A Remanent Fe / Si Supermirror Transmission Polarizer

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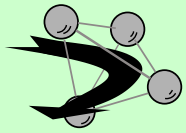
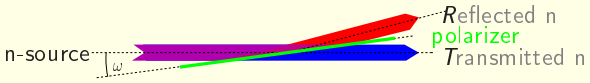


Introduction

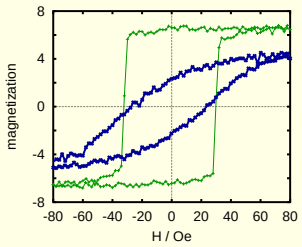
In order to develop a neutron spin polarizer based on magnetically remanent supermirrors we produced a Fe / Si supermirror ($m = 2$) giving polarizations of 96 % to 98 %.



↓: spin down neutrons, ↑: spin up neutrons.

Advantages of Fe / Si and transmission geometry:

- remanence is achievable by preparation with DC magnetron sputtering [1]:

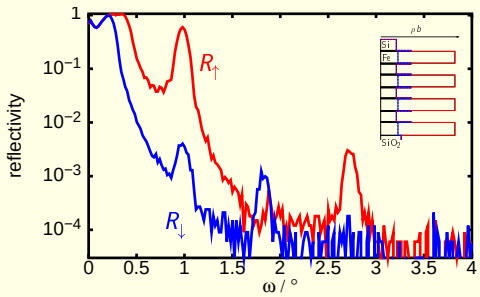


Magnetic hysteresis of a multilayer measured parallel and orthogonal to the direction of the substrate movement during the sputtering process.

  remanence allows for a compact set up [2];
- $\rho_{Fe}(b_{Fe} + p_{Fe}) \gg \rho_{Si} b_{Si}$, $\rho_{Fe}(b_{Fe} - p_{Fe}) \approx \rho_{Si} b_{Si}$;
  ⇒ Fe / Si on Si is almost invisible for ↓;
- low absorption;
- unaltered beam path.

Problems:

- $\rho_{Fe}(b_{Fe} - p_{Fe}) \neq \rho_{Si} b_{Si}$
  ⇒ increased $R_\downarrow$ ⇒ first order $R_\downarrow$ peak:



Neutron reflectivity R of a multilayer ([Fe(75 Å) / FeSi(5 Å) / Si : (N, O)(66 Å) / FeSi(5 Å)]$_{10}$ on glass) for ↑ and ↓ measured on TOPSI at SINQ / PSI (neutron wavelength $\lambda = 4.74$ Å).

- formation of an ≈ 5 Å thick *magnetically dead* interdiffusion layer at the interfaces [3, 4, 5]
  ⇒ increased $R_\downarrow$ ⇒ 'second order' $R_\downarrow$ peak;
- anisotropic stress:
  – condition for magnetic remanence,
  – might cause mechanically instable multilayer films.

Solution

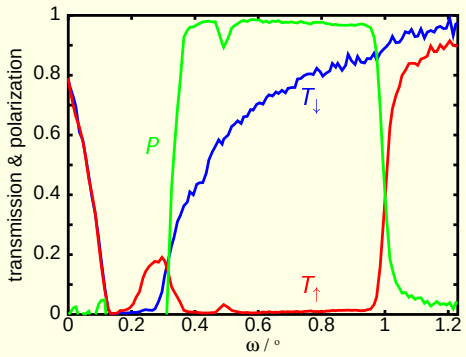
Reactive gases (N_2, O_2) can be incorporated in the Si layer to tune '$\rho_{Si} b_{Si}$', stress and to prevent interdiffusion. Optimization:

- production of multilayers,
- measurement of reflectivity, stress and hysteresis,
- R simulation with EDXR [6],
- variation of preparation parameters.

Results

Si sputtered in Ar, N_2 and O_2 (60:9:1) allows to prepare a stable Fe / Si supermirror:

- reflecting ↑ up to $q = 0.044$ Å^{-1} ($m = 2$);
- 149 layers;
- measured in a guide field of < 2 mT, (saturation field: 80 mT);
- Polarizing efficency: $P = \dfrac{T_\downarrow - T_\uparrow}{T_\downarrow + T_\uparrow} = 98\,\%$ to $96\,\%$



Neutron transmission T through a $m = 2$ Fe / Si supermirror on a Si wafer for ↑ and ↓. The bump in the spin up curve shows that the layer thicknesses still have to be optimized.

Outlook:

- further reduction of stress;
- go to higher q ($m = 2.5$);
- build a compact polarizer.

References

[1] P. Böni et al. *Physica B Condensed Matter* **267-268**, 320 (1999).
[2] C. F. Majkrzak et al. *SPIE* 1738, 90 (1992).
[3] D. J. Müller et al. *Physica B* **234**, 1050 (1997).
[4] L.N. Tong et al. *Eur. Phys. J. B* **5**, 61 (1998).
[5] P. Høghøj et al. *Physica B* **268**, 355 (1999).
[6] P. Mikulík. EDXR — X-ray and neutron reflectivity calculation program. mikulik@physics.muni.cz.

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