Advanced Magnetic Materials

‘Spin Seebeck Effect’

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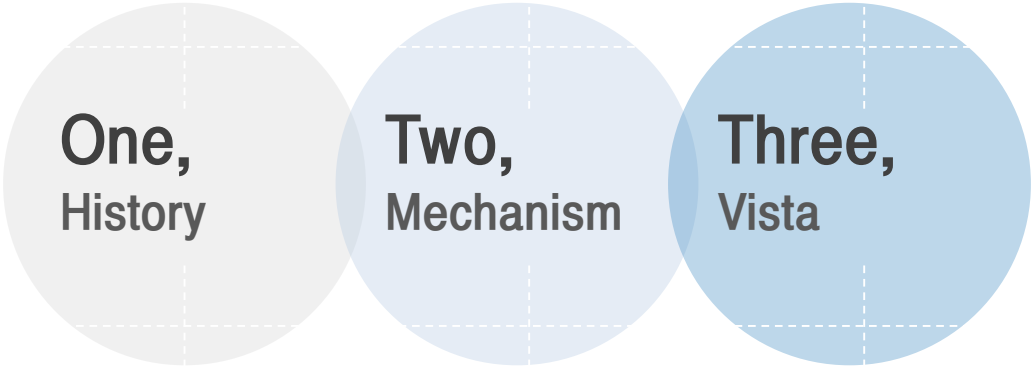
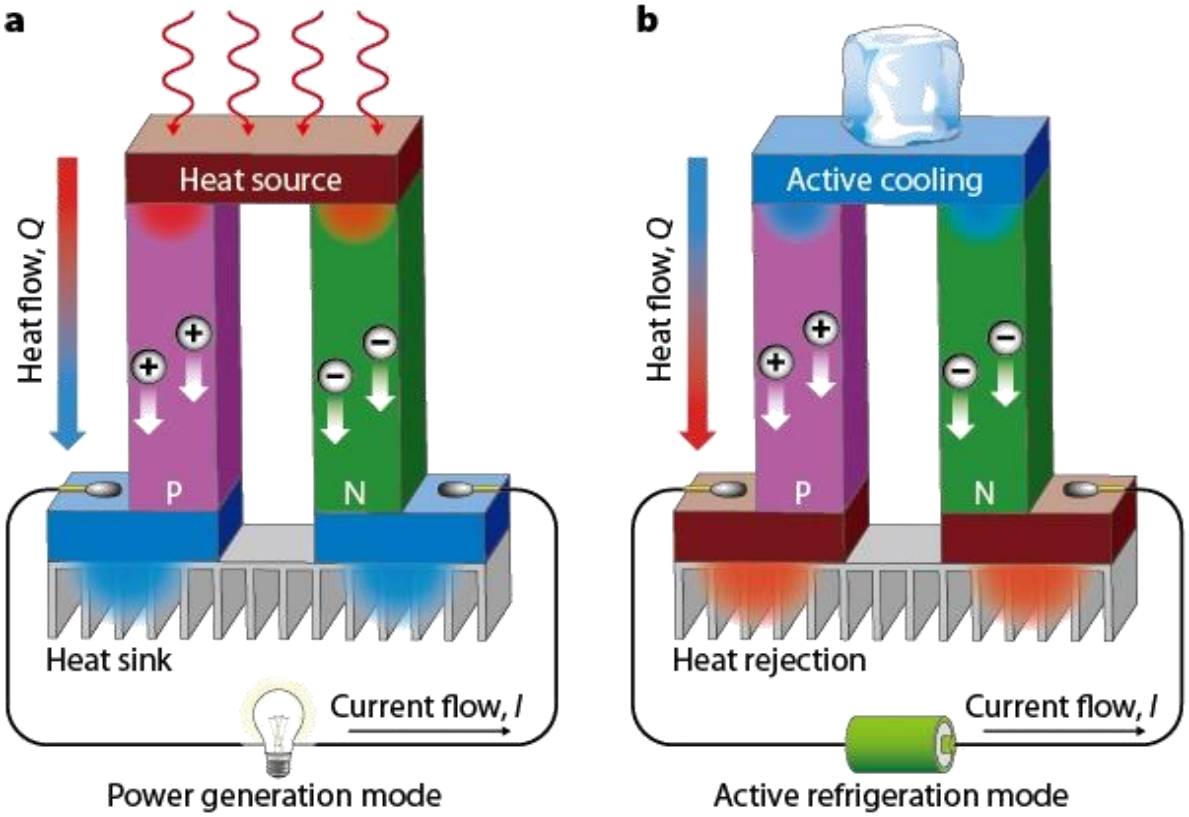


1 History

Thermoelectric Effect, and Spin Seebeck Effect(SSE)

Thermoelectric Effect

[Temperature gradient to electric voltage and vice versa]

