Spin-to-Charge Conversion in Bi Films and Bi/Ag Bilayers

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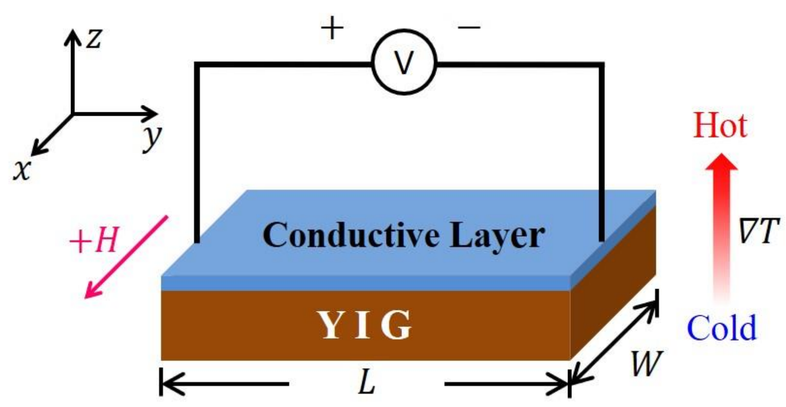
Introduction

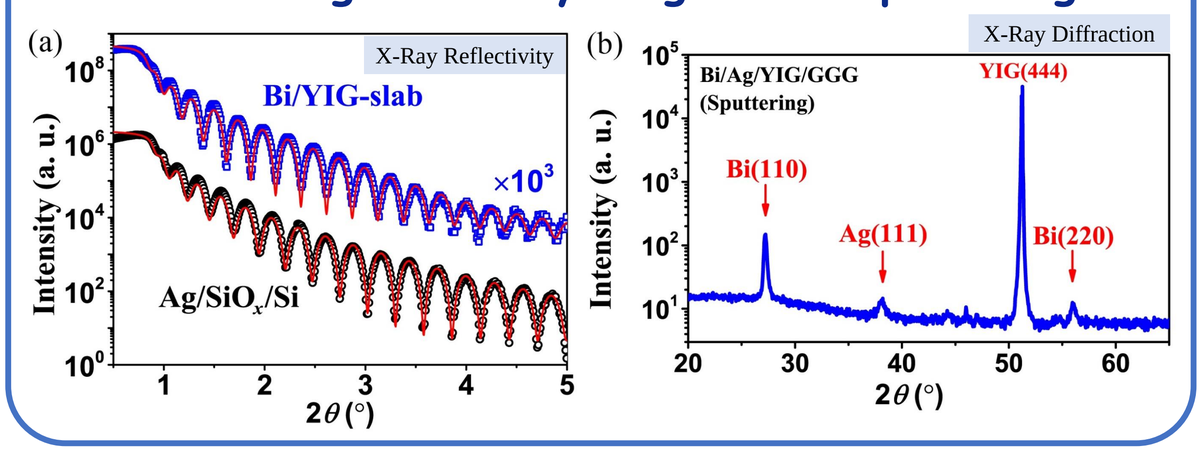
Spin-orbit coupling plays an important role in pure spin current transport phenomena, including conversion of spin current to charge current via the inverse spin Hall effect (ISHE) or the inverse Rashba-Edelstein effect (IREE). As the heaviest non-radioactive element in the periodic table, thus with strong spin-orbit interaction, bismuth (Bi) has attracted much interest for spin-to-charge conversion [1]. Remarkably, inserting a thin silver (Ag) layer substantially enhances the spin pumping signals in NiFe/Bi, which has been believed to be the evidences of the IREE at Bi/Ag interfaces [2]. In this work [3], we investigate the spin-to-charge conversion in Bi films and Bi/Ag bilayers with thermally injected spin current from a ferrimagnetic insulator YIG via the longitudinal spin Seebeck effect (LSSE) at room temperature. We have reached very different conclusions.

