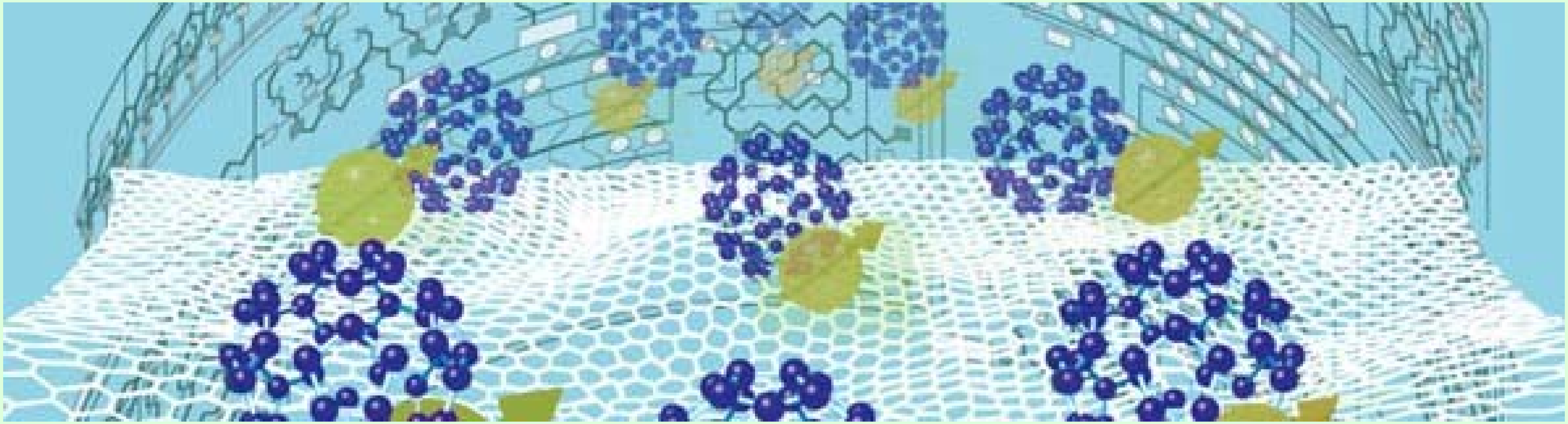
JST･さきがけ｢革新的次世代デバイスを目指す材料とプロセス｣第1期生成果報告会

シンポジウム　次世代革新的デバイス創成を指向した物理とテクノロジーの探索

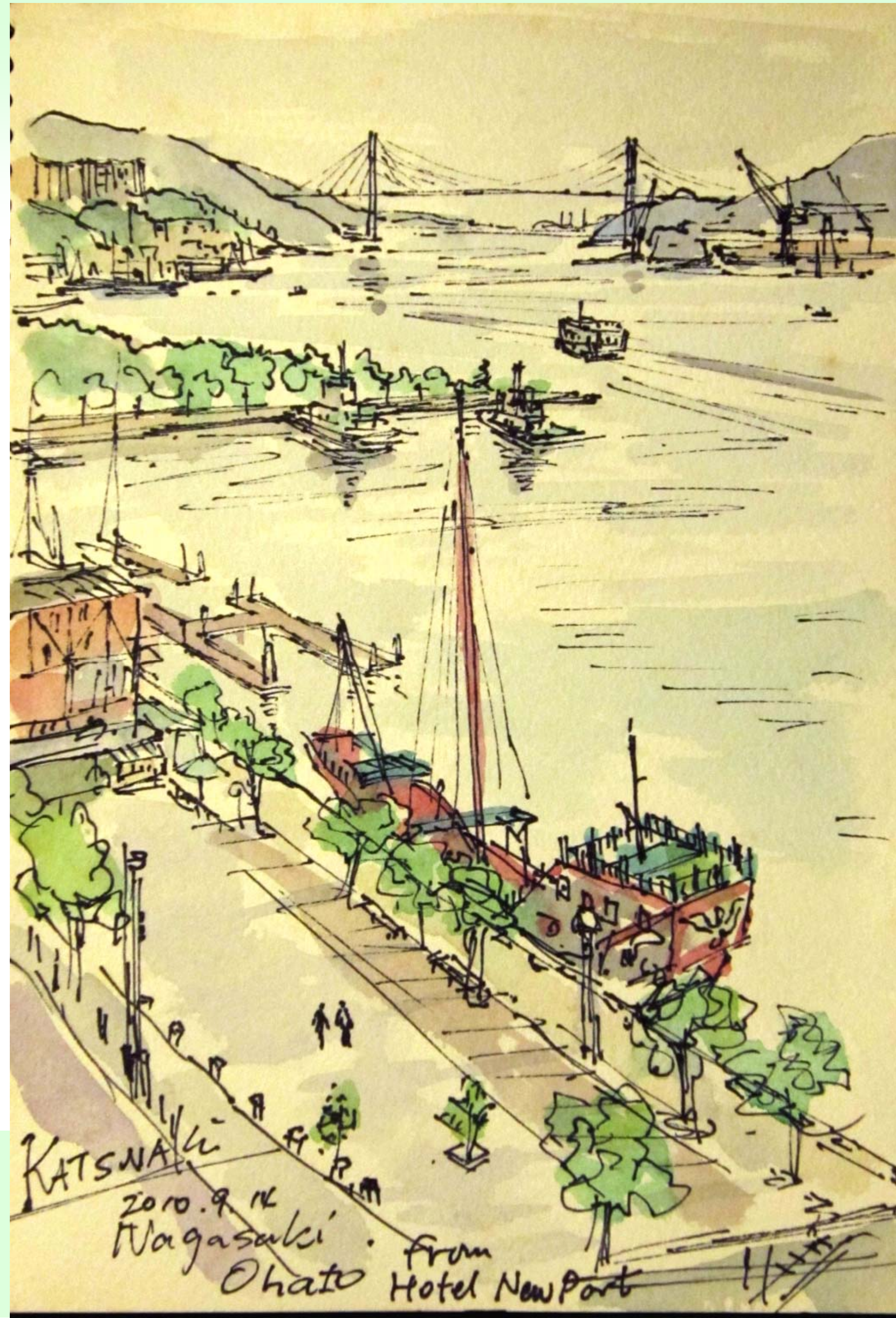
基礎研究が拓くデバイスイノベーション



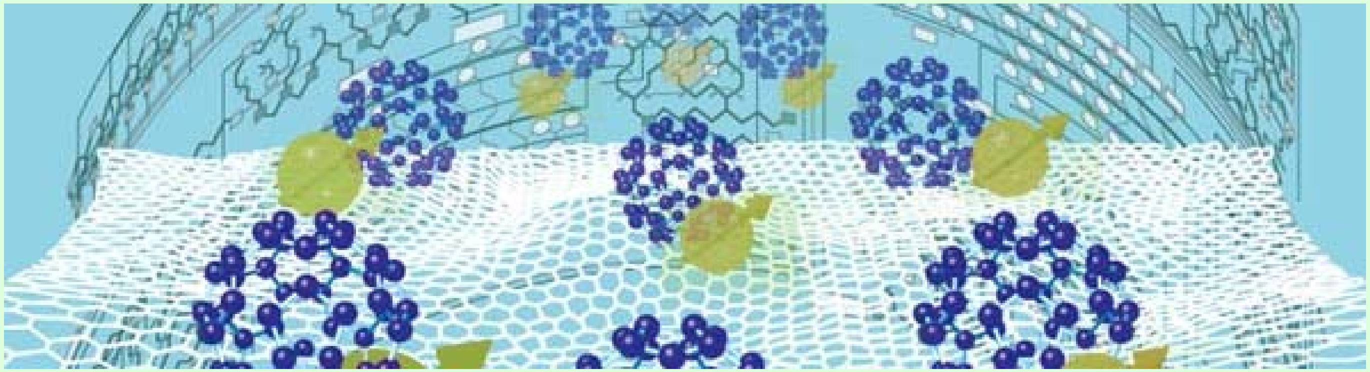
研究総括　佐藤勝昭

はじめに

- このシンポジウムは、JSTの戦略的創造研究事業さきがけ「革新的次世代デバイスをめざす材料とプロセス」の第1期生（2007.10～2011.3）の成果報告会として企画されたものです。
- 折角の成果をぜひ多くの研究者に知って頂きたいと本学会のシンポジウムの場をお借りしました。
- 美しい長崎の地で、さきがけ成果報告会ができることは、この上ない喜びです。
- 世話人を引き受けて頂いた葛西誠也研究者（北大）に感謝します。[本日はやむを得ない事情により欠席]

