Fourfold Symmetry of Anisotropic Magnetoresistance in Epitaxial Fe_3O_4 Thin Films

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Ⅰ. INTRODUCTION

- In high quality epitaxial Fe_3O_4 films grown on MgO(001) substrates, the Planar Hall effect (PHE) contains only a twofold angular dependence, but the anisotropic magnetoresistance (AMR) below 200K is constituted with both twofold and fourfold symmetric terms.
- The origin of the four-fold symmetry of AMR is either due to the symmetry of the lattice or the spin scattering near the antiphase boundaries(APBs)?

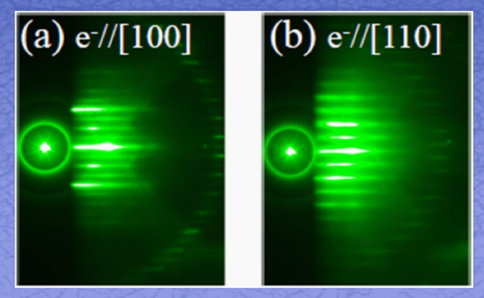
Ⅱ. EXPERIMENT STEPS

Sample:

1. MgO(001) substrate annealing at 600℃ 10nm seed layer was grown at 500 ℃.
2. Evaporating the Fe atoms at an oxygen pressure of ~1×10^{-5} Torr.
3. Patterned into the Hall geometry by two-step lithography.

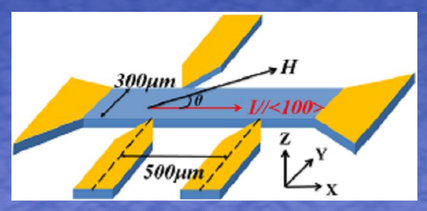
Measurement:

Physical Property Measurement System



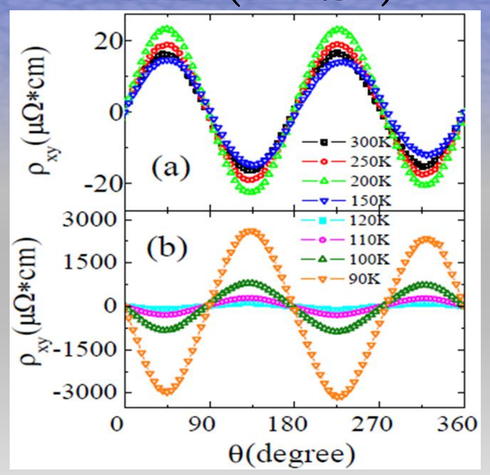
RHEED pattern of Fe_3O_4

Ⅲ. In-plan AMR and PHE



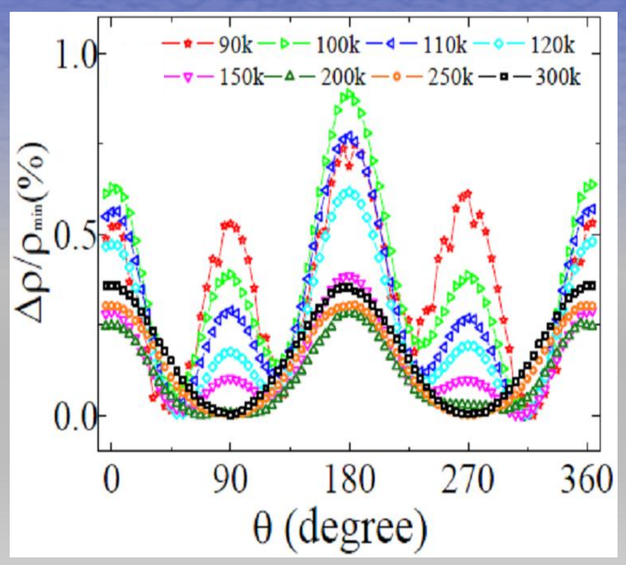
Magnetic field rotational plan parallel to the current

PHE（H=1.5T）

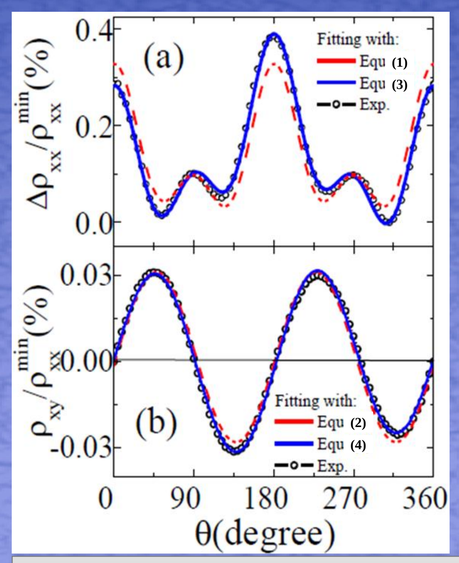


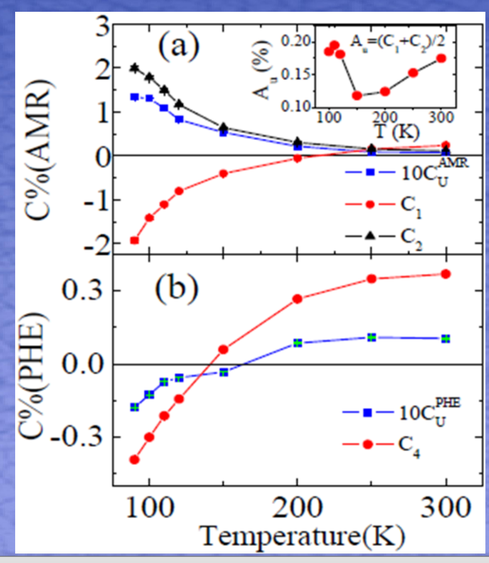
Only two-fold symmetry

AMR（H=1.5T）



Higher temperature: two-fold symmetry
Lower temperature: two-fold symmetry and four-fold symmetry





The four-fold symmetry origin from the APBs ?

