Anomalous Hall Effect of Fe_2CoSi/Pt Multilayers

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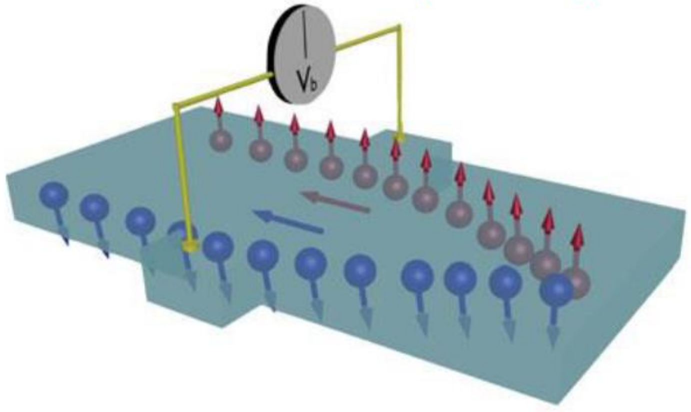
Spin-Hall effect (SHE)

Anomalous Hall effect (AHE)

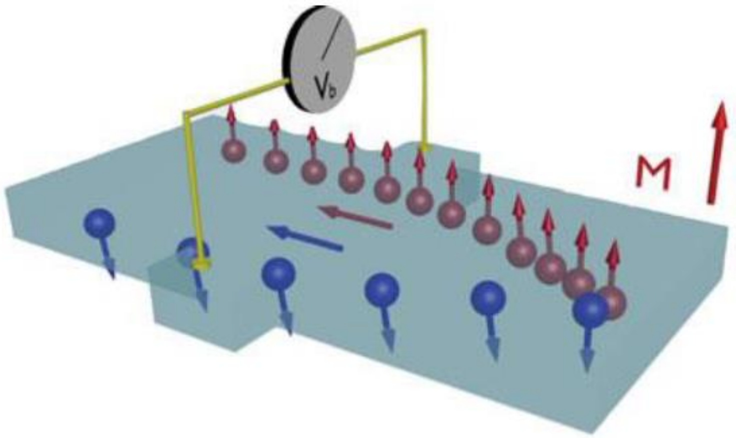


Spin-orbit interaction

$$\vec{L}\cdot\vec{S}\sim(\vec{v}\times\vec{r})\cdot\vec{S}$$

$\vec{S}$ up: attractive

$\vec{S}$ down: repulsive

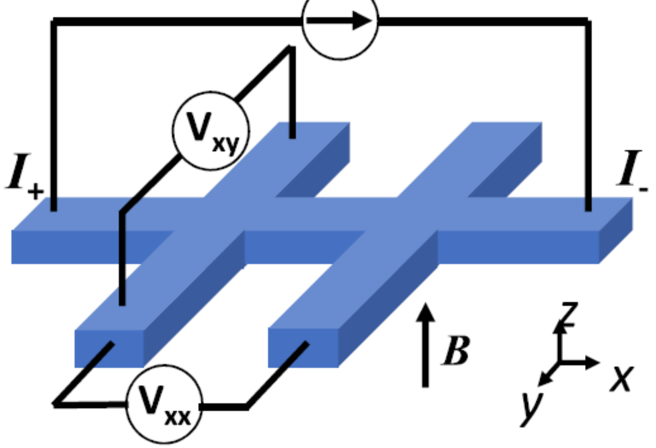


Spin Hall effect （nonmagnetic）

makes a spin accumulation at edges of the wire

Anomalous Hall effect （magnetic）

makes a charge accumulation at edges of a wire.

