Spin Hall Effect in Gold H-pattern

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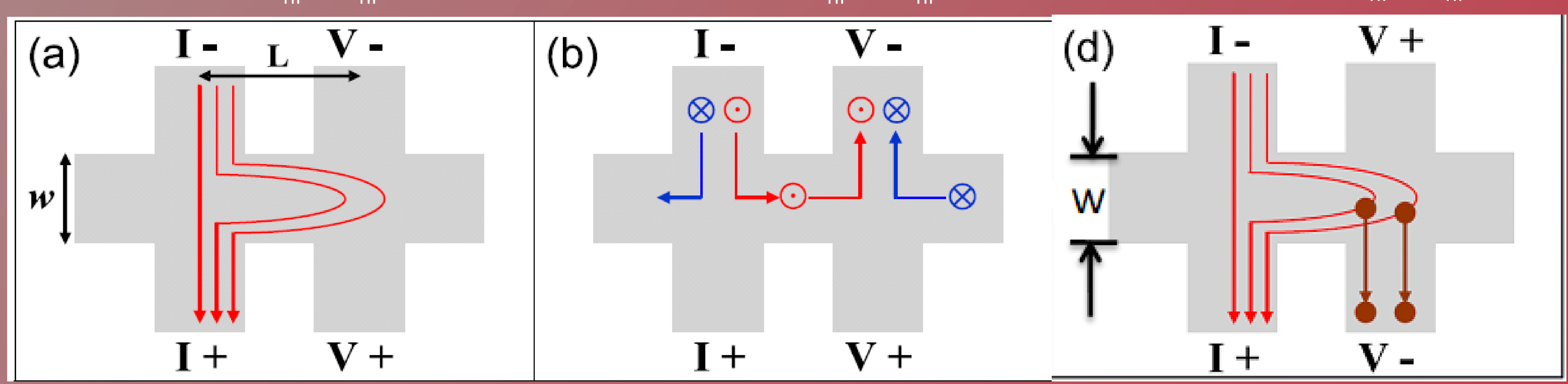
Motivation

In 2008 TAKANASHI reported giant Hall angle in Gold. By using of a multi-terminal device with a Au Hall cross and a FePt perpendicular spin injector system, a hall angle of 0.113 has been acquired[1]. However, in 2009 Hoffmann presented a different experimental results tested in Au H-pattern[2]. Data shows no sign of giant spin Hall angle in the same material, and also a negative Non-Local signal is acquired, the relative long mean free path of Au is believed to be responsible for the negative signal in the H-Pattern.

We could successfully reduce the MFP, by reducing the thickness of Au sample[3], and furthermore we may finally find a proper way to measure the Hall angle of Au.

Three mechanisms in H-Pattern

Classical R_{nl}~ R^{C}_{nl} | SHE induced R_{nl}~ R^{SH}_{nl} | Quasibalistic R_{nl}~ R^{b}_{nl}

