Leibniz Institute for Solid State and Materials Research Dresden

Institut für Physikalische Hochtechnologie Jena

Institut für Ionenstrahlphysik und Materialforschung

Forschungszentrum Rossendorf

Tailoring magnetic properties of permalloy by means of Cr implantation

J. Fassbender[1], J. McCord[2], R. Mattheis[3], K. Potzger[1], A. Mücklich[1], J. von Borany[1]

[1]FZ Rossendorf, [2]IFW Dresden, [3]IPHT Jena

Motivation

- **Magnetic properties can be modified by doping**
  - Magnetization (Co, Fe)
  - Curie temperature (Cr)
  - Coercivity (Si, B)
  - Magnetic damping (Tb, Dy, Ho)

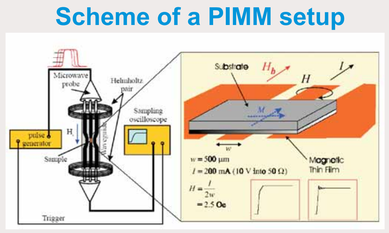
only a limited number of investigations so far

- **(Focused) ion implantation**
  - Post deposition treatment
  - Magnetic patterning without changing the surface topography
  - Patterning below the intrinsic micromagnetic feature size leads to artificial magnetic materials with new adjustable properties

Experimental techniques

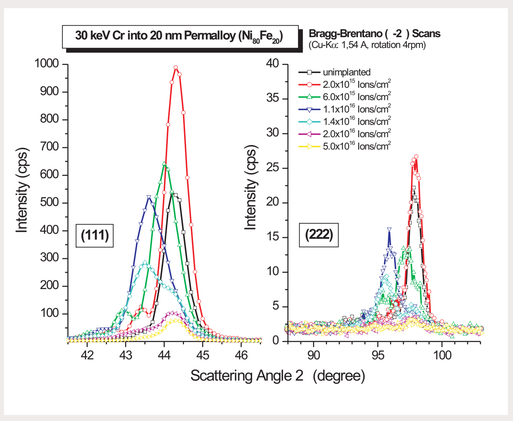
- **Sample Preparation**
  - Magnetron sputtering and 30 keV Cr implantation at room temperature
- **Structural characterization**
  - X-ray diffraction (XRD)
  - Transmission electron microscopy (TEM)
  - Rutherford backscattering (RBS)
  - Auger depth profiling (AES)
- **Magnetic characterization**
  - Magneto-optic Kerr magnetometry (MOKE)
  - Pulsed inductive microwave magnetometry (PIMM)