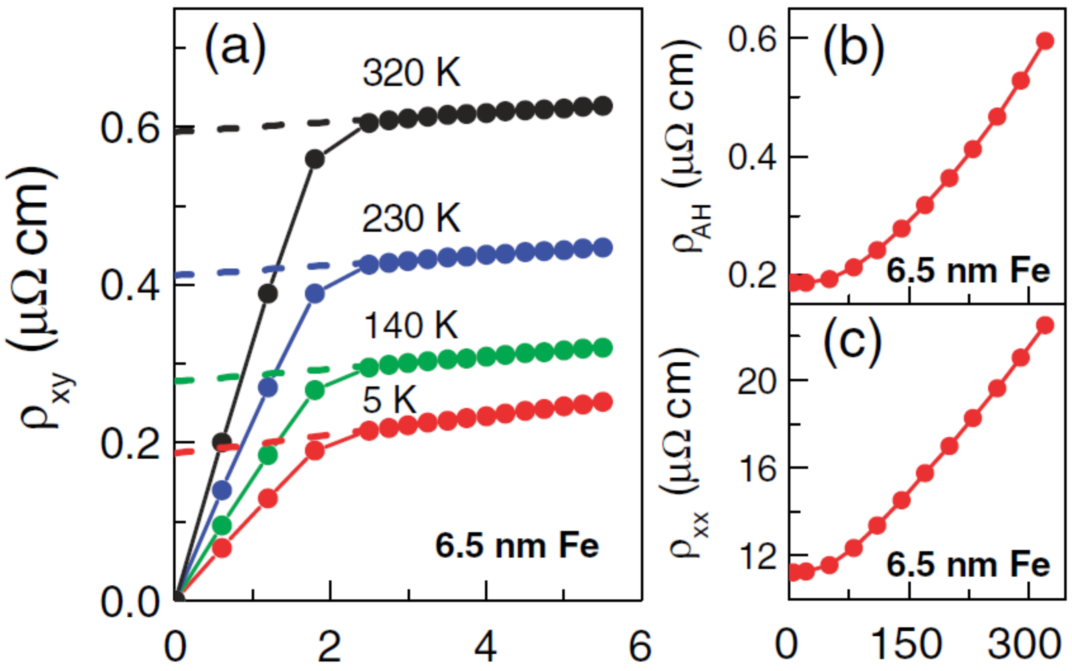


Measure ρ_{xy} and ρ_{xx}

$$\rho_{xy}(H,T) = R_0 \cdot H + R_A \cdot M(H,T)$$

$R_0 \cdot H$: ordinary Hall effect term. Depend on *H*

$R_A \cdot M(H,T)$: anomalous Hall effect term. Depend on *M*



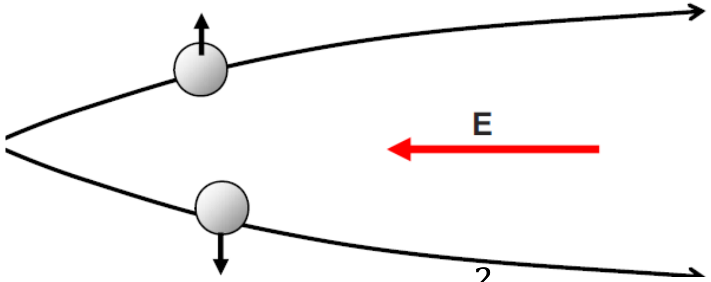
$$\rho_{xy}(H,T) = \quad R_0 \cdot H \quad + \; R_A \cdot M(H,T)$$

After eliminate Hall effect from ρ_{xy}, we will get ρ_{AH}(H=0, T)

ρ_{AH} is called anomalous Hall resistivity

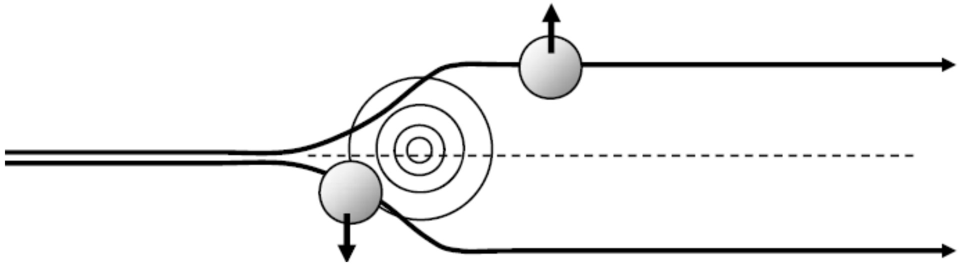
$R_A$is also written as R_s called anomalous Hall coefficient

