 2 – beam interference: $$A = 2\cdot A_0\cdot\cos\left(\frac{\pi\cdot(r_1-r_2)}{\lambda}\right)$$

for 3 – beam interference: $$A = A_0\cdot\sqrt{2\cdot\cos\left(\frac{2\cdot\pi\cdot(r_1-r_2)}{\lambda}\right)+2\cdot\cos\left(\frac{2\cdot\pi\cdot(r_1-r_3)}{\lambda}\right)+2\cdot\cos\left(\frac{2\cdot\pi\cdot(r_2-r_3)}{\lambda}\right)+3}$$

for 4 – beam interference: $$A = A_0\cdot\sqrt{\left(\cos\left(\frac{2\cdot\pi\cdot r_1}{\lambda}\right)+\cos\left(\frac{2\cdot\pi\cdot r_2}{\lambda}\right)+\cos\left(\frac{2\cdot\pi\cdot r_3}{\lambda}\right)+\cos\left(\frac{2\cdot\pi\cdot r_4}{\lambda}\right)\right)^2+\left(\sin\left(\frac{2\cdot\pi\cdot r_1}{\lambda}\right)+\sin\left(\frac{2\cdot\pi\cdot r_2}{\lambda}\right)+\sin\left(\frac{2\cdot\pi\cdot r_3}{\lambda}\right)+\sin\left(\frac{2\cdot\pi\cdot r_4}{\lambda}\right)\right)^2}$$

The energy and the intensity are proportional to the square of the amplitude

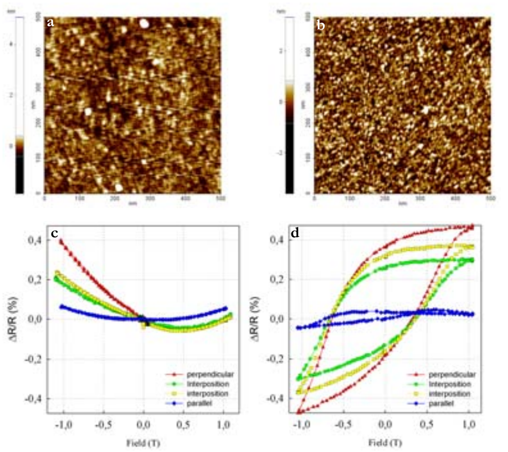
$$I \sim A^2 \Rightarrow I/I_0 \sim \left(\frac{A}{A_0}\right)^2$$

A_0, I_0, A, I – amplitudes and intensities of incidence and interfered beams respectively.

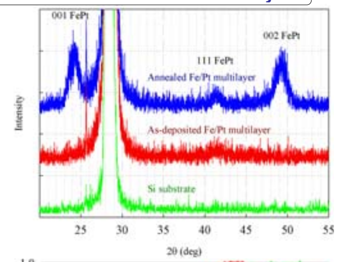
The A/A_0 ratio rises with the increasing number of the beams. Therefore intensities of the interfering beams will increase. Thus, the bigger difference between the interference maxima and minima ($I_{max} - I_{min}$) is, the better contrast will be achieved. The increase of the contrast gives more precise localization of the energy in the laser ablation process. That explains why it is easier to achieve the patterning in case of 3-beams than in case of 2-beams.

Results

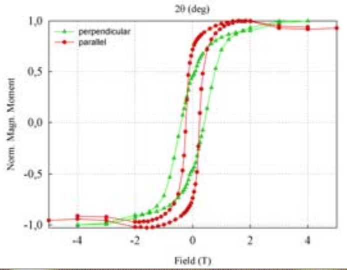
Structural and magnetic properties of RTA annealed Fe/Pt multilayer



AFM topography of as-deposited sample (a) and RTA annealed at 600 °C for 90 s (b), and its magnetoresistance (c, d), respectively.

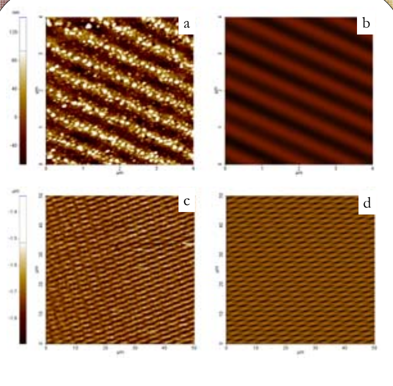


X-ray diffraction (XRD) patterns of Si substrate and Fe/Pt multilayer measured before and after RTA annealing. (001) texture lead to magnetic easy axis aligned perpendicular to the plane.



Magnetic hysteresis loop of the RTA annealed Fe/Pt multilayered film measured by SQUID at magnetic field parallel and perpendicular to the sample plane. It is seen that the easy axis is perpendicular to the sample plane, which is consistent with XRD results.

Topological modification



AFM image (a, c) and calculated interference pattern (b, d) of multilayer irradiated with three laser beams.

Summary

- DLIP technique was used for structural modification of thin multilayers.
- Combination of DLIP and RTA allow to produce nanoparticle arrays with tunable magnetic properties.
- Due to the correlation between SQUID results and magnetoresistance the latter can be used as a quality indicator of RTA treatment.
- The simulations of the different setup geometry show that resulting interference pattern is quasi-periodical.
- On the small local areas of the sample surface the periodicity of interference pattern is preserved.
- For 10 mm laser spot diameter periodicity of the interference pattern can be assumed as constant.
- The interference pattern period decreases with the decrease of the laser wavelength λ, and distance Z between the sample and source as well as with the increase of the distance S between the sources.
- The contrast of the interference pattern images improves with the increasing interference beam number.
- Due to the fact that the 2-beam interference image has the weak contrast more suitable for the application is the 3-beam interference.

Acknowledgement

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