Leibniz Institute for Solid State and Materials Research Dresden

Stiftung Caesar Smart Materials

Forschungszentrum Rossendorf
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Magnetic properties and domain formation in amorphous films anisotropy patterned by ion irradiation

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Applications of amorphous films

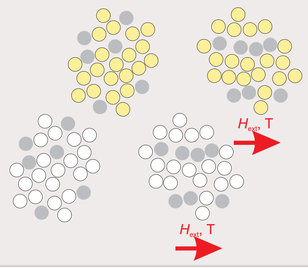
- **High frequency applications**
  - High resistivity
  - Soft magnetic properties
  - Soft magnetic underlayer for magnetic recording
- **Tunnel magnetoresistance structures**
- **Strain sensors**
  - Magnetostriction
  - Soft magnetic properties

CoFeSiB and characterization

- **Rf-sputtered $Co_8Fe_{70}Si_{12}B_{10}$**
  - Amorphous ferromagnetic alloy
  - Thickness 30 nm
  - Magnetic anisotropy set during deposition (applied field)
- **Magnetometry**
  - Magneto-optic Kerr effect
  - Inductive
- **Magneto optical Kerr microscopy**
  - Domain imaging
  - Local hysteresis measurements

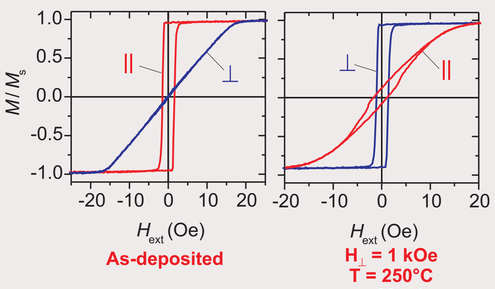
Magnetic anisotropy in amorphous alloys

- **High short range mobility of atoms**
- **Short range order leads to anisotropy**
  - Pair ordering of metalloids and ferromagnetic atoms
  - Easily changed by annealing



Anisotropy rotation by temperature

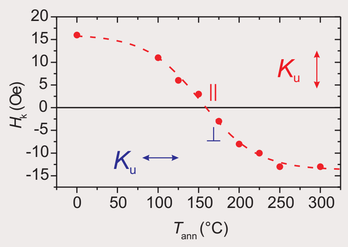
Perpendicular field anneal



As-deposited

$H_\perp$ = 1 kOe
T = 250°C
t = 20 min

Rotation of anisotropy axis



$H_\perp$ = 1 kOe, t = 20 min

→ **Rotation of anisotropy by 90° above 150°C**

Anisotropy rotation by He ion irradiation

- **He irradiation (5 keV)**
- **Fluence: 5×10^{14} - 5×10^{17} ions/cm²**
- **Orthogonal field: $H_\perp$ = 600 Oe**

Perpendicular field irradiation

Magnetization reversal curves

$H_\perp$ = 600 Oe
$He^+ = 5\times10^{14}$ ions/cm²

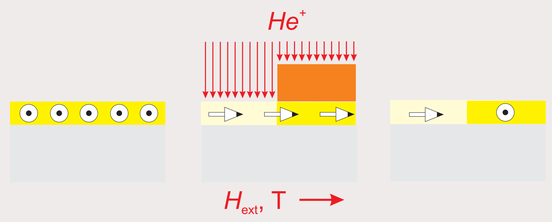
$H_\perp$ = 600 Oe
$He^+ = 5\times10^{16}$ ions/cm²

Anisotropy versus fluence

$H_\perp$ = 600 Oe

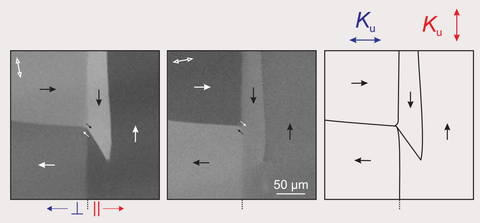
→ **Rotation of anisotropy by 90° above 5×10^{15} ions/cm²**

Partially covered He irradiation



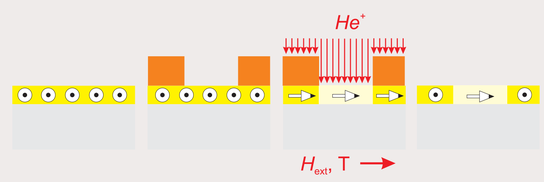
- **He irradiation (5 keV)**
- **Fluence: 1×10^{17} ions/cm²**
- **Orthogonal field: $H_\perp$ = 600 Oe**

Two regions of uniaxial anisotropy K_u



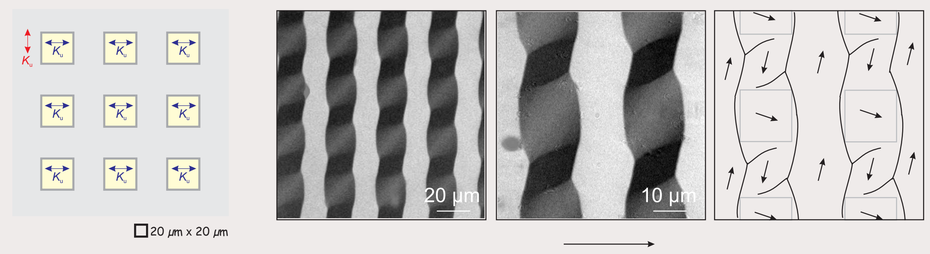
- **Orthogonal alignment of anisotropy**
- **No clear border**
  Domain structures

Anisotropy patterning



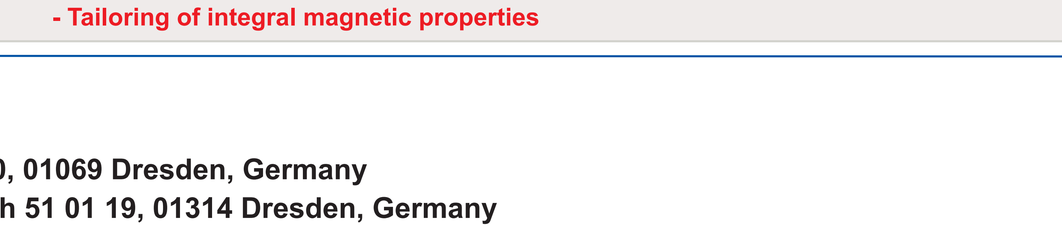
- **Masking with photo resist**
- **Photo resist patterning**
- **Ion irradiation**
  Anisotropy patterning

Kerr microscopy



- **"Braid" domains**
- **Periodic domain structures, modulation with anisotropy structure**

Local magnetization loops



- **5×5 µm MOKE loops**
- **Strong interaction, easy and hard axis loops observed**

More domains circles

Summary

- **Anisotropy in CoFeSiB modified in an applied field by**
  - Temperature
  - He ion irradiation
- **Anisotropy patterning**
  - Anisotropy structure ≠ micromagnetic structure
  - Indirect correlation between patterning and magnetization
  - Domain wall width and "closure domain" size dependent
  - Tailoring of integral magnetic properties

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