$R_s = \frac{\rho_{AH}}{M_s}$



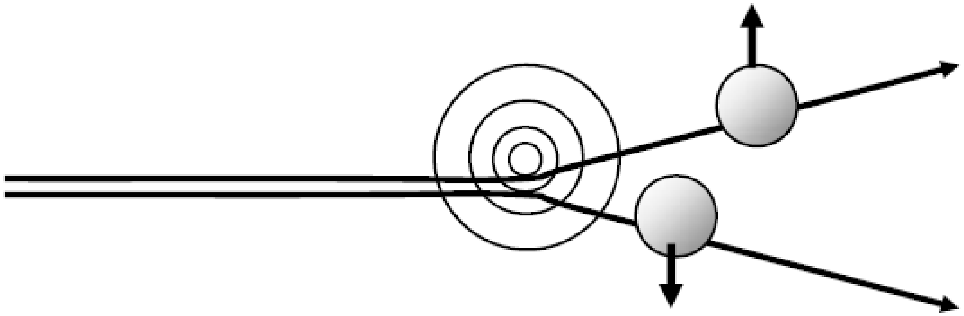
$\rho_{xy} \sim \rho_{xx}{}^2$

Intrinsic deflection: Interband coherence induced by an external electric field gives rise to a velocity contribution perpendicular to the field direction. These currents do not sum to zero in ferromagnets.



$\rho_{xy} \sim \rho_{xx}{}^2$

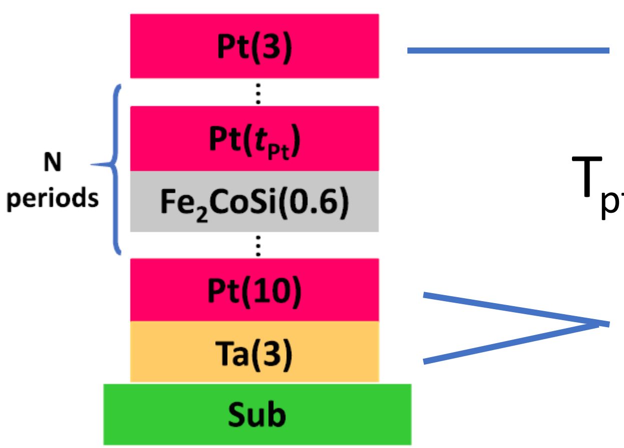
Side jump: The electron velocity is deflected in opposite directions by the opposite electric fields experienced upon approaching and leaving an impurity. The time-integrated velocity deflection is the side jump.



$\rho_{xy} \sim \rho_{xx}$

Skew scattering: Asymmetric scattering due to the effective spin-orbit coupling of the electron or the impurity.