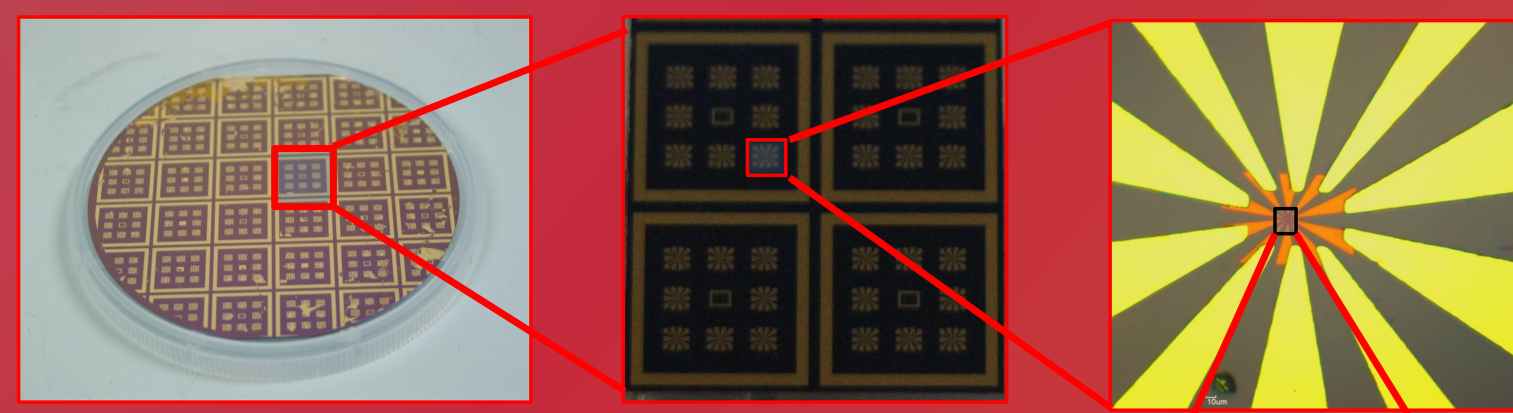


$$R^{c}_{nl} = R_{sq}\exp\left(-\frac{\pi L}{w}\right), \quad R^{SH}_{nl} = \frac{1}{2}\gamma^2 R_{sq}\frac{w}{l_s}\exp\left(-\frac{L}{l_s}\right), \quad \frac{R_{nl}}{R_{sq}} = a\left[1 - b\exp\left(-\frac{w}{l_e}\right)\right]$$

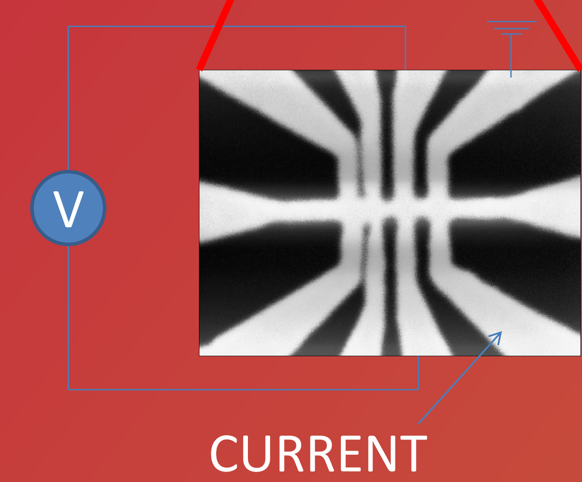
Schematic depiction of the physical mechanisms giving rise to (a) R^{C}_{nl} positive , (b) R^{SH}_{nl} positive and (d) R^{b}_{nl} negative[2]