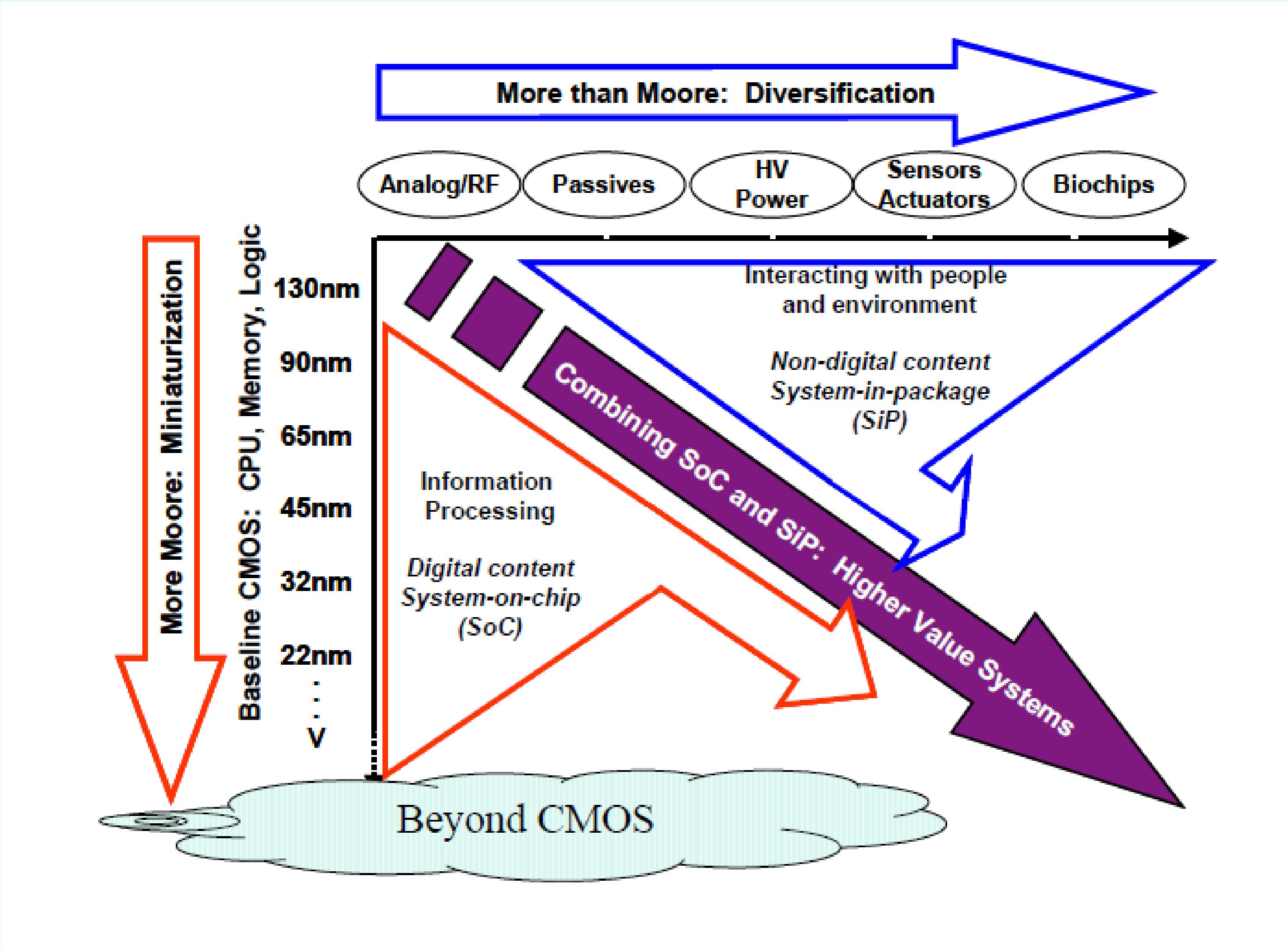


「さきがけ研究」佐藤領域について



- JSTは、2007年度発足の新しい戦略的創造研究事業(さきがけ)「革新的次世代デバイスを目指す材料とプロセス」の研究課題を3期にわたり公募しました。
- この研究領域は、文部科学省の戦略目標「新原理・新機能・新構造デバイス実現のための材料開拓とナノプロセス開発」に沿って設置されたものです。

ITRS Roadmap



Emerging Research Materials

Low Dimensional Materials(Nano-mechanical memory, Nanotube, Nanowire, Graphene･･･)
Macromolecules(Molecular memory, Molecular devices, Resists, Imprint polymers･･･)
Self-Assembled Materials(Sub-lithographic patterns, selective etch･･･)
Spin Materials (MRAM by spin injection, Semiconductor spin transport, FM semiconductors･･)
Complex Metal Oxides (Multiferroics)
Interfaces and Heterointerfaces(Electrical and spin contacts)

Table ERM2 Applications of Emerging Research Materials

Materials	ERD Memory	ERD Logic	Lithography	FEP	Interconnects	Assembly and Package
Low Dimensional Materials	Nano-mechanical Memory	Nanotube Nanowire Graphene and graphitic structures	High-index immersion liquids		Nanotubes Metal nanowires	Electrical applications Thermal applications Mechanical applications
Macromolecules	Molecular memory	Molecular devices	Resists Imprint polymers	Novel cleans Selective etches Selective depositions	Low-κ ILD	Polymer electrical and thermal/ mechanical property control
Self Assembled Materials			Sub- lithographic patterns Enhanced dimensional control	Selective etch Selective deposition Deterministic doping	Selective etch Selective deposition	High performance capacitors
Spin Materials	MRAM by spin injection	Semiconductor spin transport Ferromagnetic (FM) semiconductors FM metals Tunnel dielectrics Passivation dielectrics				
Complex Metal Oxides	1T Fe FET Fuse-anti-fuse	Multiferroics (Spin materials) Novel phase change				High performance capacitors
Interfaces and Heterointerfaces	Electrical and spin contacts and interfaces	Electrical and spin contacts and interfaces			Contacts and interfaces	

Low Dimensional Materials

Table ERM3 Potential Applications and Challenges for Low Dimensional Materials

APPLICATION	POTENTIAL MATERIAL VALUE	KEY CHALLENGES
Devices: 1D Memory and Logic Devices	Nanotubes:Ballistic Transport Nanotubes exhibit ballistic transport and potential high performance	Control of bandgap and metallic versus semiconducting Control of carrier type and concentration Electrical properties must not degrade when embedded in a dielectric Control of location and orientation Control of contact resistance
	Nanowires:SRT Nanowires could enable surround gate structures and novel heterostructures	Control of location and orientation Performance exceeding patterned materials Catalyst and processing temperatures compatible with CMOS
Devices: Planar CMOS	Graphene: high mobility Graphene and related graphitic structures have high mobility without CNTs alignment challenges	Compatibility with CMOS Edge passivation Control of dielectric interfaces
Interconnects and Vias: Nanotube	Nanotubes:robustness Nanotubes have ballistic transport, high current carrying ability, and resistance to electromigration (EM)	Ability to place CNTs in precise locations and with controlled direction Ability to grow with high density Conductivity must not degrade when embedded in a dielectric Low contact resistance
Interconnects: Nanowire	Single crystal smooth metal nanowires could reduce grain-boundary and sidewall scattering	Ability to grow long single-crystal high-conductivity nanowires Ability to place the nanowires in precise locations and with controlled direction