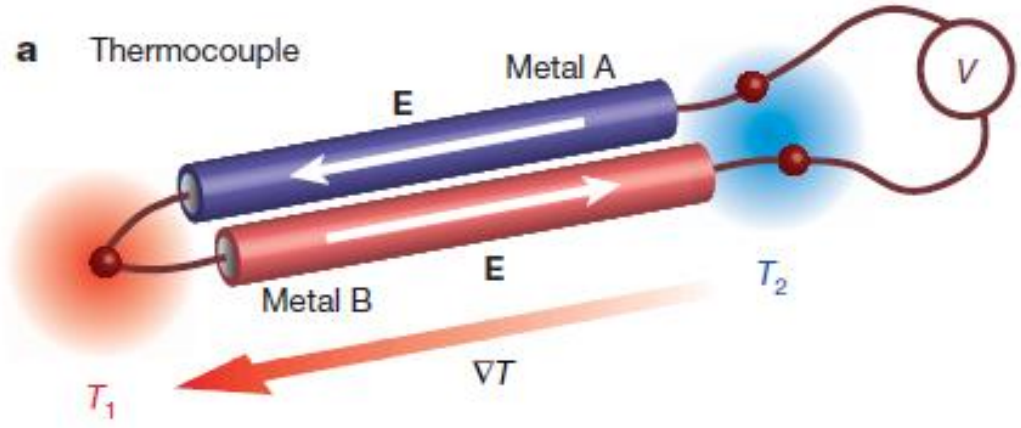


Seebeck effect (1821)

Peltier effect (1843)

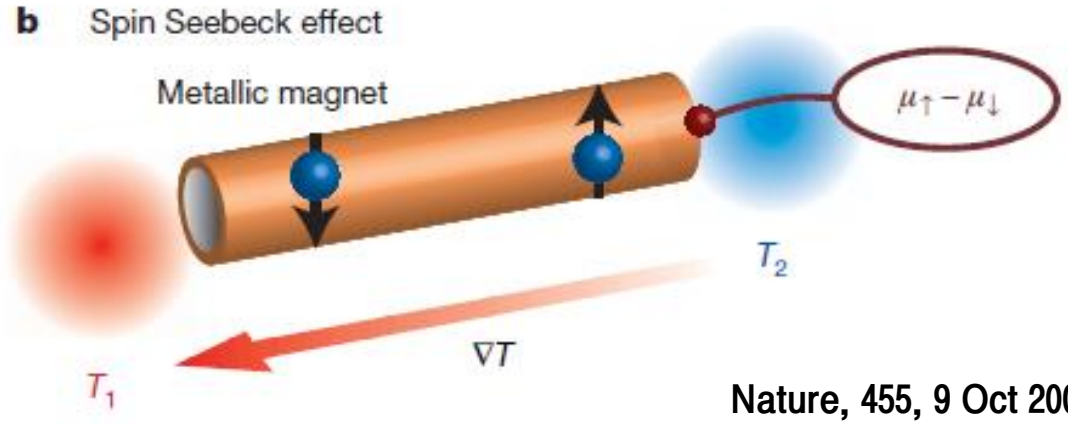
Spin Seebeck Effect (SSE)

[Temperature gradient to spin voltage]