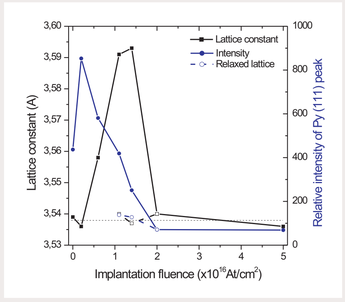
Scheme of a PIMM setup



Structural characterization

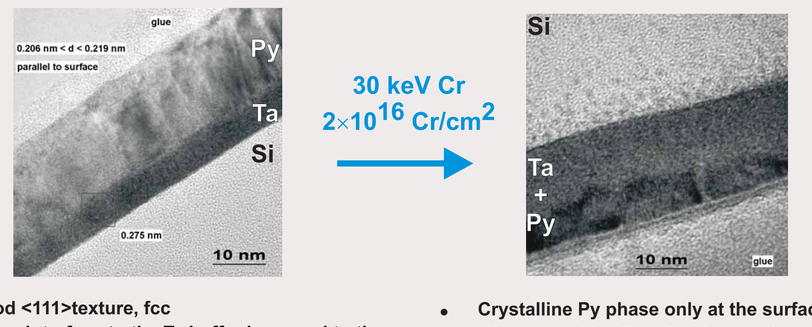
X-ray Diffraction





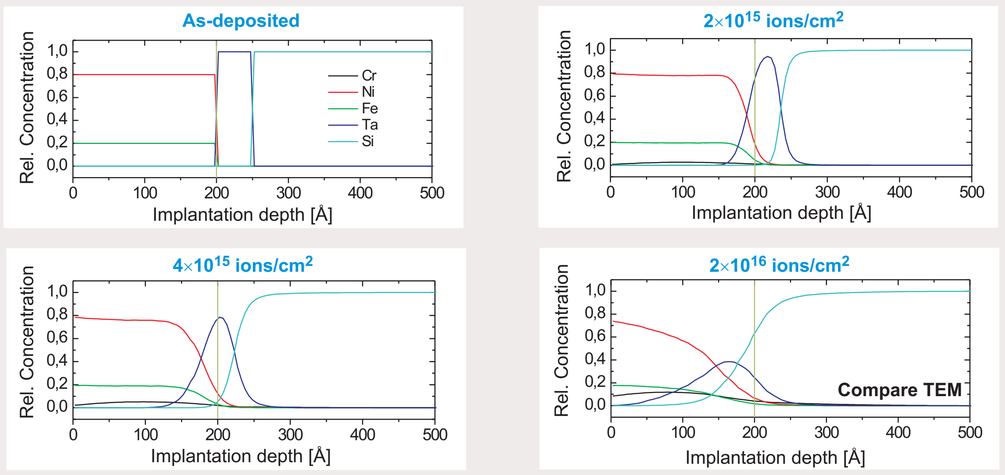
0.2×10^{16} Cr/cm²:	Improvement of (111) texture
$0.3–1\times10^{16}$ Cr/cm²:	Lattice expansion up to 1.5% strain from Cr implant
$1–2\times10^{16}$ Cr/cm²:	Mixture of contributions from strained and relaxed lattice
$>2\times10^{16}$ Cr/cm²:	Low amount of completely relaxed lattice (partial amorphization)

Cross-section Transmission Electron Microscopy



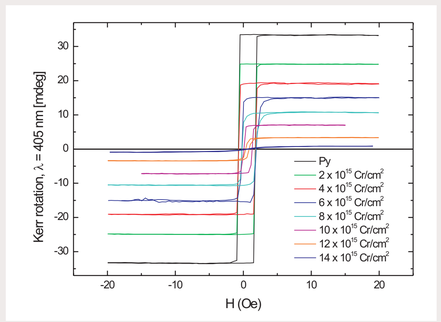
- Good <111>texture, fcc
- Sharp interface to the Ta buffer layer and to the Si substrate
- Crystalline Py phase only at the surface
- Nanocrystalline Ta + Py phase adjacent to the Si substrate
- Small metallic precipitates in Si substrate

TRIdyn simulations



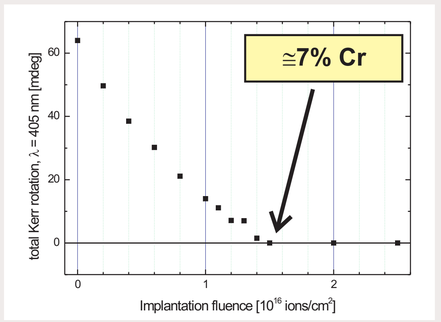
Magnetic characterization

Magnetization reversal



- Decrease of Kerr rotation
- Reduction of magnetization (assumption)

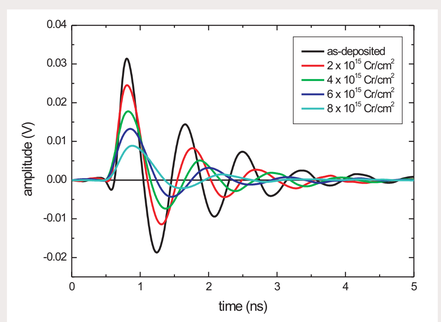
Curie temperature



- Reduction of Curie temperature
- 7% Cr ≅ room temperature

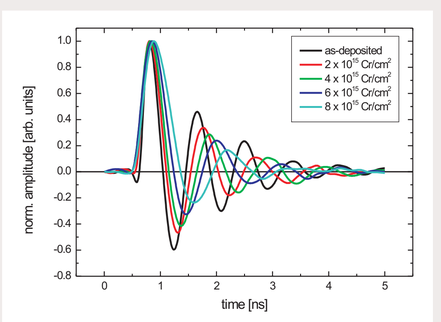
Magnetization dynamics and damping

Magnetization traces



- Decrease of PIMM amplitude
  - Reduced saturation magnetization
- Increase in magnetic damping

Normalized



- Decrease of precession frequency due to
  - Reduced saturation magnetization
  - Reduced uniaxial anisotropy