R_{sq}=ρ*t (t stands for thickness)
L_s spin diffusion length
L_e Mean free path

Sample Fabrication

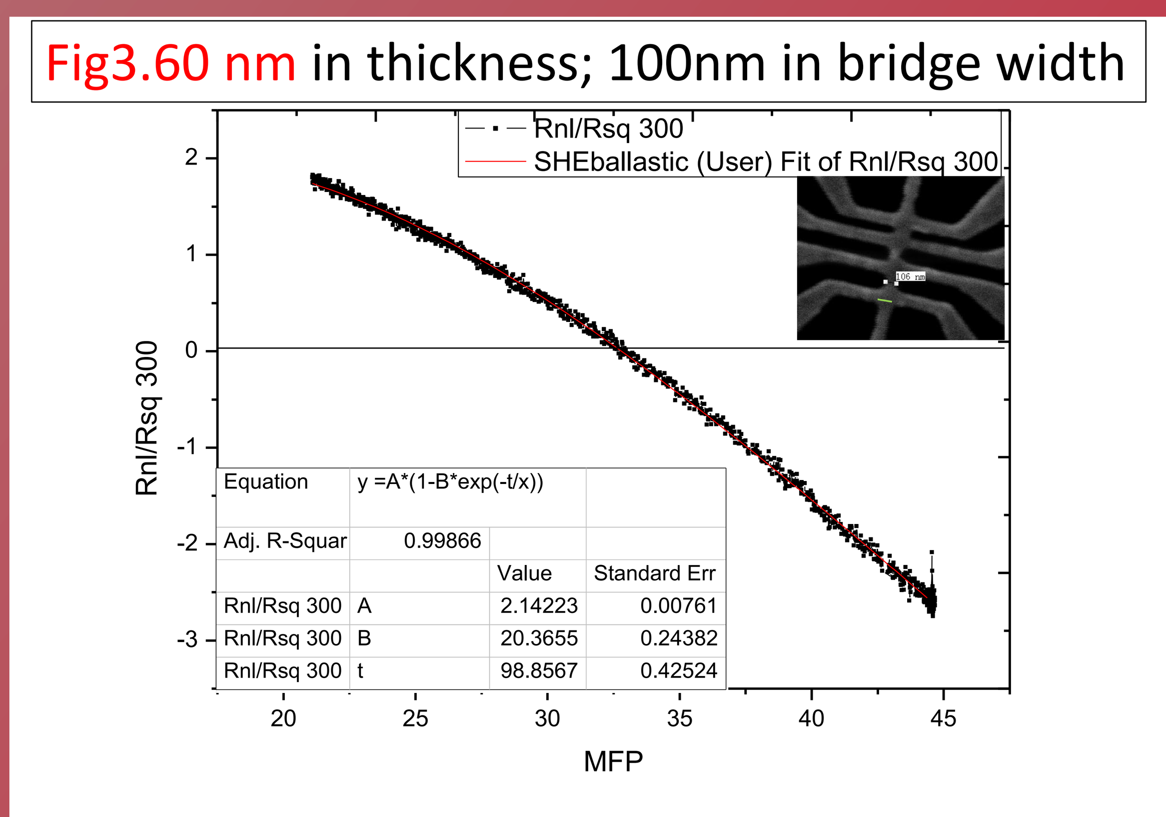


1. Electron Beam Lithography，minimum line width is 100nm
2. e-beam evaporation Au @ RT
3. Lift-off
4. Photolithography
5. e-beam evaporation Au @ RT
6. Lift-off



Results I reproduce the results in Ref[2]