Different S between A and B

→ Voltage(V) ∝ ΔT



Different S between ↑ and ↓

→ Spin Voltage ∝ ΔT

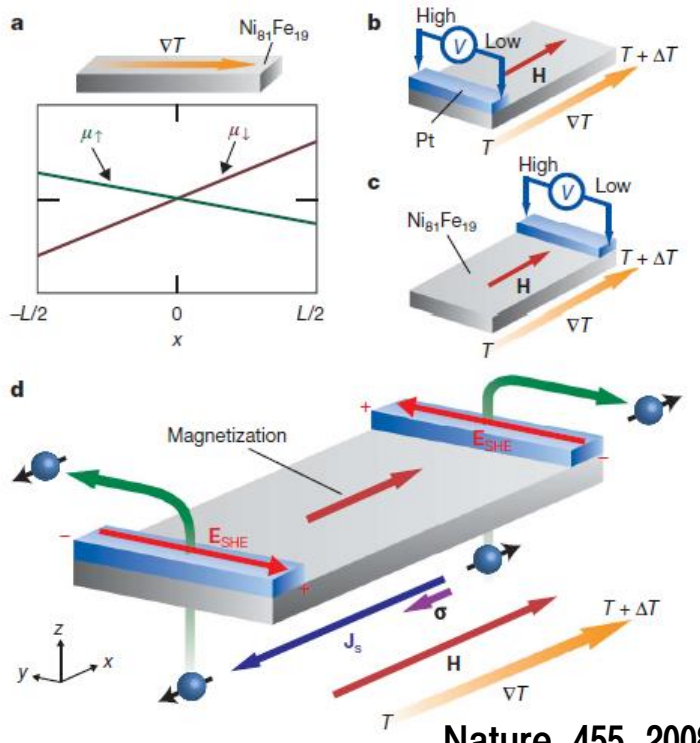
= Spin current potential

= $\mu_\uparrow - \mu_\downarrow$

Nature, 455, 9 Oct 2008

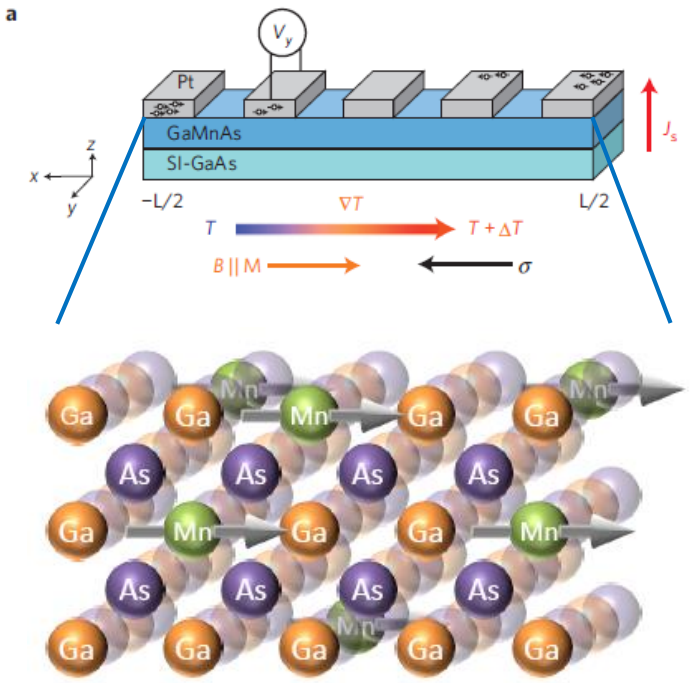
Spin Seebeck Effect (SSE)

Metallic Magnet (2008)



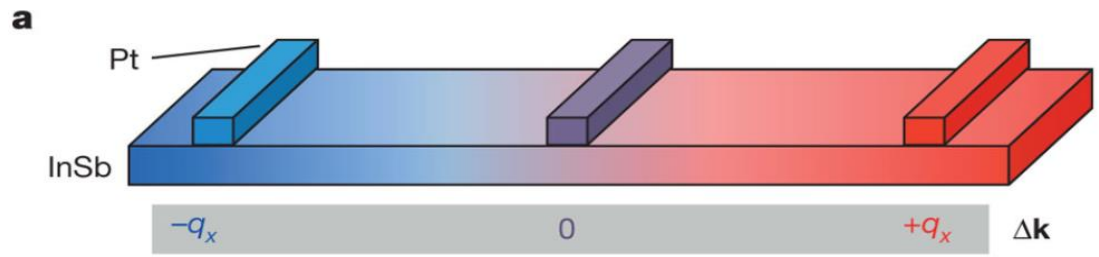
Nature, 455, 2008

Ferromagnetic Semiconductor (2010)



Nature Materials, 9, 2010

Non Magnetic Material (2012)



Nature, 487, 2012

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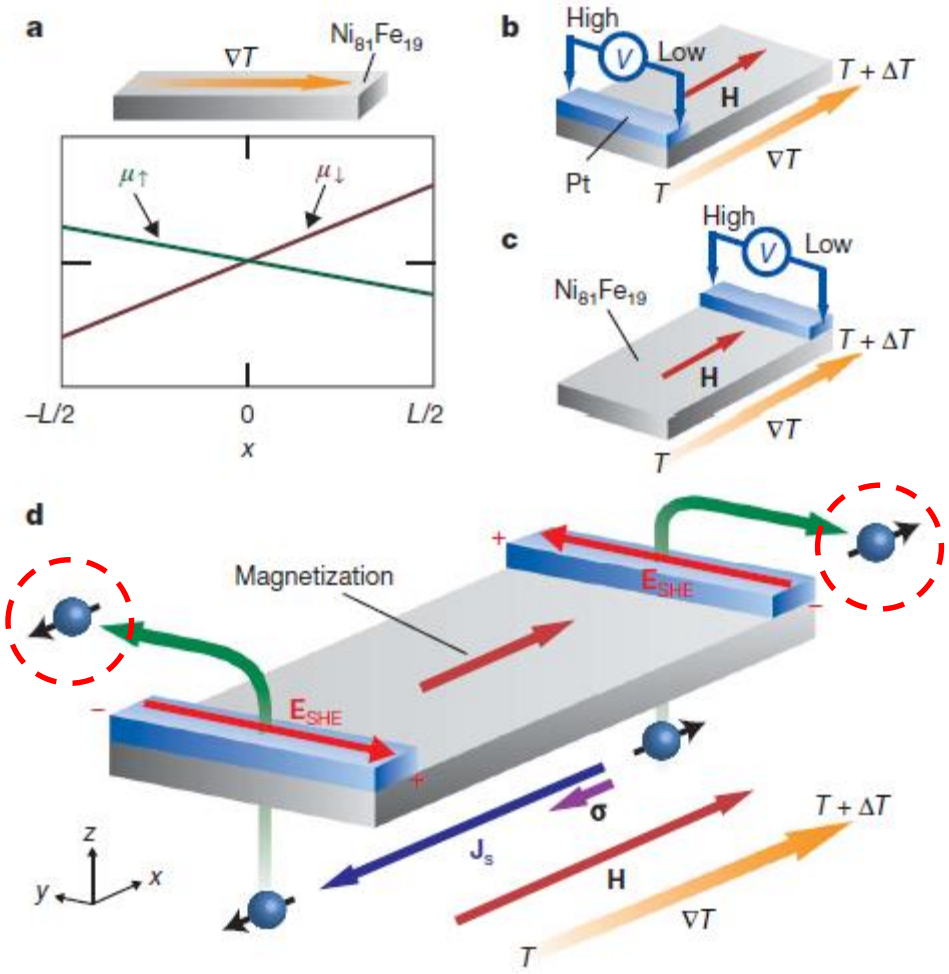
Mechanism

