Perfect Optical Absorption-Enhanced Magneto-Optic Kerr Effect Microscopy

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Abstract

We present a technique enhancing Magneto-Optic Kerr Effect (MOKE) microscopy via Perfect Optical Absorption (POA). Near-100% absorption at specific wavelengths enables Kerr rotations up to **20°**, allowing high-resolution imaging of nanoscale magnetic domains. This facilitates advanced spintronic studies.

Introduction

Magnetic and spintronic media are fundamental to both scientific research and technological applications. Magneto-optic Kerr effect (MOKE) microscopy is a powerful tool for studying the dynamics of spins, magnetic quasi-particles, and domain walls. However, conventional optical techniques are limited by:

- **Weak Magneto-Optical Activity**: Traditional MOKE signals are extremely weak, making it challenging to detect and image nanoscale spin textures.
- **Diffraction Limit**: Optical techniques are limited by the diffraction barrier, necessitating expensive alternatives like electron microscopy or scanning probe methods.

This study introduces **Perfect Optical Absorption (POA)** as a novel approach to overcome these limitations. POA enhances MOKE performance by:

- Suppressing non-magnetic optical reflection (r_{xx}).
- Enhancing magneto-optical reflection (r_{xy}).

Key Advantages of POA

- Enables high-sensitivity detection of magnetized domains.
- Facilitates real-time imaging of sub-wavelength magnetic domain reversals.
- Allows statistical analysis of nanoscale magnetic phenomena beyond the optical diffraction limit.

Methods

POA Setup

POA is achieved using two thin SiO_2 spacer layers and a bottom Al mirror. This setup:

- Suppresses non-magnetic reflection through destructive interference.
- Enhances magneto-optical reflection through a highly confined electric field.

Sample Fabrication

- 100-nm-thick Al mirror deposited via electron beam evaporation.
- SiO_2 layers deposited via radio-frequency sputtering.
- Co/Pt and Pt/Co/Pt/Ta layers deposited via physical vapor deposition.

Measurement

- Samples mounted on a non-magnetic XYZ translation stage.
- External magnetic field applied using a neodymium magnet.
- Spectral measurements using a broadband LED and spectrometer.
- MOKE imaging using a narrowband LED and CMOS camera.

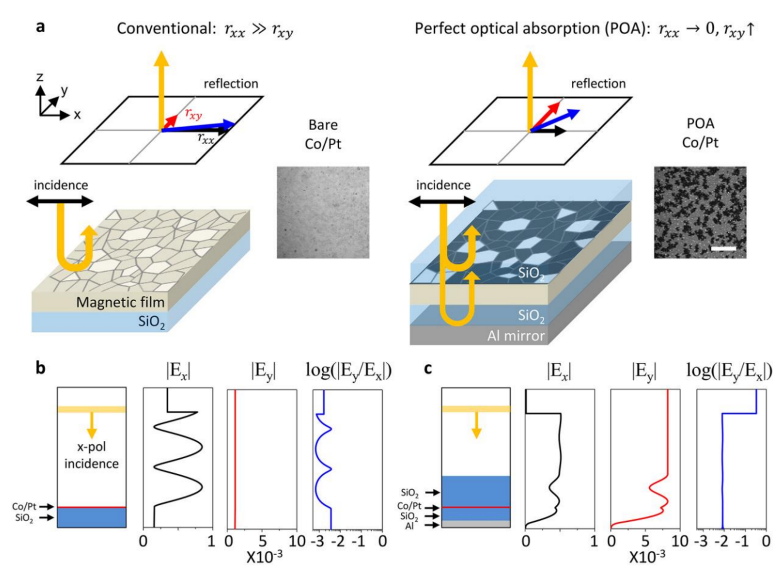

Figure 1. Conventional vs. POA-enhanced MOKE.

Result

Enhanced Kerr Amplitude

For a 1-nm-thin Co film, the Kerr amplitude reached **20°**, which is **66 times larger** than the bare Co/Pt film. This enhancement allows for highly sensitive detection of magnetized domains.

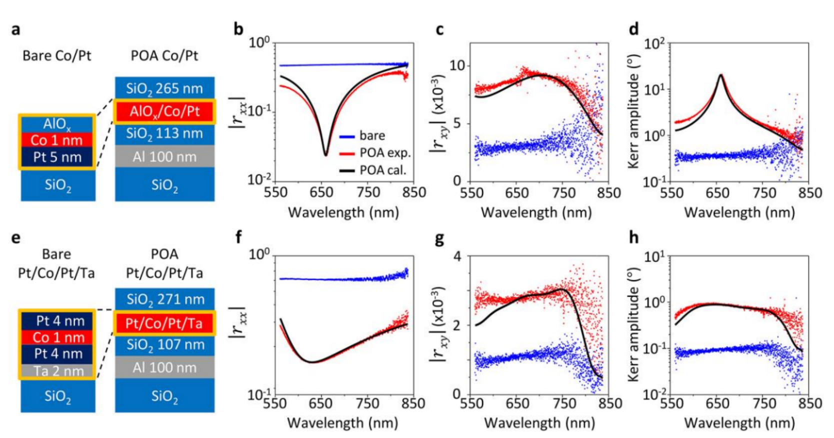

Figure 2. Measured Kerr amplitude for POA and conventional MOKE.

High-Visibility MOKE Imaging POA enables high-visibility imaging over a wide range of analyser angles. The visibility reached **0.72** with a high-extinction analyser, significantly improving the detection of magnetic domains.

