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INESC MN
Microsistemas & Nanotecnologias

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Magnetic domain structure of micro-patterned PtMn/NiFe exchange bias bilayers

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Motivation

- **Magnetic behavior determined by**
  - Exchange coupling
  - Magnetic anisotropies
  - Curie temperature
  - Magnetic damping
- **Structural origins**
  - Interface morphology
  - Structural phases (chemically ordered)
  - Composition

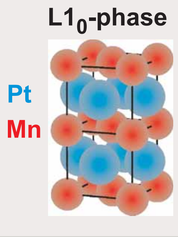
→ Ion irradiation and implantation changes structure or composition and thereby magnetic properties

- **Non-topographic magnetic patterning**
  - Exchange coupling between irradiated (implanted) and virgin areas
  - Magnetic features are determined by micromagnetism only
  - Patterning below the intrinsic micromagnetic feature size leads to artificial magnetic materials with new adjustable properties
- **Topographic magnetic patterning**
  - Magnetic features are determined by topography and micromagnetism

Exchange Bias System $Ni_{80}Fe_{20}/Pt_{50}Mn_{50}$

- **PtMn – antiferromagnetic only in chemically ordered $L1_0$-phase**
  - Very sensitive on structural changes (ion irradiation)
- **High exchange bias field** → technologically relevant
- **Magnetic sensor applications**

$L1_0$-phase



Experimental techniques

- **Sample Preparation**
  - Ion beam and physical vapor deposition
  - Focused Ga irradiation (magnetic patterning)
- **Magnetic characterization**

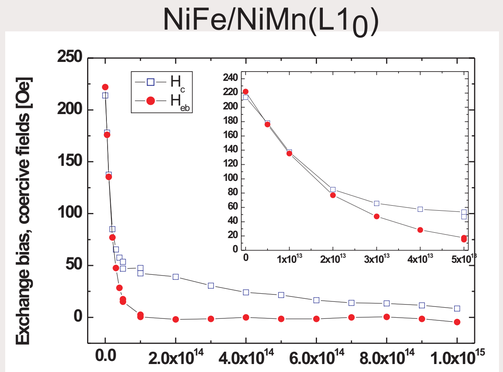
  Integral:
  - Magneto-optic Kerr magnetometry (MOKE)
  - Vibrating sample magnetometry (VSM)

  Spatially resolved:
  - Wide-field Kerr microscopy
  - Magnetic force microscopy (MFM)

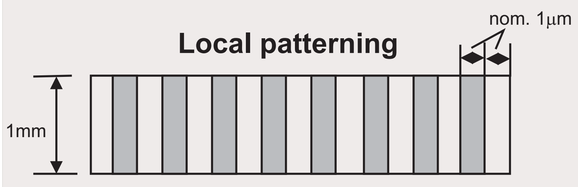
Ion fluence dependence

- 25 keV Ga irradiation with focused ion beam
- Fluence dependence investigated for $Ni_{50}Mn_{50}$ which is comparable to $Pt_{50}Mn_{50}$
- 1×10^{14} Ga/cm^2 are sufficient to suppress exchange bias completely

NiFe/NiMn($L1_0$)



Sample structure



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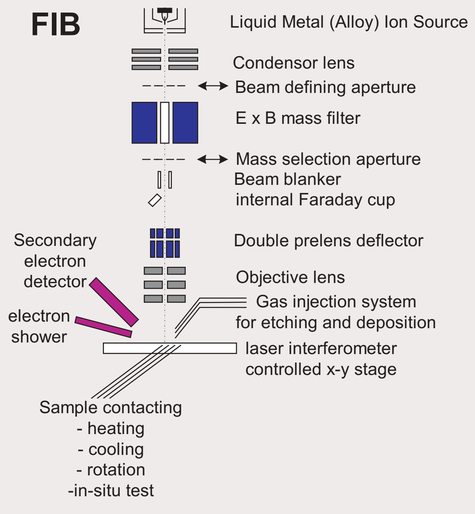
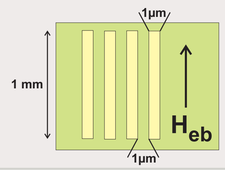
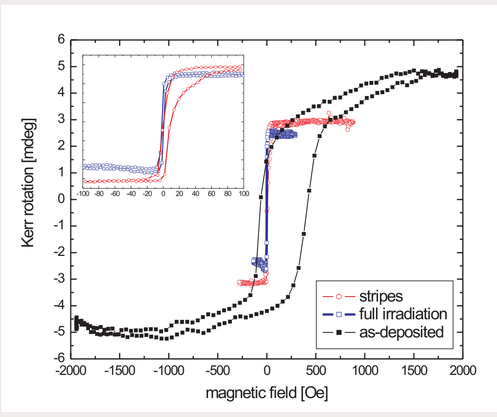