Principles of Spin Seebeck Effect(SSE)

SSE in Metallic Magnet

Nature, 455, 2008

Structure



Material

- $Ni_{81}Fe_{19}$ film: Soft Ferromagnet
- Pt wire: Paramagnet

Mechanism

- Film: ΔT ($Ni_{81}Fe_{19}$ layer) → spin V → spin current (Pt layer)
- Wire: Spin current → ISHE

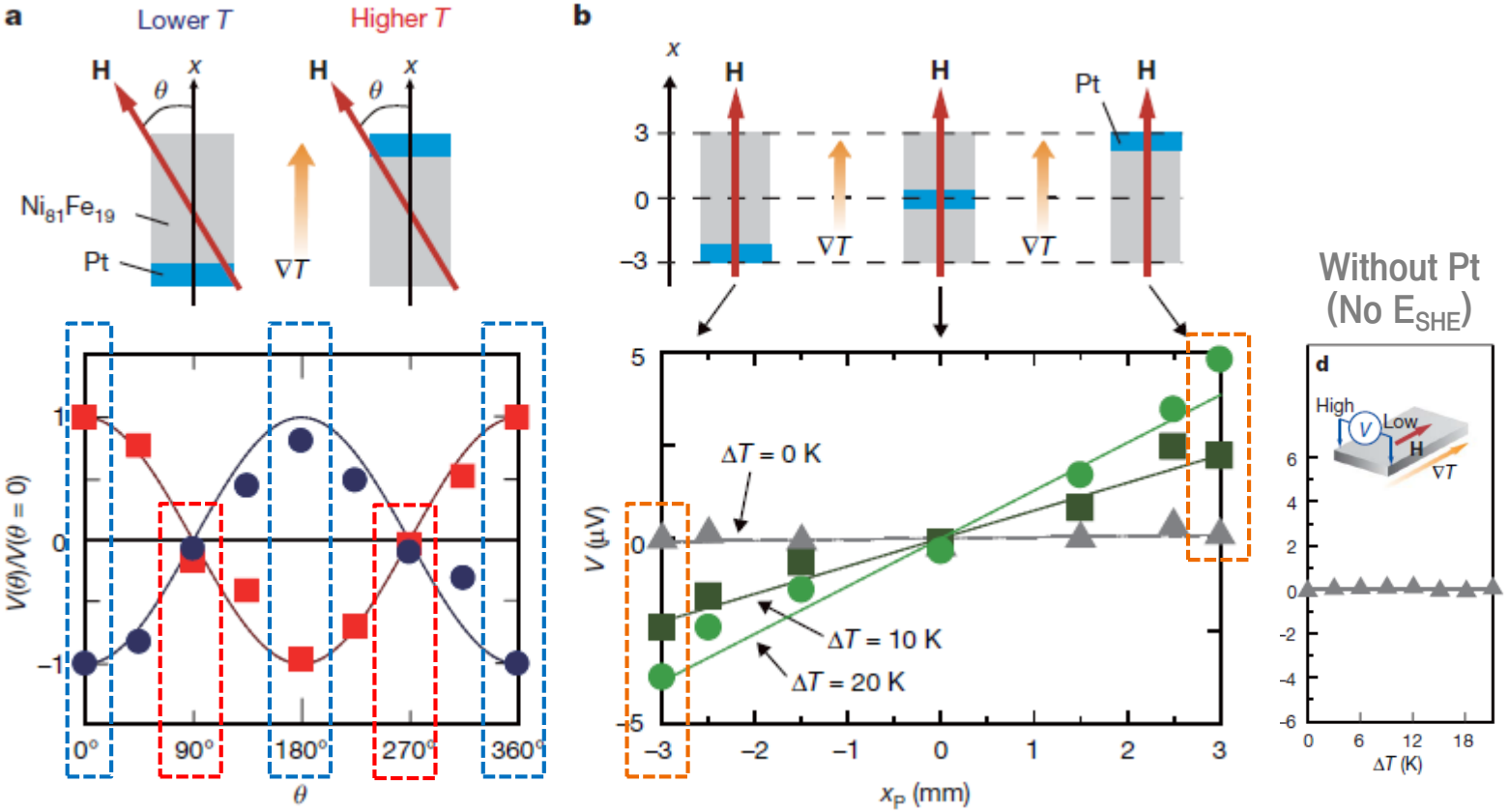
Related Principle

- Inverse Spin Hall Effect (ISHE)
  : spin current → Electromotive force

SSE in Metallic Magnet

Nature, 455, 2008

Dependence



[Angle] : spin V varies with Θ

- Consistent with the Prediction of the ISHE

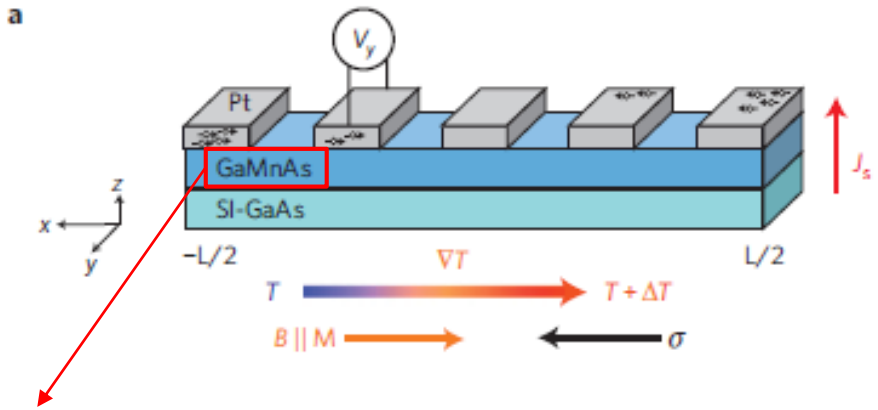
[Position] : spin V ∝ ΔT, x_p

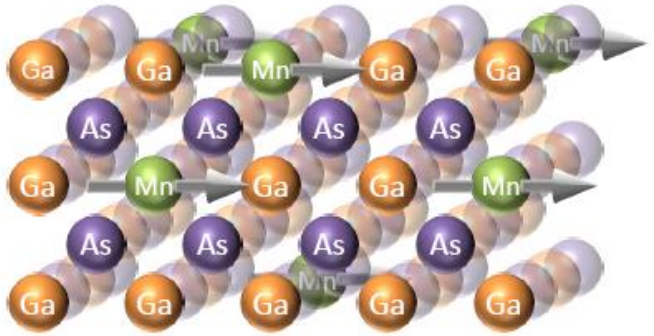
- Spins can be extracted from every position of film surface (by attaching a metal contact)

SSE in Ferromagnetic Semiconductor

Nature Materials, 9, 2010

Structure





GaMnAs: Ferromagnetic Semiconductor

- Much higher fraction of spin-polarized carriers

  (GaMnAs 〉 85% , NiFe ~ 35%)