基礎研究はイノベーションに寄与するか

- OECDが定めたFrascati manual（ 2002年の改訂版）では基礎研究をpure basic researchとoriented basic researchに分け、後者を将来の広範な応用をゴールとして明示したものと定義しています。
- JSTのさきがけ研究は、まさに後者の基礎研究です。決して、3年半の間に実用化までつながる必要はないが、将来にわたる課題解決を明確に意識した研究であることが求められているのです。

デバイスイノベーションとは？

- イノベーションというのは、新しい技術の発明だけではなく、新しいアイデアから社会的意義のある新たな価値を創造し、社会的に大きな変化をもたらす自発的な人・組織・社会の幅広い変革のことです。
- ここでいうデバイスイノベーションとは単なるCMOS技術の改良ではなく、物理とテクノロジーのシナジーを通じて社会にパラダイムシフトを起こすような新現象、新材料、新デバイスの創出を意味しています。

（例：湯浅新治氏のMgOバリアTMR←さきがけの成果）

デバイスイノベーションにむけて

- 本研究領域は、CMOSに代表される既存のシリコンデバイスを超えるデバイスイノベーションを惹起するような材料・プロセスの開拓を目標としています。
- そのための研究分野の候補として、私は、(1)スピントロニクス材料、(2)ワイドギャップ・ナノエレクトロニクス材料、(3)高温超伝導体を含む強相関材料、(4)ナノカーボン・有機エレクトロニクス材料を対象としました。
- 課題採択の段階から、Oriented basic researchであることを強く意識し、たとえ優れた基礎研究であっても、デバイスを意識しない課題は採用しませんでした。

採択課題について

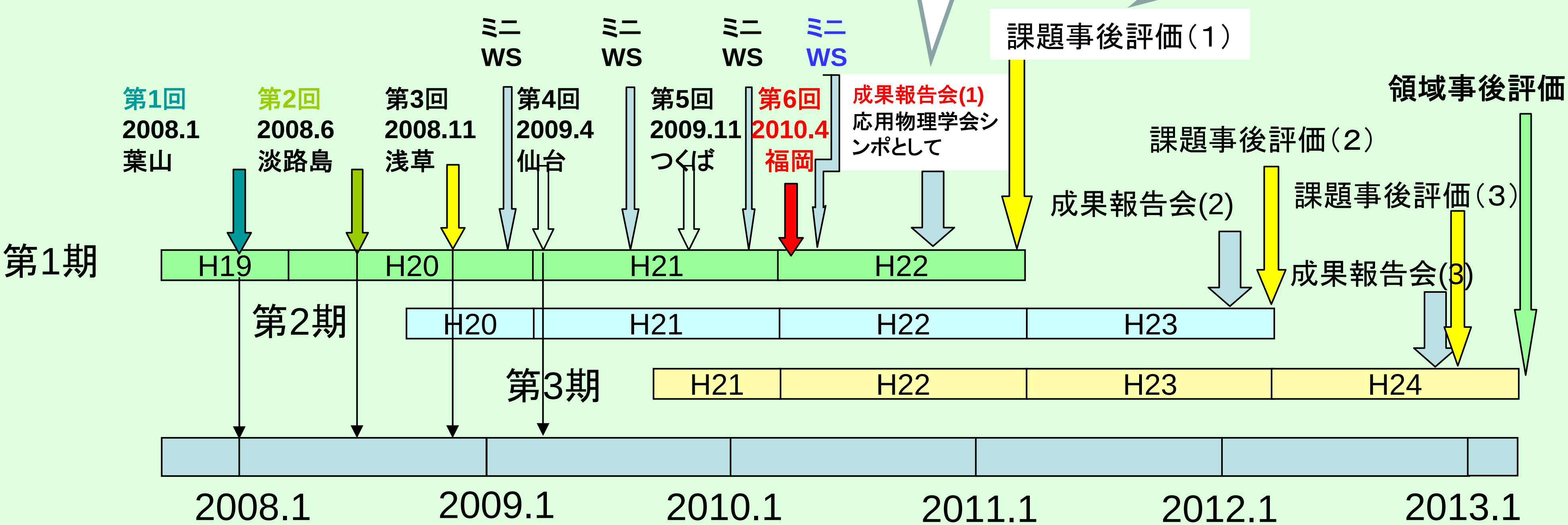
- 1期生は、スピントロニクスに関連した課題の応募が多く、結果的に採択した11課題のうち7課題がスピントロニクスに関連していました。
- 2期では、募集に当たっての文章を工夫した結果ワイドギャップ、ナノエレクトロニクスの課題が半数を占めました。
- 3期では、1－2期で応募の少なかった分子・有機エレクトロニクス材料をエンカレッジし、この分野の採択課題が半数を占めました。
- この結果3期全体を通じて所期の分野をカバーしました。

領域運営について

- 第1期生：3年経過
- 第2期生：2年経過
- 第3期生：1年経過

私たちの成果をより多くの研究者に知ってもらいたい！

国民にわかりやすい評価報告書を作りたい！



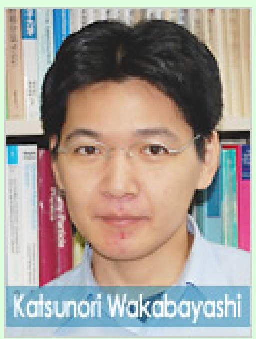
1期生(2007年度採択)の研究課題

葛西誠也(北大)	「確率共鳴を利用した新しい情報処理のためのナノデバイスと集積化」
齊藤英治(東北大)	「誘電体スピントロニクス材料開拓とスピン光機能」
白石誠司(阪大)	「分子を介したスピン流の制御」
高橋有紀子(NIMS)	「スピントロニクスデバイス用室温ハーフメタルの探索」
谷山智康(東工大)	「スピン偏極の外的制御とチューナブルスピン源の創製」
塚本新(日大)	「フェムト秒パルス・レーザによる超高速スピン制御・計測」
深田直樹 (NIMS)	「縦型立体構造デバイス実現に向けた半導体ナノワイヤの開発」
村上修一(東工大)	「デバイス応用に向けたスピン流と熱流の結合理論」
安田剛(NIMS)	「π共役高分子鎖内の超高速電荷輸送を利用した有機トランジスタ」
山口明啓(慶大)	「ナノ磁性体集結群の新奇な磁気特性の究明」
若林克法(広大)	「計算科学手法によるナノカーボン素子の設計と物性予測」