Thermally Injected Spin Current via LSSE

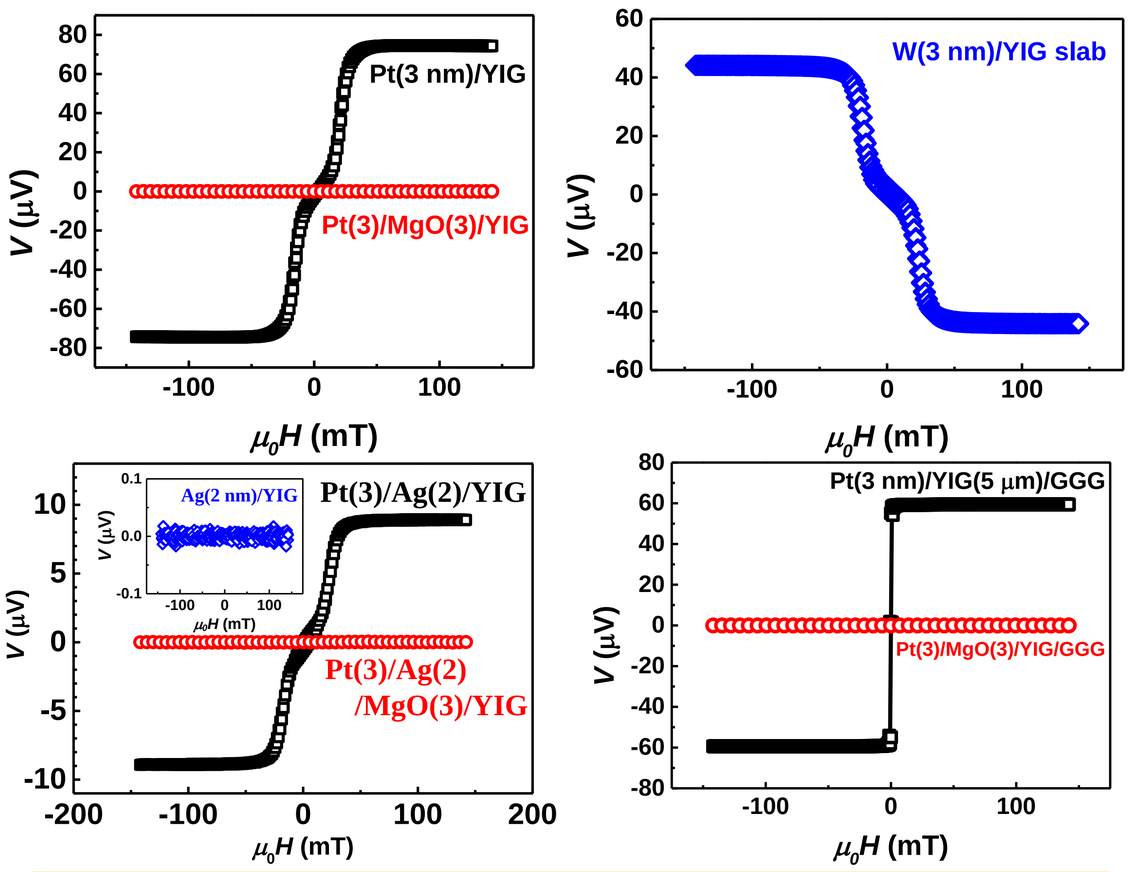


$L = 6$ mm; $W = 2$ mm; $\nabla T \approx 10$ K/mm

Bi & Bi/Ag Grown by Magnetron Sputtering



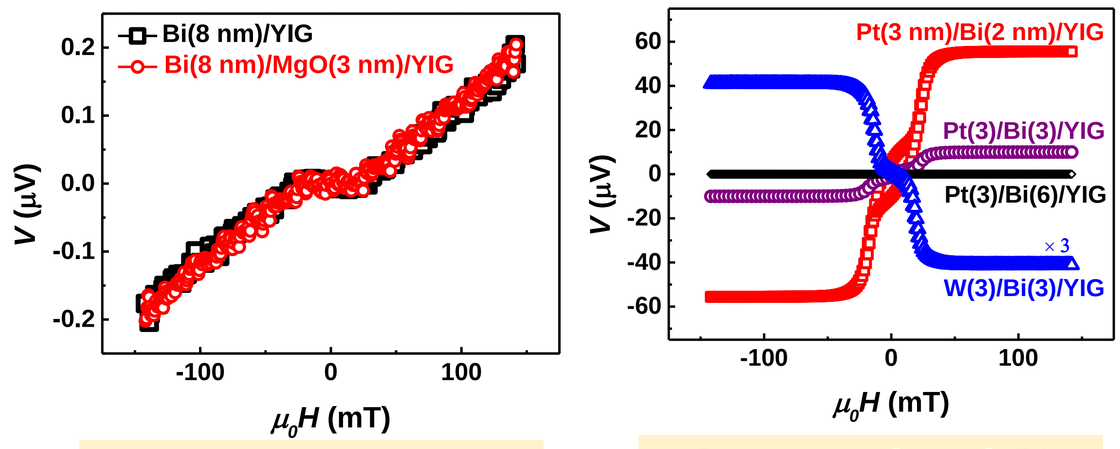
Spin-to-Charge Conversion in Pt, W…



Key features:[4]

- $\boldsymbol{E}_{\mathrm{ISHE}} \propto \boldsymbol{j}_s \times \boldsymbol{\sigma} \propto (-\nabla T) \times \boldsymbol{M}_{\mathrm{YIG}}$
- $\theta_{\mathrm{SH}}(\mathrm{Pt}) > 0$, $\theta_{\mathrm{SH}}(\mathrm{W}) < 0$
- MgO(3 nm) completely blocks the spin current.
- Spin current passes through Ag and is detected in Pt.
- Similar results were observed with **YIG slab** & **YIG/GGG** substrates.

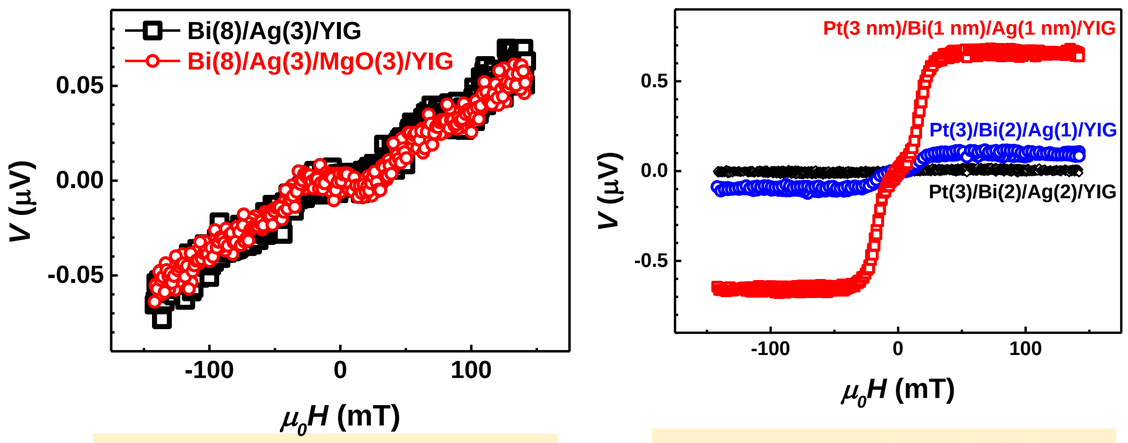
Negligible spin-to-charge conversion in Bi/YIG



Not spin current signal

Spin current **through** Bi

Negligible spin-to-charge conversion in Bi/Ag/YIG



Not spin current signal

Spin current **through** Bi/Ag

Single-Crystalline Bi(111) Films grown by MBE

Spin Injection from YIG(5 μm)/GGG

$\boldsymbol{E}_{\mathrm{Nernst}} \propto \nabla T \times \boldsymbol{B}$

No evidence of spin-to-charge conversion in **Bi/YIG & Bi/Ag/YIG**

References

[1] Dazhi Hou *et al.*, Appl. Phys. Lett. **101**, 042403 (2012).

[2] J.-C. Rojas-Sánchez *et al.*, Nat. Commun. **4**, 2944 (2013).

[3] Di Yue *et al.*, Phys. Rev. Lett. **121**, 037201 (2018).

[4] K. Uchida *et al.*, J. Phys.: Condens. Matter **26**, 343202 (2014).

Conclusions

In our work, although pure spin current has been injected into the Bi layer and the Bi/Ag bilayer, there is little detectable signal of spin-to-charge conversion, except the ordinary Nernst signal from the Bi layer, in sharp contrast to the inverse Rashba-Edelstein effect claimed in these systems.

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