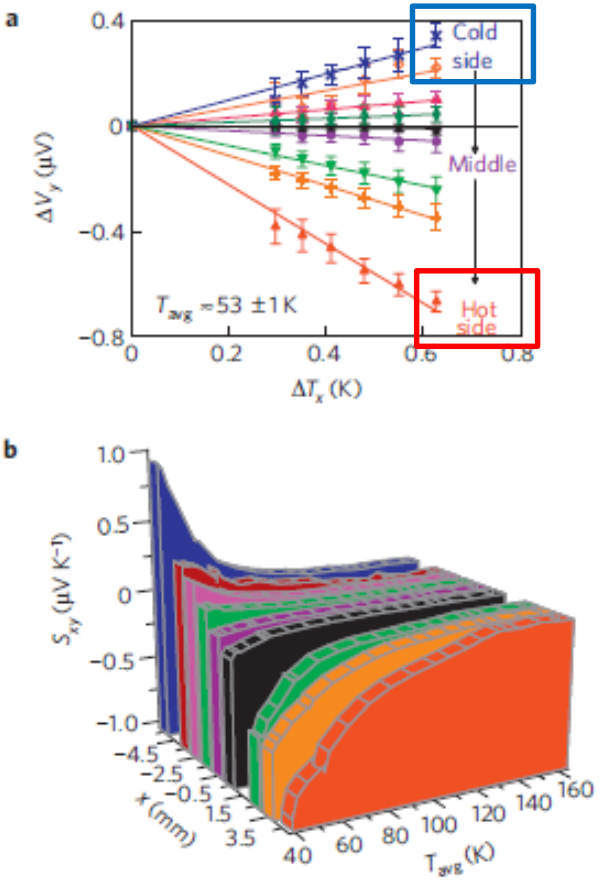
  → Larger spin polarization

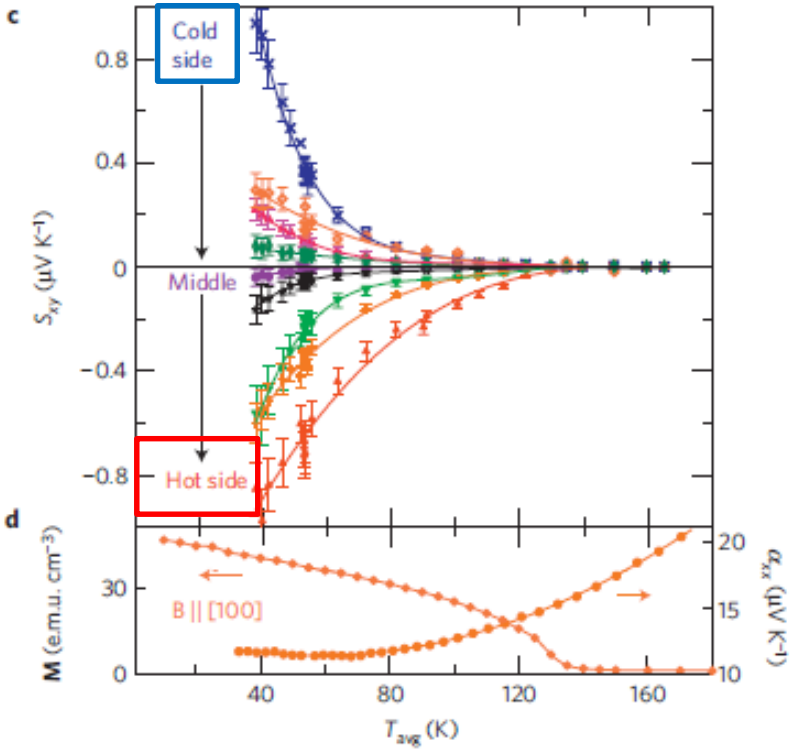
- Flexible design of magnetization direction