さきがけ佐藤領域第1期生(2007年度採択）

スピントロニクス

ナノカーボン・オーガニック



ナノエレクトロニクス

研究内容の分類マップ

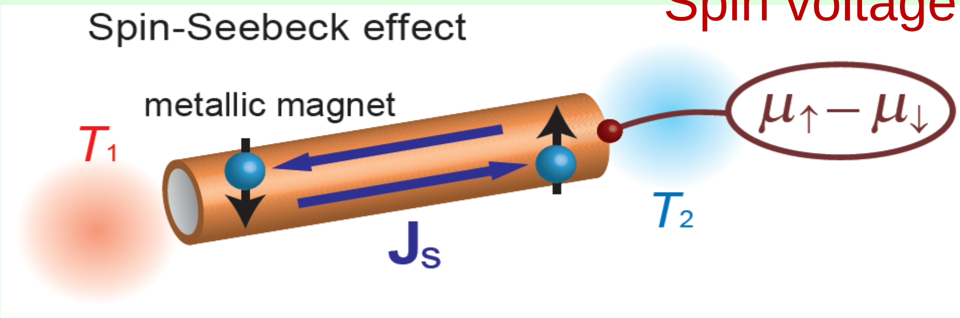
	酸化物 WG半導体 ダイヤモンド	半導体ナノ構造	金属・合金・複合	分子・有機	アドバイザ
強相関・超伝導エレクトロニクス	川山(YBCO)				藤巻 波多野 岡本 谷垣
フォトニクス・フォトスピニクス	片山(GaN, ZnO)	中岡(GaAs QD) 高橋_和	塚本(RE-TM alloy)	野口(OSET)	五明 小森 岡本
スピントロニクス	齊籐(YIG) 谷山(Fe_3O_4) 水落(^{13}C, SiC) 福村(TiO_2:Co) 中村($KTaO_3$)	浜屋(Si-QD spinFET)	高橋_有(heusler) 谷山(FeRh) 山口(metamateria 村上(Bi)	白石(grapheme) 海住(Spin QC)	高梨 粟野 谷垣
ナノデバイス	須崎(MgO/STO) 組頭(Al_2O_3,Fe,Mn酸化物) 東脇（III-O/III-N）	葛西(III-V nanowire) 深田(Si nanowire) 中岡(GaAs QD SET) 竹中(Ge nano LSI) 冨岡(Si/III-V nanowire)		若林(nanocarbon) 安田(PP V) 西永(C60/GaAs) 中野(OFET) 山本(Mott-OFET) 町田(graphene) 野口(OSET)	五明 波多野 小田 小森 名西 粟野 谷垣
サーモエレクトロニクス	小林(LCO/LSCO)		村上(Bi)	村上(graphene)	波多野 粟野
プロセス	寒川(ALN)	冨岡(Si/III-V nanowire)		安田(OFET) 野田(nanocarbon) 中野(OFET)	工藤 名西
アドバイザ	藤巻、岡本、名西、粟野	小田、五明、波多野、小森、粟野、谷垣	高梨、谷垣	工藤、岡本 粟野、谷垣	

Spin current and heat flow

- Saito et al. observed the spin voltage generated from a temperature gradient in a metallic magnet and name the phenomenon as *spin-Seebek effect* using a recently developed spin-detection technique that involves the SHE.
  - K. Uchida, S. Takahashi, K. Harii, J. Ieda, W. Koshibae, K. Ando, S. Maekawa and E. Saitoh: Nature **455** (2008) 778.

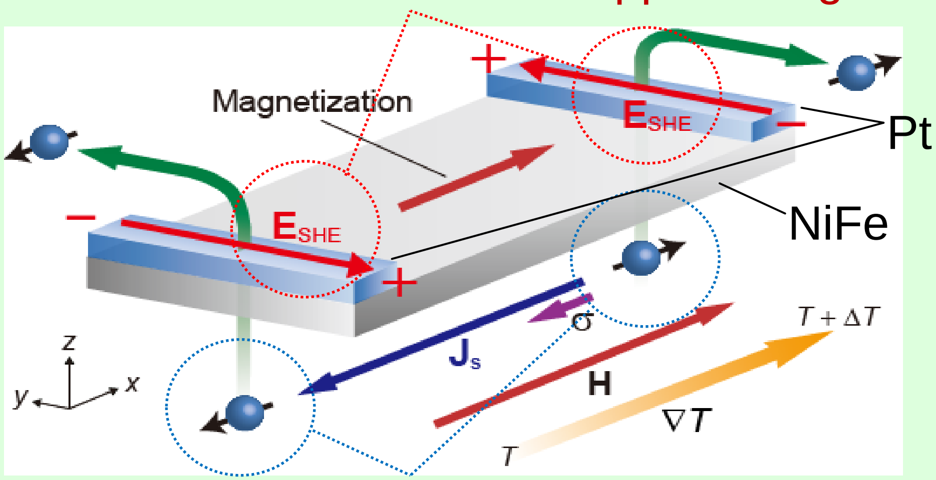
Observation of spin-Seebeck effect

Spin voltage



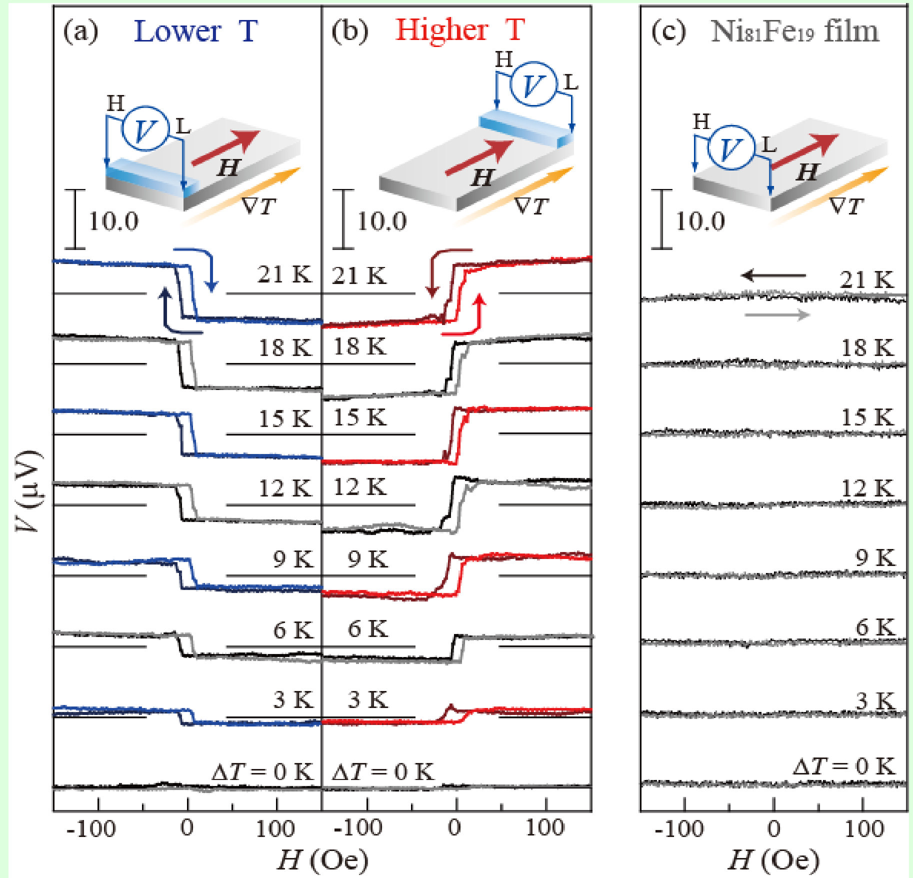
using the inverse spin-Hall effect (ISHE)

electromotive force of opposite signs



Spin voltage of opposite sign

Magnetic field dependence of V



ISHE voltage induced by the spin-Seebeck effect

K. Uchida, E. Saitoh *et al.* Nature (2008).

A magnetic insulator transmits electrical signals via spin waves

- Saito succeeded in transmitting electric signals through YIG using spin waves (pure spin current) in the insulator.
- The spin Hall effect, which converts the charge current to a spin current, and its inverse forms the basis for a proof of principle. **(cited in Physic Today)**

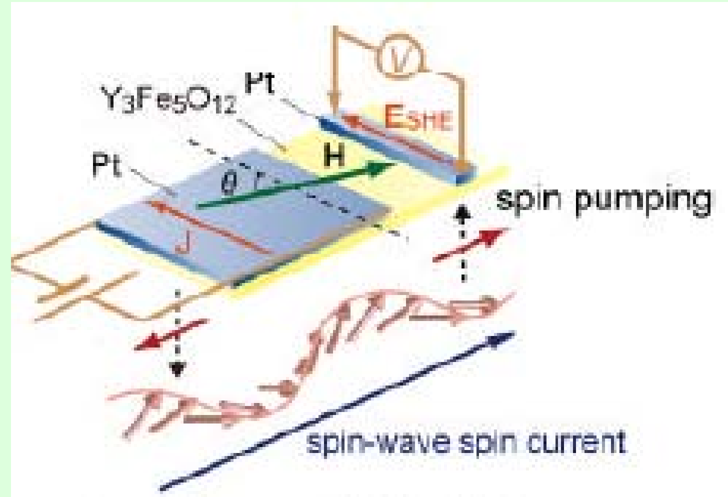
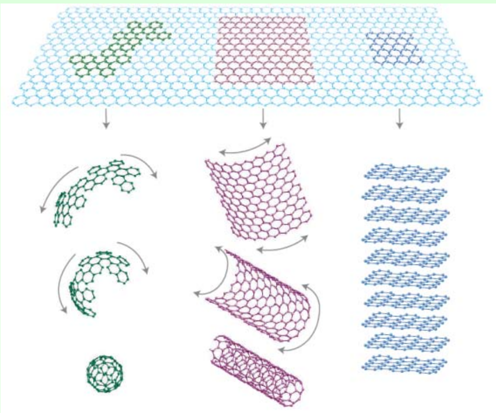