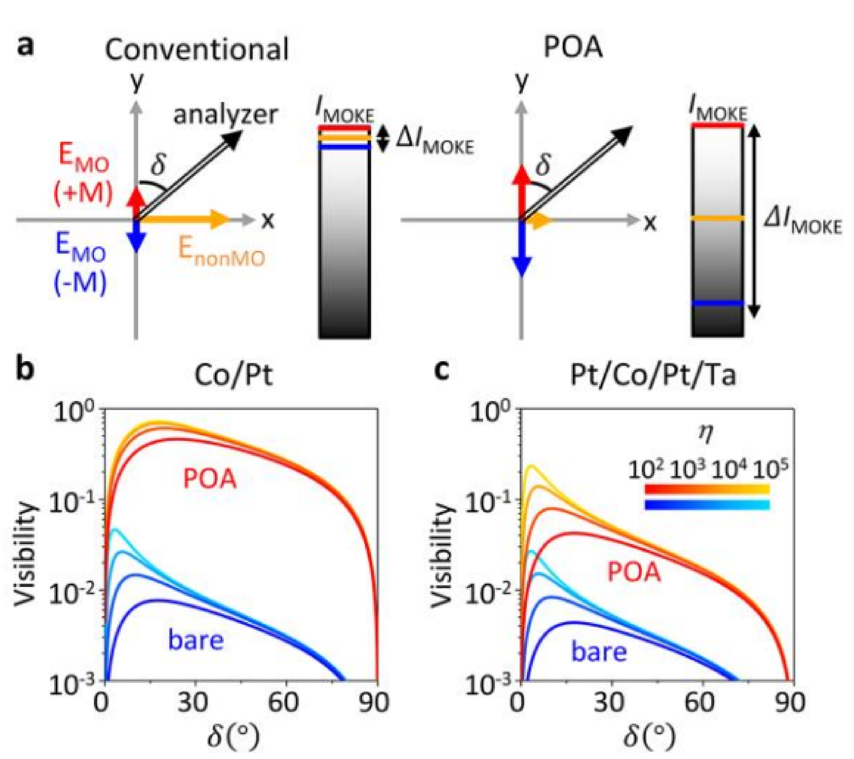

Figure 3. High-visibility MOKE imaging of magnetic domains.

Barkhausen Jumps Real-time detection of Barkhausen jumps below the diffraction limit. Power-law scaling verified down to the **10-nm scale**.

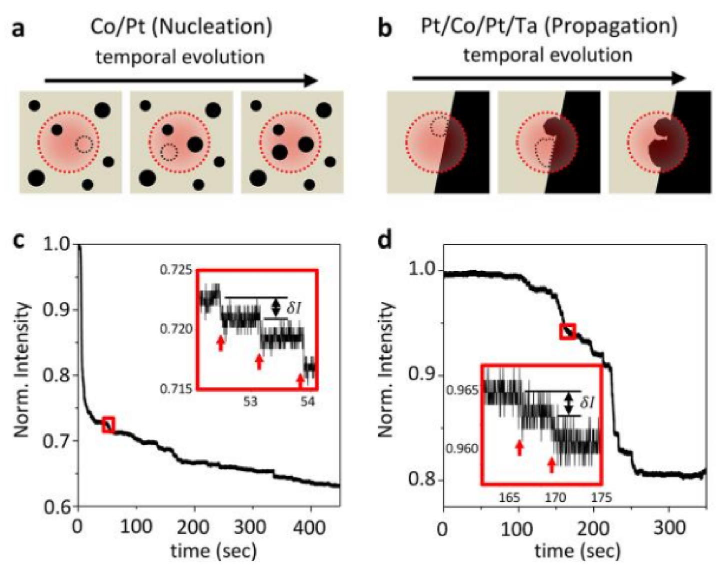

Figure 4. Real-time measurement of Barkhausen jumps.

Analyser-Free MOKE Microscopy High circular birefringence enables analyser-free MOKE microscopy. Bright-field microscopy using circularly polarized illumination.

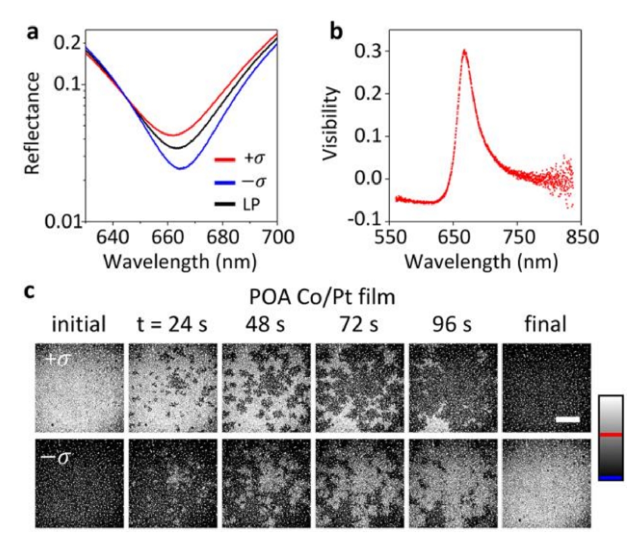

Figure 5. Analyser-free MOKE microscopy images.

Conclusion

POA significantly expands the capabilities of MOKE microscopy by:

- Enhancing sensitivity and visibility for nanoscale magnetic domain imaging.
- Enabling real-time measurement and statistical analysis of magnetic domain reversals.
- Providing a pathway for studying advanced magnetic phenomena such as skyrmions, magnons, and magnetic solitons.

References

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