SSE in Ferromagnetic Semiconductor

Nature Materials, 9, 2010

Result 1: Different Seebeck Coefficient



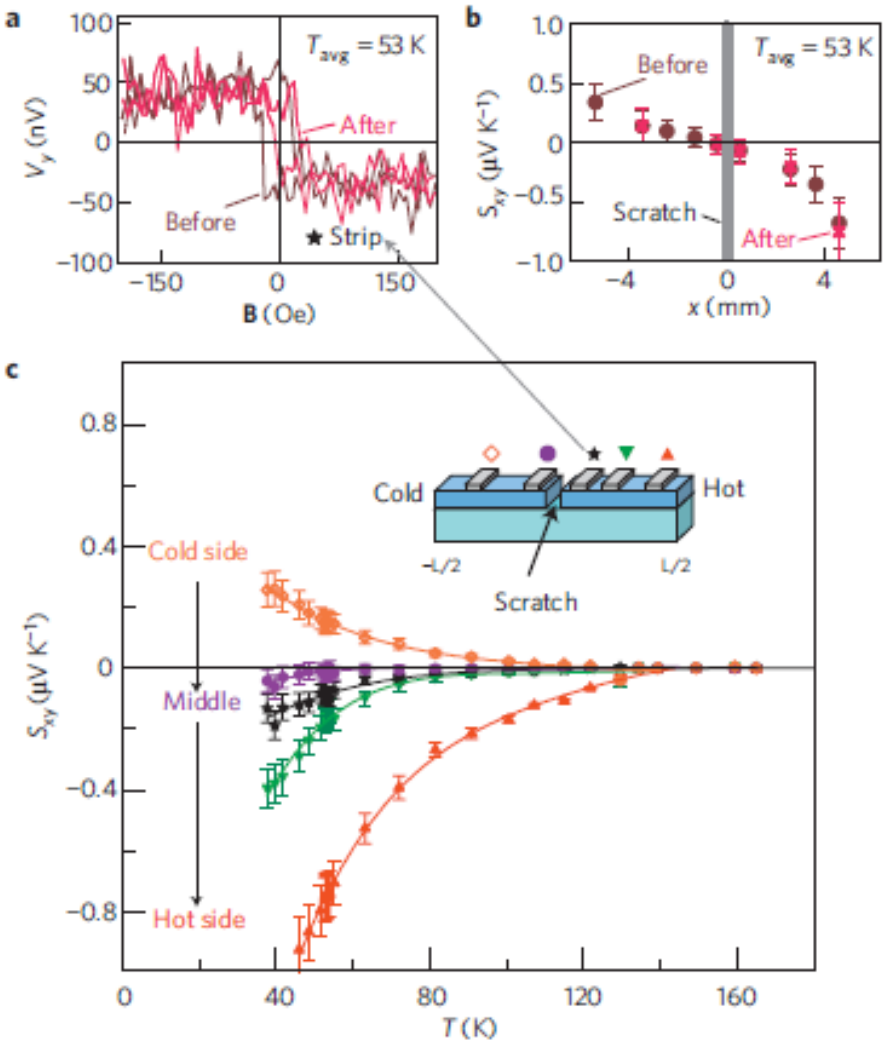


⇒ Two ends have different S

SSE in Ferromagnetic Semiconductor

Nature Materials, 9, 2010

Result 2: Longitudinal Spin Current Test



- No qualitative change in signal resulting from the scratch