図 1 誘電体スピン流伝送の概念図

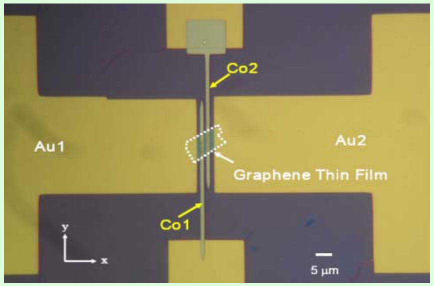
Y. Kajiwara**,** K. Harii, S. Takahashi, J. Ohe, K. Uchida, M. Mizuguchi, H. Umezawa, H. Kawai, K. Ando, K. Takanashi, S. Maekawa & E. Saitoh, Nature **464** 262 (2010)

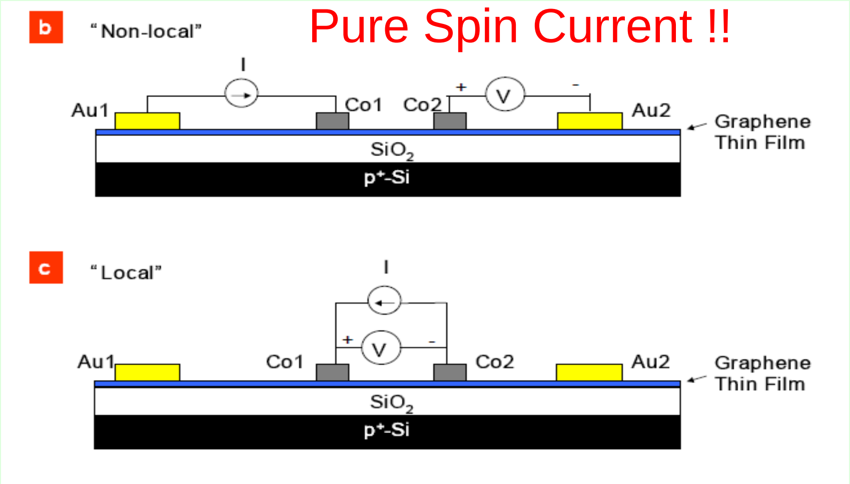
Graphene Spintronics (1)

Graphene

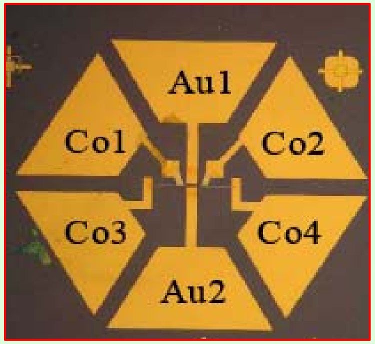


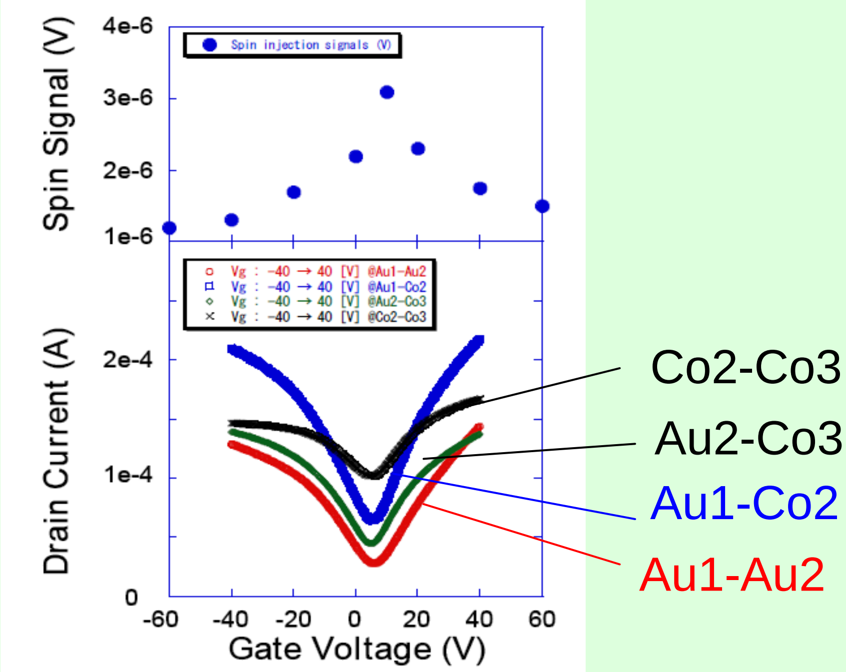
1. Generation of a pure spin current
2. Injection of spins in graphene
   at ROOM TEMPERATURE





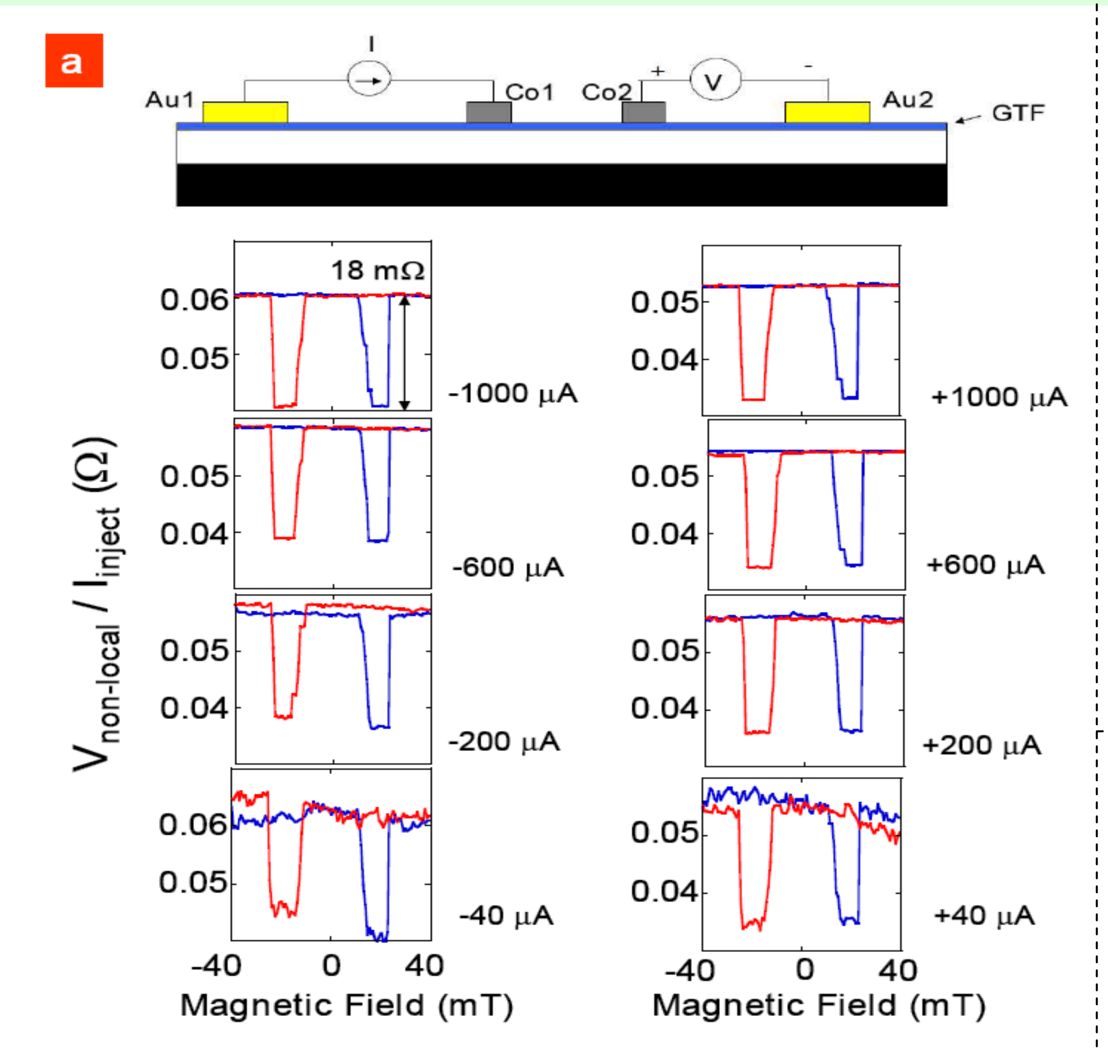
Gate-induced Modulation of Spin Signals in single-layer graphene