$$R_s = \frac{\rho_{AH}}{M_s} = a\rho_{xx} + b\rho_{xx}{}^2$$

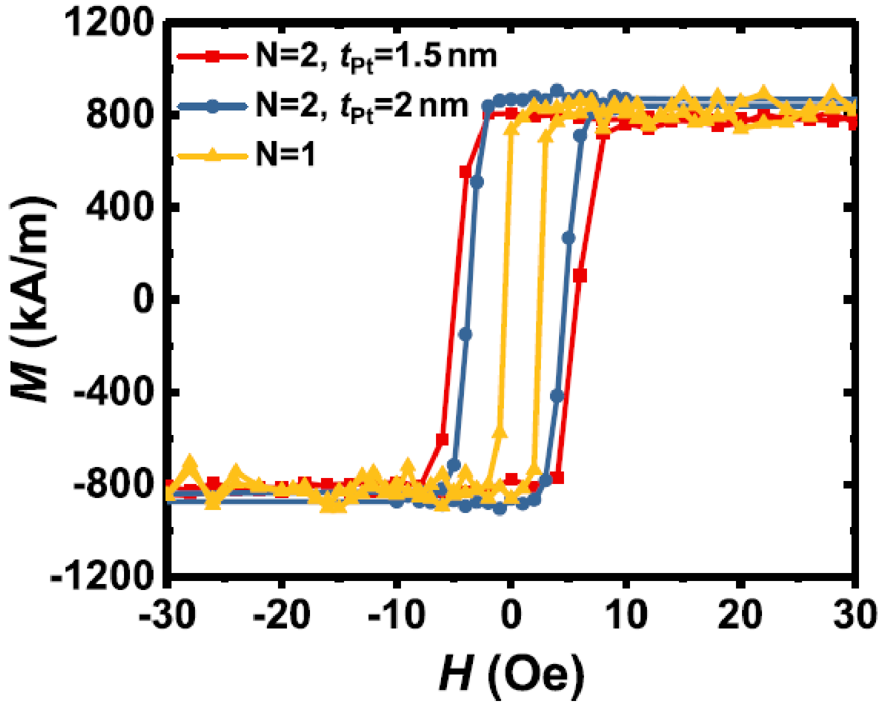


top layer

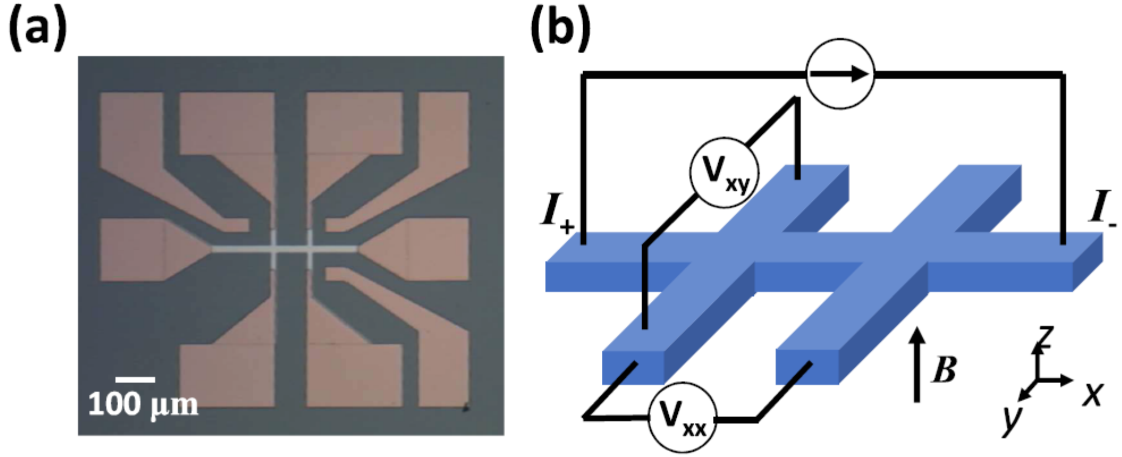
T_{pt} is the thickness of Pt in nanometer