- Charge/Spin carrier cannot cross
  → SSE is not comes from longitudinal spin current

⇒ Spin Seebeck Effect comes from the ΔT even ferromagnetic –semiconductor

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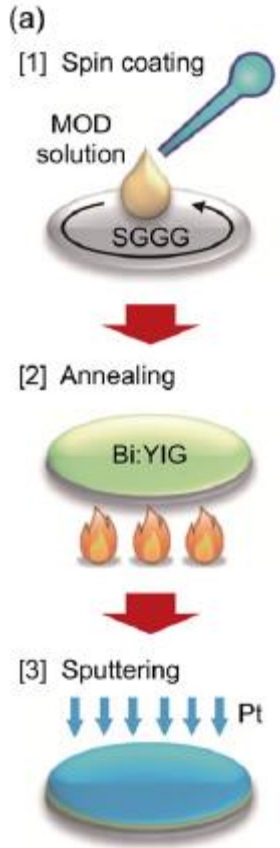
Vista

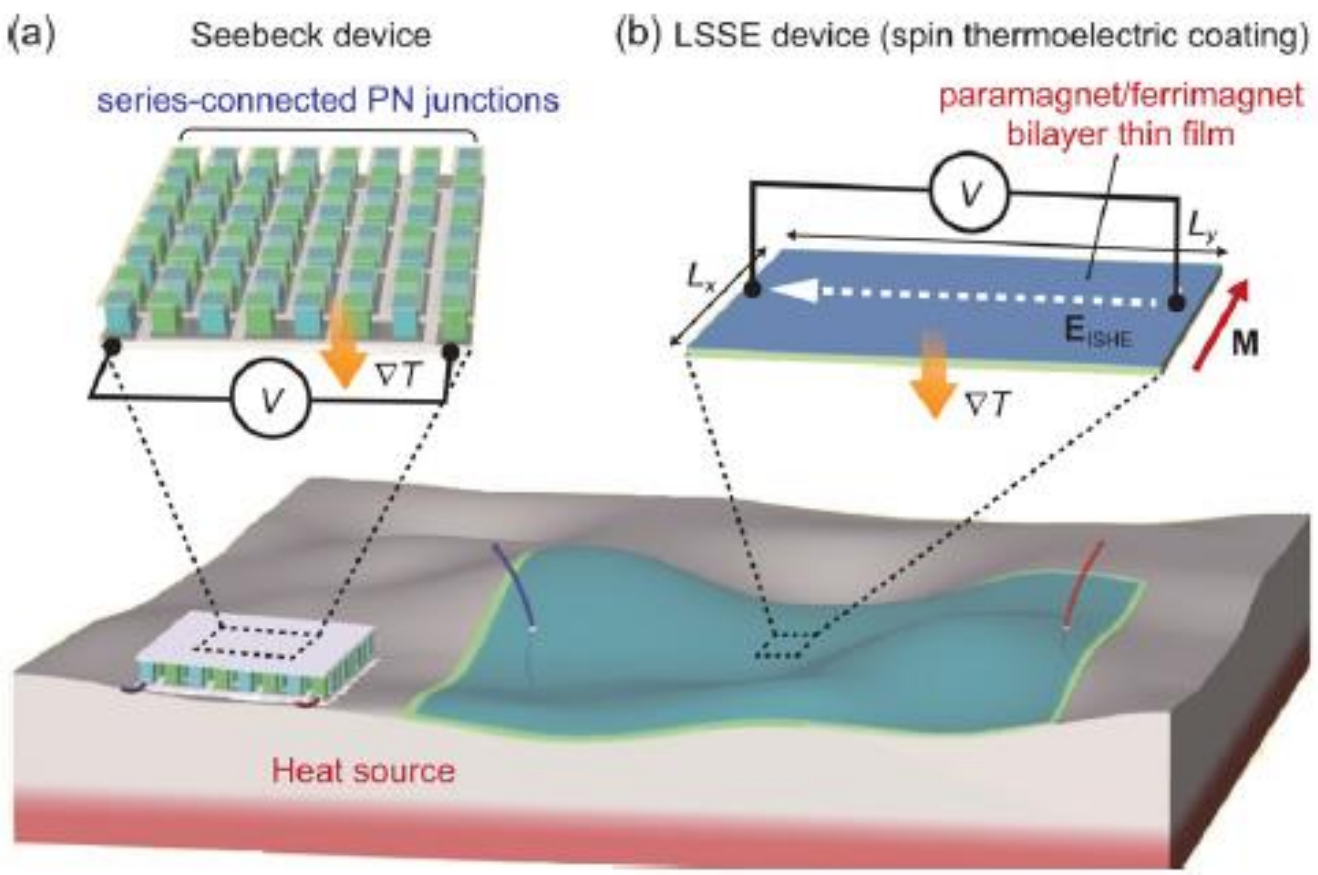
Future of Spin Seebeck Effect(SSE)