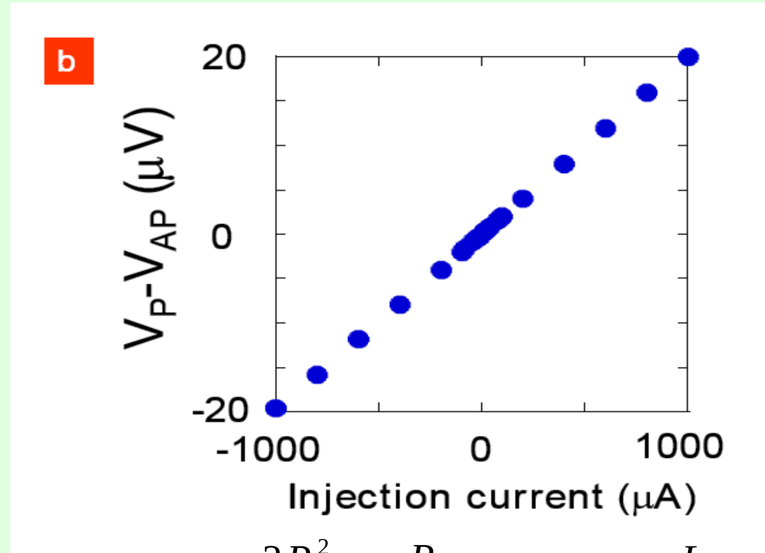




N. Mitoma, M.Shiraishi. et al., in preparation.

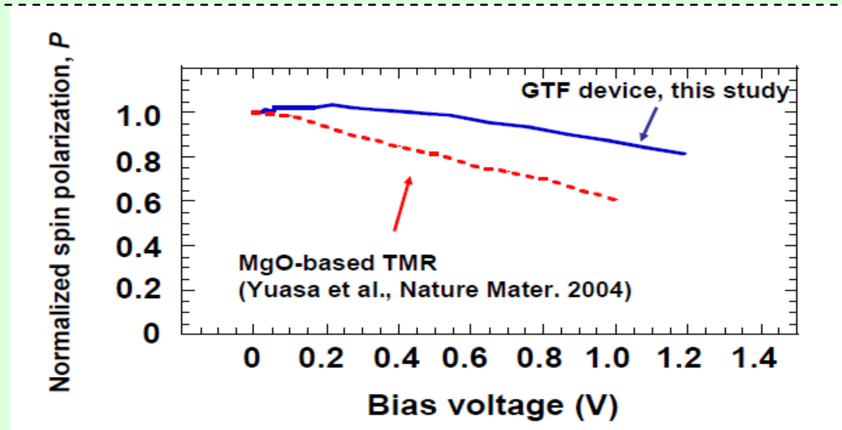
Graphene Spintronics (2)





$$\Delta V_{non-local} = \frac{2P^2}{(1-P^2)^2}\left(\frac{R_F}{R_N}\right)R_F \cdot [\sinh(\frac{L}{\lambda_{sf}})]^{-1} \cdot I_{inject} ,$$

Spin polarization is CONSTANT.

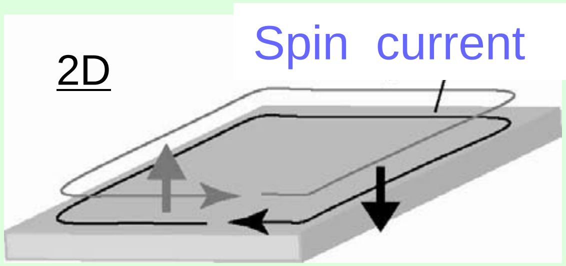


Better robustness than that in MgO-TMR

M. Ohishi, M.S. et al., JJAP 46, L605 (2007).
M. Shiraishi et al., Adv. Func. Mat., in press.
K. Muramoto, M.S. et al., in preparation.

Theory of spin current and heat current

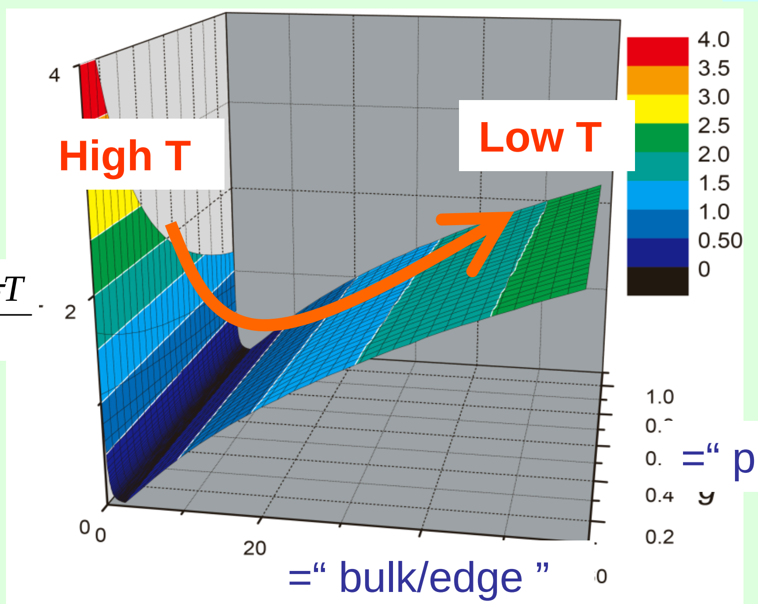
1) Bismuth ultrathin films as quantum spin Hall phases
2) Universal Phase Diagrams for 2D and 3D quantum spin Hall phases
3) Quantum spin Hall systems as candidates for efficient thermoelectrics



Expectation : QSH systems can be good thermoelectric.

* suppress phonon conduction, keeping electron conduction
* Low-dimensional states (edge states, surface states)
* Similar materials involved ($Bi_{1-x}Sb_x$, Bi_2Se_3 etc.)

$$ZT = \frac{S^2 \sigma T}{\kappa}$$



Result

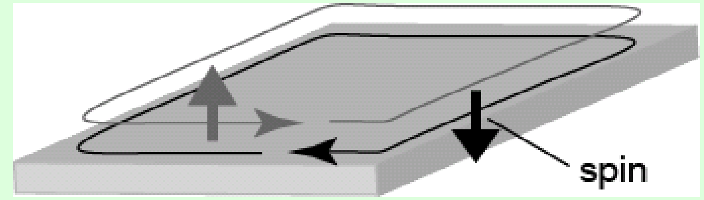
- Lower temp.
  → longer inelastic scattering length for edge states
  → edge states become dominant
  bulk-to-edge crossover of thermoelectric transport
- Ultrathin & narrow ribbon (of QSH system)
  → crossover occurs at around 10K

Quantum spin Hall systems can be good thermoelectrics at low temp.