Buffer layer

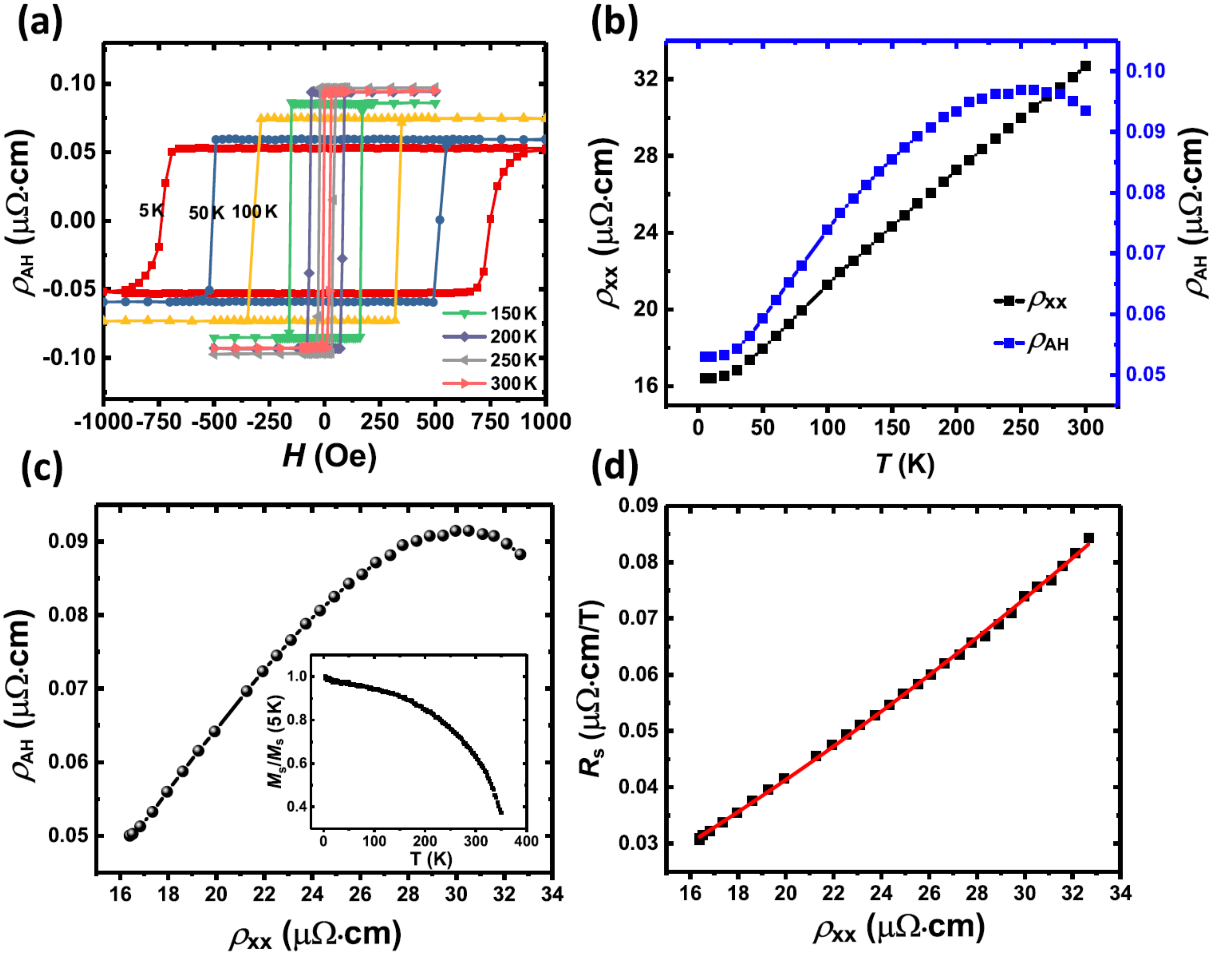
The idea of using Multilayers is to remain perpendicular magnetic anisotropy, and multilayers has very little Intrinsic deflection



M–*H* hysteresis loops under out-of-plane magnetic field.



(a)Optical image of Hall bar devices.
(b)Schematic of Hall resistivity and longitudinal resistivity measurement setup.



Fit $R_s = a\rho_{xx} + b\rho_{xx}^2$ with (d)

a = 0.00169 T^{-1}
b = 3.075 ×10−5 $\mu\Omega^{-1}cm^{-1}$ T^{-1}.

absolute magnitude of Side jump (0.0277 *μΩ·cm/T*) is about 3 times as large as that of Skew scattering (0.0083 *μΩ·cm/T*) at 5 K

conclusion

1. Anomalous Hall effect has the same mechanism with spin hall effect which is cause by spin-orbit coupling

2. Anomalous Hall effect can give you the magnetization of ferromagnetic material, it can be used to measure the hysteresis loop or exchange bias.

3. Mechanism of anomalous Hall effect (Side jump, Skew scattering) can be further investigated with anomalous Hall resistivity.

reference

[1]Liu, Y., Liu, Y., Cai, K., Ren, L., Zheng, Y., Yang, H. and Teo, K. (2018). Anomalous Hall Effect of Fe2CoSi/Pt Multilayers With Large Perpendicular Magnetic Anisotropy. *IEEE Transactions on Magnetics*, 54(11), pp.1-4.
[2]Nagaosa, N., Sinova, J., Onoda, S., MacDonald, A. and Ong, N. (2010). Anomalous Hall effect. *Reviews of Modern Physics*, 82(2), pp.1539-1592.
[3]Tian, Y., Ye, L. and Jin, X. (2009). Proper Scaling of the Anomalous Hall Effect. *Physical Review Letters*, 103(8).
[4]Staff.aist.go.jp. (2019). *Anomalous Hall effect, Anisotropic magnetoresistance (AMR) Research V.Zayets*. [online] Available at: https://staff.aist.go.jp/v.zayets/spin3_50_AnomalousHall.html [Accessed 8 Feb. 2019].