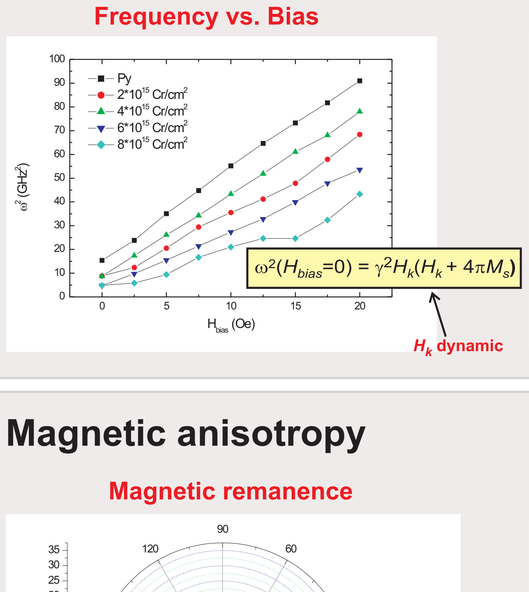
Model

$$\Phi(t) = \beta \sin(\omega_p t + \phi) \exp(-t\,\lambda_{LL}/2)$$

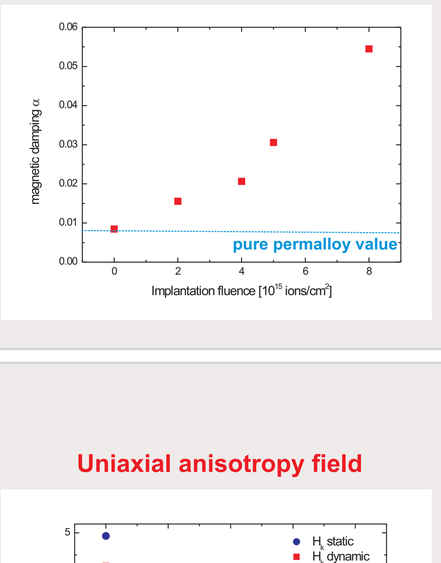
$$\alpha = \lambda_{LL} / (|\gamma|\, 4\pi M_s)$$

$\Phi(t)$:	in-plane precession angle	β:	amplitude
ω_p:	precession frequency	ϕ:	phase
λ_{LL}:	Landau-Lifshitz damping parameter		
α:	Gilbert damping parameter		
γ:	gyromagnetic ratio		
M_S:	saturation magnetization		

Frequency vs. Bias

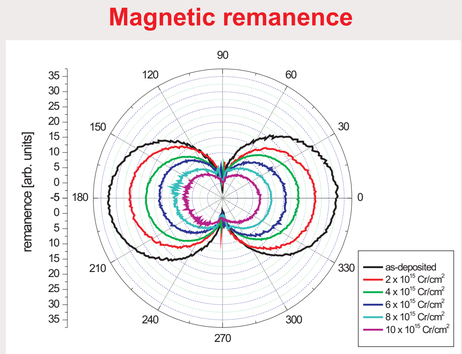


Gilbert damping parameter



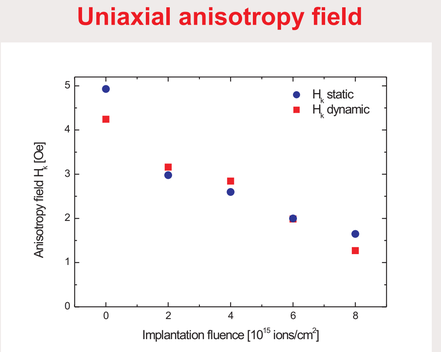
Magnetic anisotropy

Magnetic remanence



- 2-fold symmetry in magnetic remanence
- Static uniaxial anisotropy field (H_k static) determined from hard axis loop

Uniaxial anisotropy field



- H_k static and H_k dynamic consistent

→ Determination of saturation magnetization by Kerr rotation amplitude correct

Summary

Decrease:

- Saturation magnetization
- Curie temperature
- Uniaxial magnetic anisotropy (static = dynamic)

Increase:

- Magnetic damping parameter

Open question:
Alloying versus structural changes

Contact:
Dr. Jürgen Fassbender, J.Fassbender@fz-rossendorf.de, FZ Rossendorf, Postfach 51 01 19, 01314 Dresden, Germany