Fig3.60 nm in thickness; 100nm in bridge width



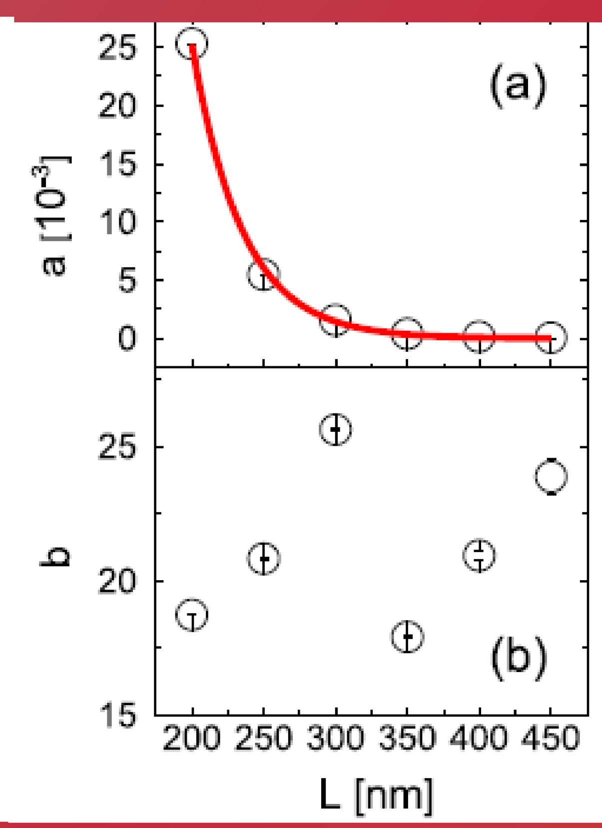


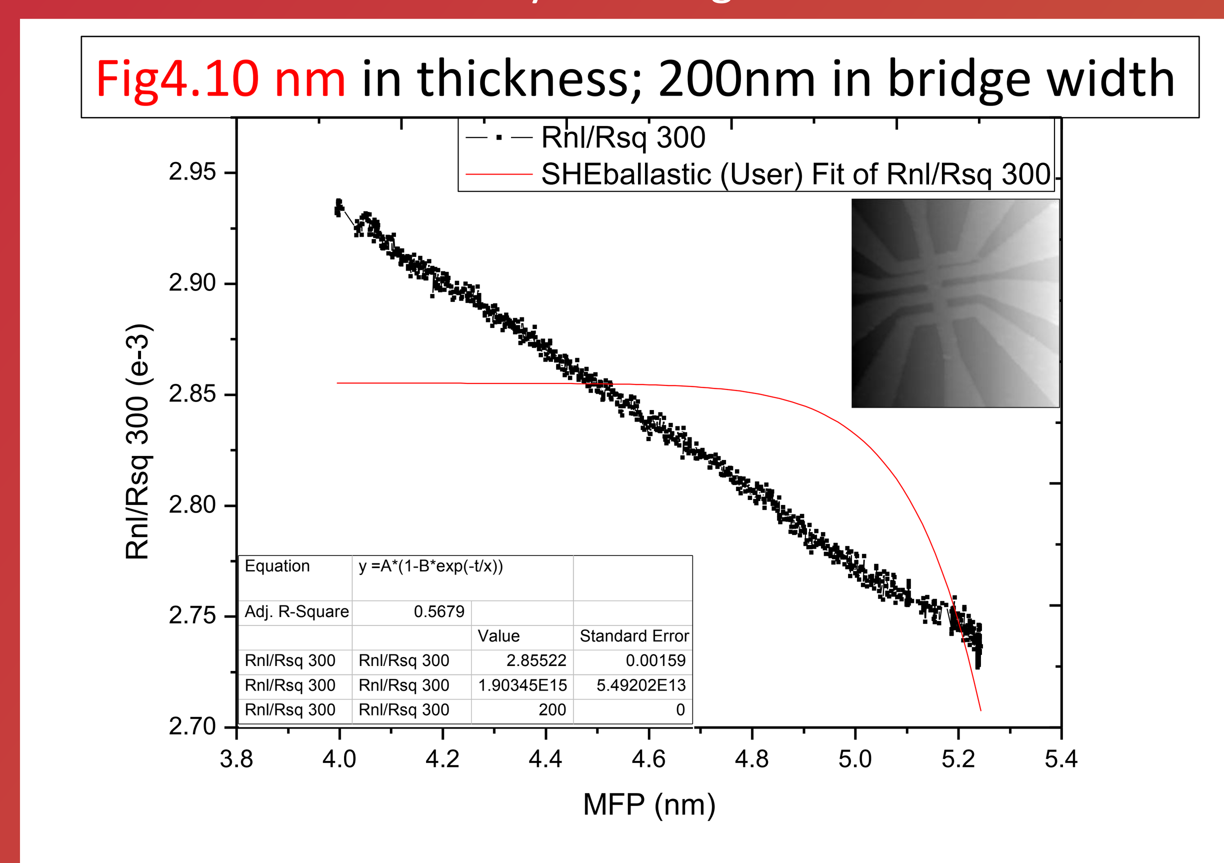
Fig5 .fitting parameter a & b versus distance.[2]

First we reproduced the results in Ref[2]. A negative signal is required.

Fitting with Equation $\frac{R_{nl}}{R_{sq}} = a[1 - b\exp\left(-\frac{w}{l_e}\right)]$ which is presented in [2],this equation contains two terms, the first term a indicates the Classical contribution, and the second term b indicates the Quasibalistic contribution. It is clear to see, the curve of 60nm sample fits the equation very well, and the fitting parameter t= 98.85 is in an agreement of the bridge width 106nm (see the SEM image, inset of Figure.3) and also a &b is quiet consist with former report (see FIG.5 [2])

Results II tune MFP by reducing thickness

Fig4.10 nm in thickness; 200nm in bridge width



As mentioned above, in 60nm sample, the quasibalistic contribution would contribute a negative signal in Nonlocal measurement. However, in 10nm sample, ***because of the reduction of MFP, there is no sign of the negative signal.***

On the other hand, While fixing the parameter t to 200nm(In Fig4), this ***Equation cannot fit to the 10nm sample curve***, this maybe indicates that an extra term should be induced to explain the data in 10nm sample, ***the extra term existence might suggests that there is a Spin Hall signal involved.***

Summary

We test the Nonlocal signal in H-Pattern Au sample, the thickness is 10nm and 60nm. In 60nm samples, we reproduce the results as former reported, classic and quasibalistic contribution domain the Nonlocal signal. In 10nm samples, the classic and quasibalistic contribution can not explain our data, this phenomena maybe indicates to a new term of Spin Hall.

References

[1] TAKESHI SEKI1*, YU HASEGAWA1, SEIJI MITANI1, SABURO TAKAHASHI1,2, HIROSHI IMAMURA2,3, SADAMICHI MAEKAWA1,2, JUNSAKU NITTA4 AND KOKI TAKANASHI1 nature materials VOL 7 FEBRUARY 2008
[2] G. Mihajlovic´,1,* J. E. Pearson,1 M. A. Garcia,2 S. D. Bader,1,3 and A. Hoffmann PRL 103, 166601 (2009)
[3] Yuan Tian, Li Ye, and Xiaofeng Jin 10.1103/PhysRevLett.103.087206
[4] All the data was taken at Yuanbo Zhang ‘s group