Simulation without unidirectional terms

$$\rho_{xx} = C_0 + C_1\cos^2\theta + C_2\cos^4\theta \quad (1)$$

$$\rho_{xy} = C_4 \sin\theta\cos\theta \quad (2)$$

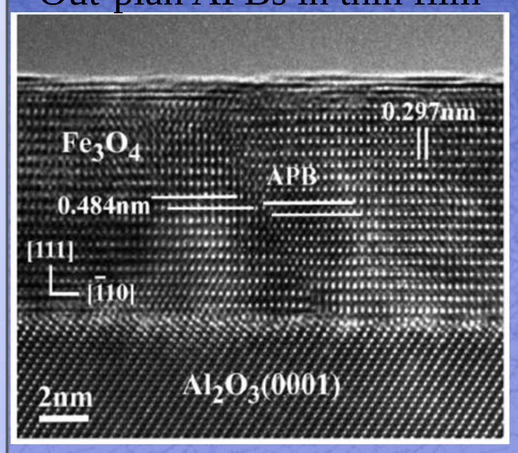
Simulation with unidirectional term

$$\rho_{xx} = C_0 + C_U^{AMR}\cos(\theta - \theta_U^{AMR}) + C_1\cos^2\theta + C_2\cos^4\theta \quad (3)$$

$$\rho_{xy} = C_U^{PHE}\cos(\theta - \theta_U^{PHE}) + C_4 \sin\theta\cos\theta \quad (4)$$

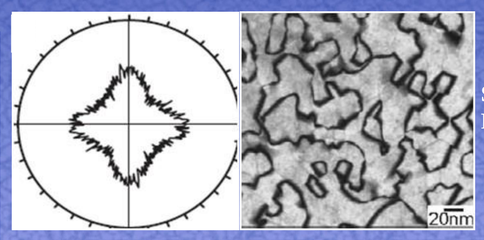
Ⅳ. Antiphase boundaries(APBs)

Out-plan APBs in thin film

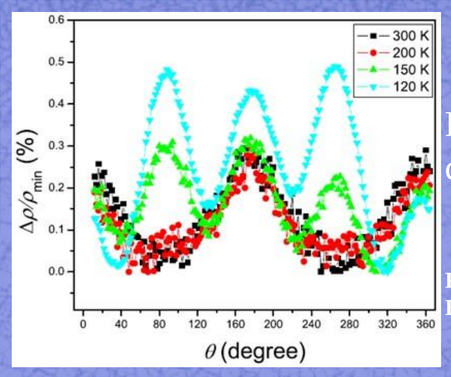


A. V. Ramos, *et. al.*, JAP. 100, 103902 (2006).

Only exist two-fold symmetry.



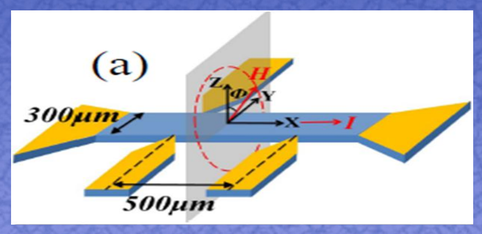
S. Celotto, *et. al.*,Eur. Phys. J. B 36, 271(2003).



Four-fold is single crystal Fe_3O_4.

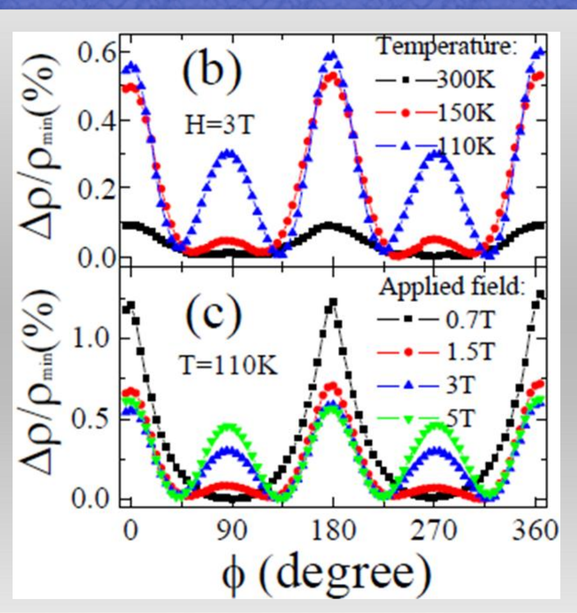
R. Ramos, *et. al.*, Phys. Rev. B 78, 214402 (2008).

Ⅴ. Out-plan AMR



Magnetic field rotational plan perpendicular to the current

The AMR amplitude is quite similar in both in-plan and out-plan measurements which indicates the four-fold symmetry of AMR is related to the cubic crystalline structure.



Ⅴ. CONCLUSION

Our measurement performed for the magnetic field rotating in the plane perpendicular to the current proved that the high order symmetric AMR at low temperature is due to the symmetry of the lattice, and is not related to the spin scattering near the APBs in the Fe_3O_4 film.