Spin Thermoelectric Coating

J. Phys.: Condens. Matter, 26, 2014



[STE coating]



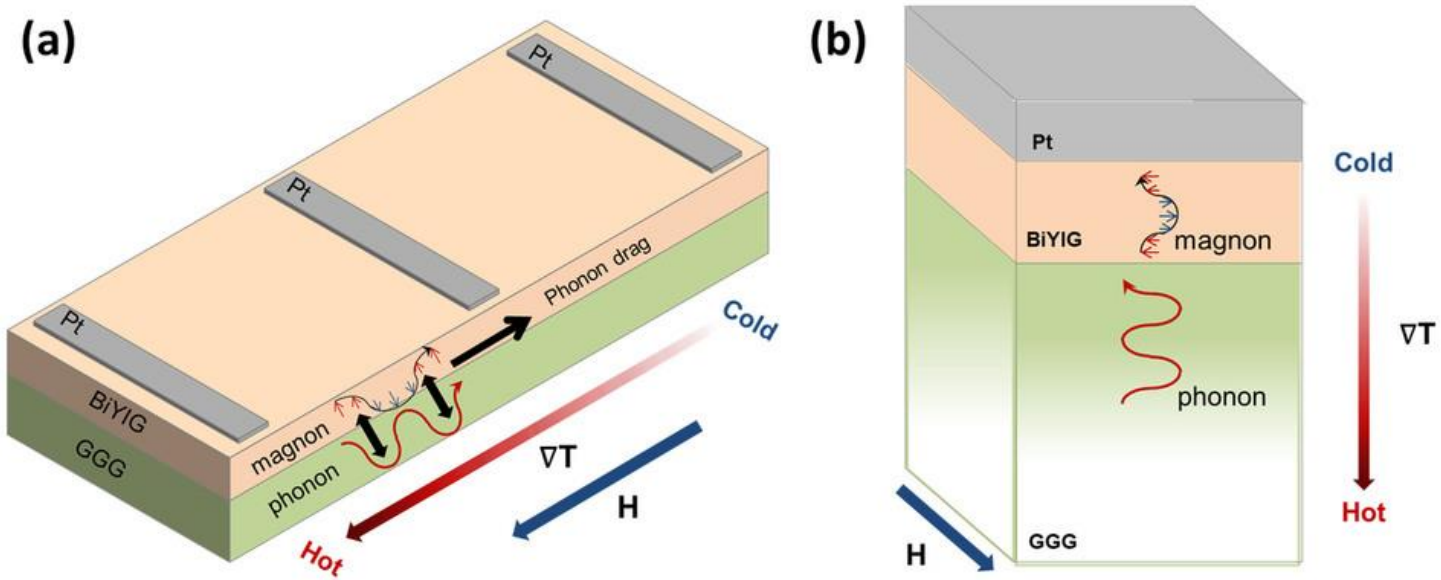
[Seebeck device vs LSSE device]

Simply process

Able to **coat directly** onto heat sources with **various shaped surfaces**

Spintronic Thermoelectric Power Generator

Scientific Reports, 4, 2014



- Phonon-drag effect in substrate → Enhance SSE
  (Only in the transverse geometry)
- Prepared by PLD technique → Large H_c

Useful for practical device application

"Minute heat emitted into useful electricity"

Q&A

Thank you for listening