Shuichi Murakami

Theoretical Approach

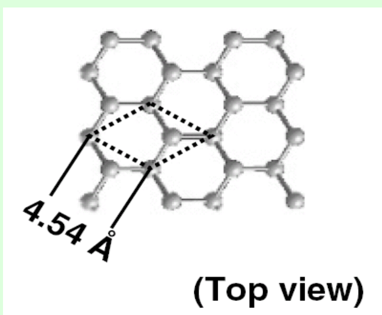
Quantum Spin Hall Effect in Bismuth

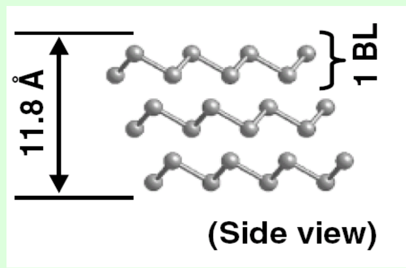


– Bulk Bi show no gap, while edge is gapless.

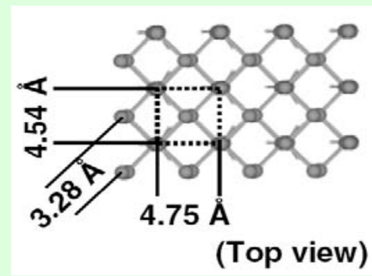
– Bi ultra thin film

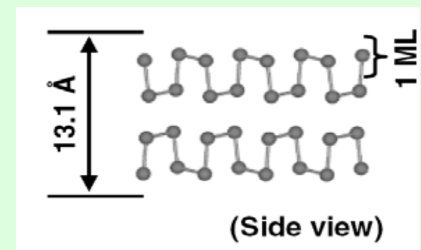
(111) 1-bilayer = quantum spin Hall phase





{012} 2-monolayer= insulating phase





- Thermoelectric figure of merit

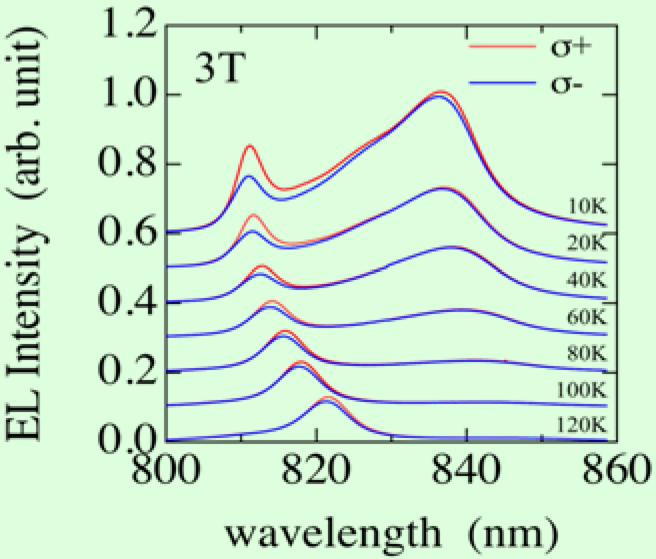
$$ZT = \frac{S^2 \sigma T}{\kappa}$$

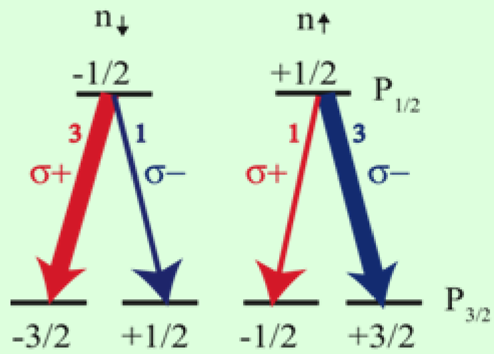
Idealized model (perfect conductor on the edge)

- In the quantum spin Hall phase, figure of merit ZT of thermoelectric conversion is determined by the balance between the edge and the bulk.
- ZT is large if the chemical potential is close to the band edge.
- ZT is large if the length of system is long. ← edge states dominantly determine ZT.
- ZT increases with temperature. ← Higher energy carriers contribute to ZT.

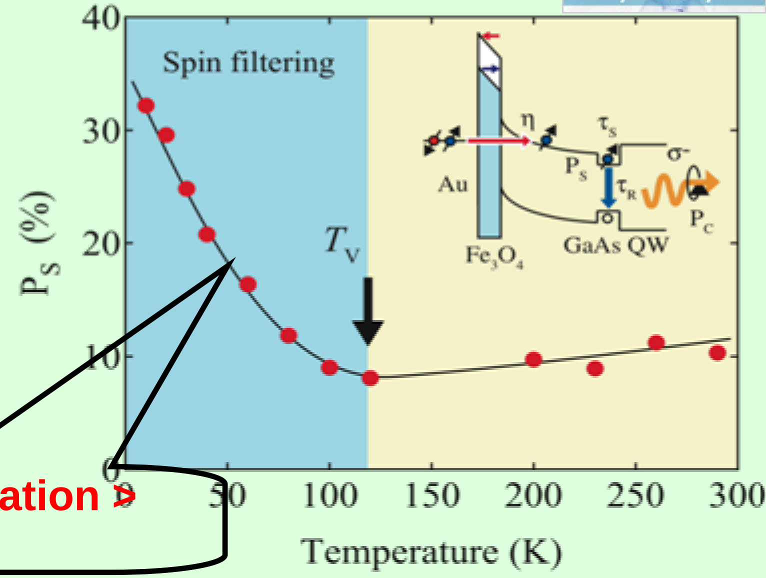
Tunable Spin Sources

Spin injection from Fe_3O_4 into GaAs quantum well





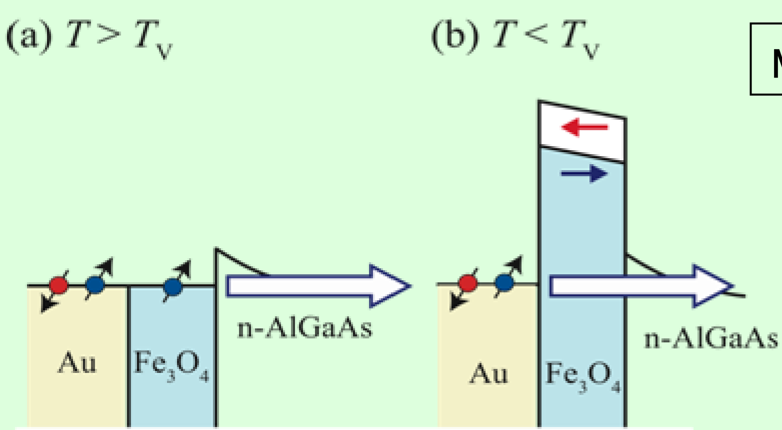
Optical Selection Rules



Large spin polarization > 30%

E. Wada, T. Taniyama et al., submitted.

■ Origin of the large spin polarization



Metal–Insulator transition at Tv=120 K（Verway transition）

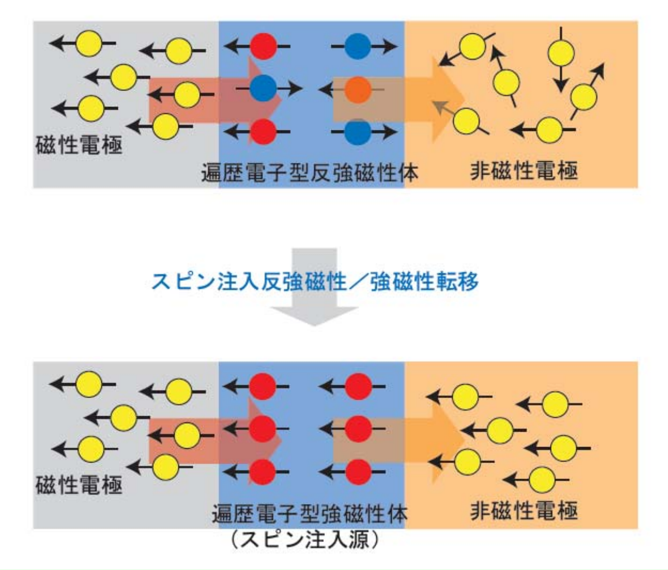
Switching of spin injection mechanism at T_V