Magnetization reversal

- As-deposited: H_{eb} = 180 Oe
- Full area irradiation (1×10^{14}Ga/cm^2): H_{eb} = 0 Oe consistend with fluence dependence
- Stripe array: $H_{eb} \cong$ 30 Oe
  strong interaction between irradiated and non-irradiated areas

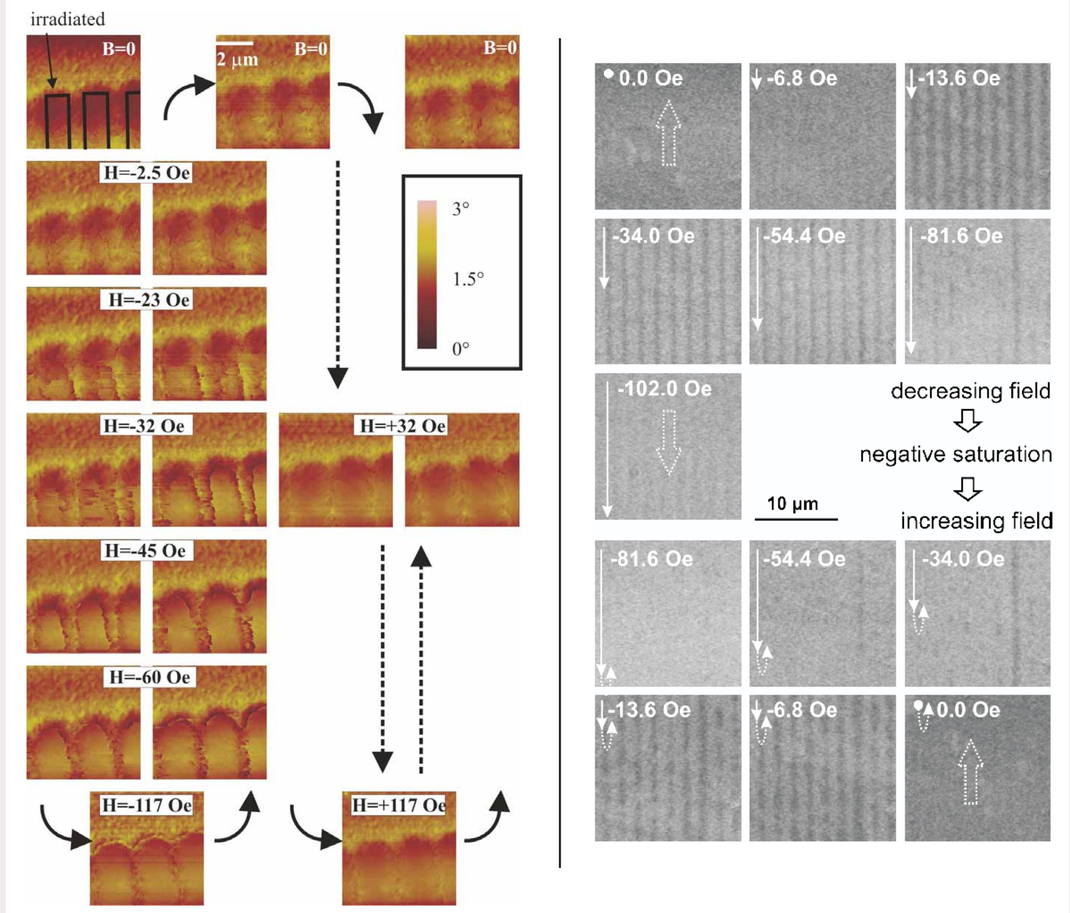




Magnetic patterning

Magnetic force microscopy

Kerr microscopy



- **Kerr microscopy**
  - Decreasing field branch: antiparallel orientation of irradiated stripes and surrounding area between H = -13 and H = -60 Oe.
  - Increasing field branch: antiparallel orientation between H = -15 and H = -5 Oe
- **Magnetic force microscopy**
  - Between H = -12 Oe and H = -80 Oe sharp Neél walls between irradiated stripes and surrounding area observed
  - For increasing negative fields successive increase in domain size of the irradiated area at the expense of the non-irradiated area
  - At H = -100 Oe – magnetization in non-irradiated areas between the stripes is completely reversed due to magnetic interactions
  - Magnetization ripple as a remainder of the non-irradiated areas persits up to large field values consistent with large exchange bias field value of the unpatterned film

Summary

- Magnetic patterning by local ion irradiation
  - $L1_0$-phase (NiMn, PtMn) very sensitive on ion irradiation
  - Interactions between irradiated and non-irradiated areas
    - Reduced exchange bias field
    - Switching field influenced by the magnetization reversal in the surrounding area
  - Domain size is a function of applied field

→ complicated magnetization reversal behavior

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