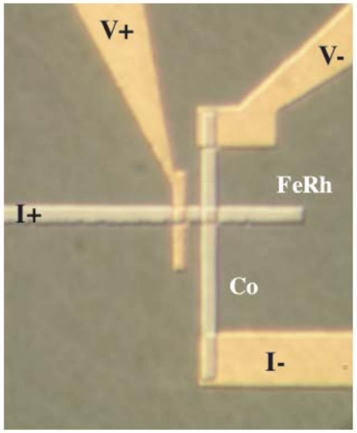
Magnetic insulator barrier is effective for efficient spin injection

Taniyama

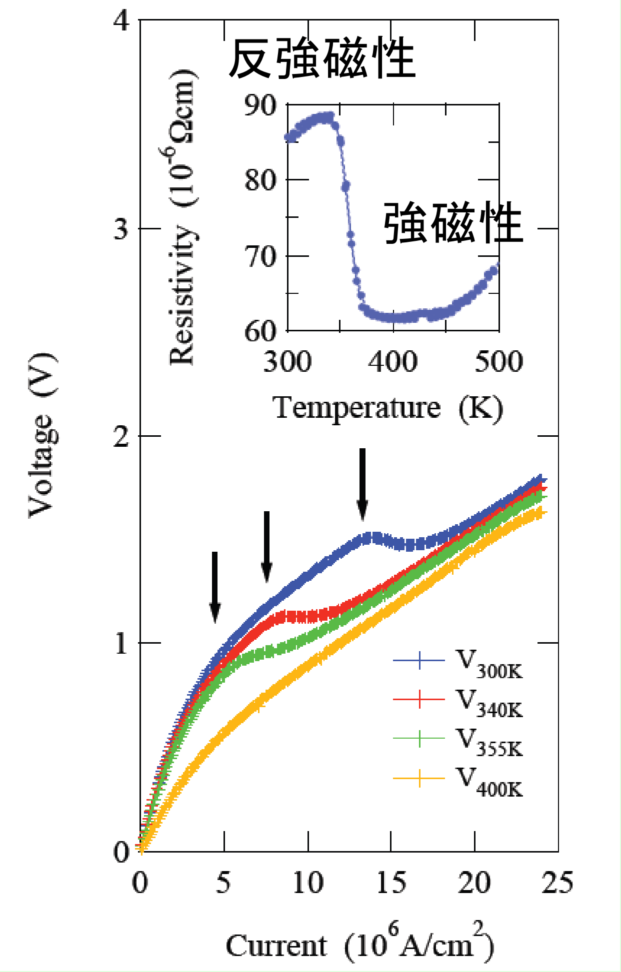
Current-induced antiferromagnet-ferromagnet transition in FeRh

- Taniyama succeeded in observation of current induced phase change due to spin-transfer torque phenomenon.





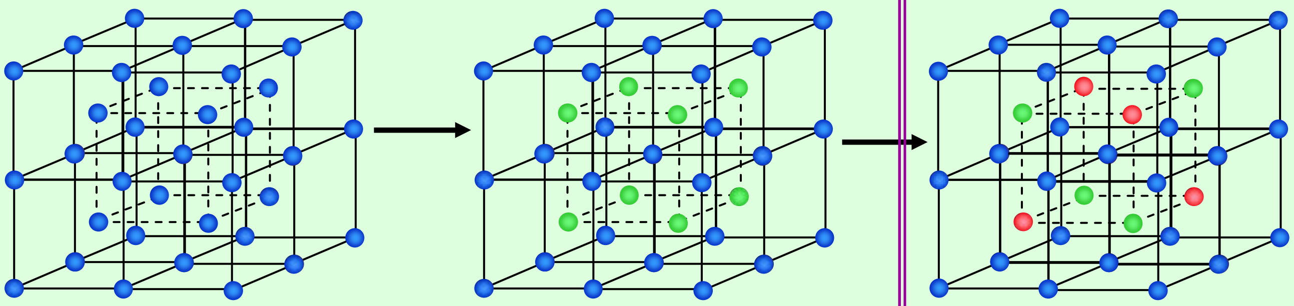
Co／FeRhスピン注入構造



Alloy search for RT half-metal

Co based Heusler alloy、X_2YZ

A2 X or Y or Z — B2 X(Y or Z) — $L2_1$ X_2YZ

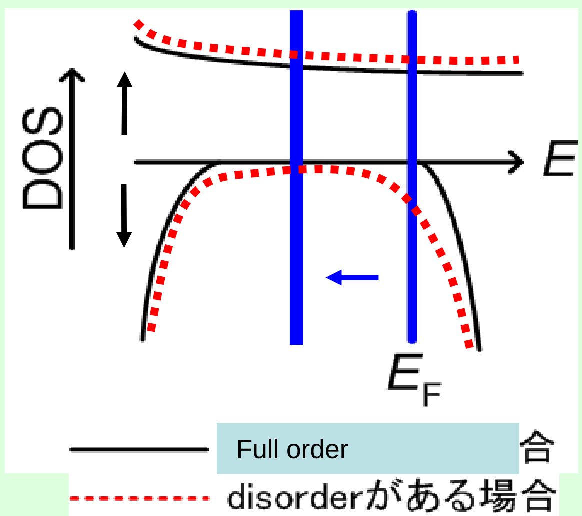


High Tc
Theoretical P=1

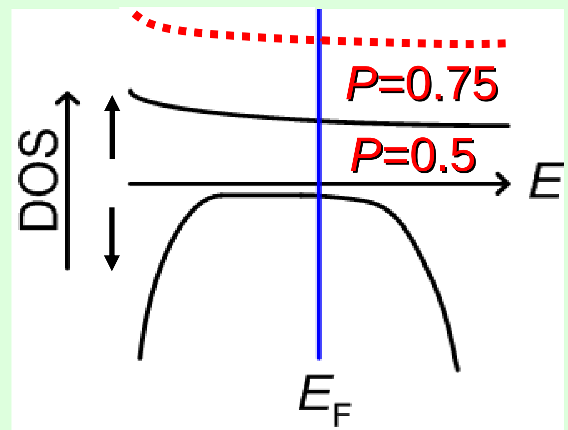
However,
Experimental P is low

How to search?

Control of E_f



Control of DOS(E_f)



Search of high spin-polarization half metals using PCARS

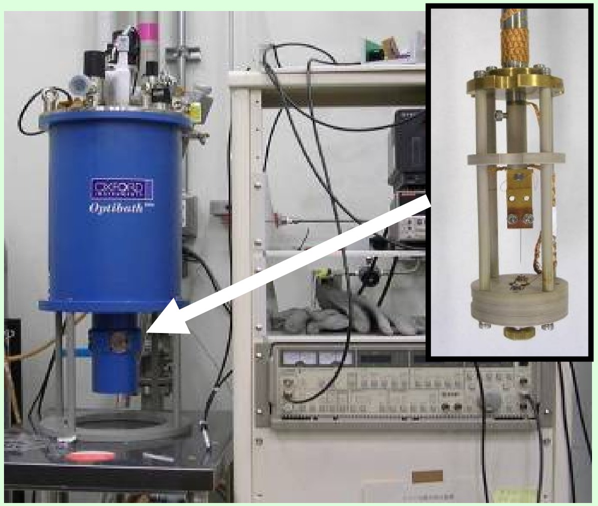
- Aiming at high performance GMR devices Takahashi has investigated as many as 32 full Heusler alloys and found 74% sipn polarization in CoMnGeGa alloy.

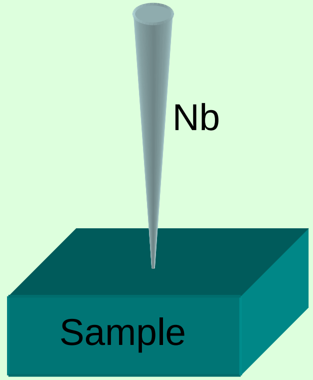
Metals and binary	P	Ref.
Fe	46	
Co	45	
FeCo	50	
Co75Fe25	58	
B2-FeCo	60	
$[Co/Pd]_n$	60	

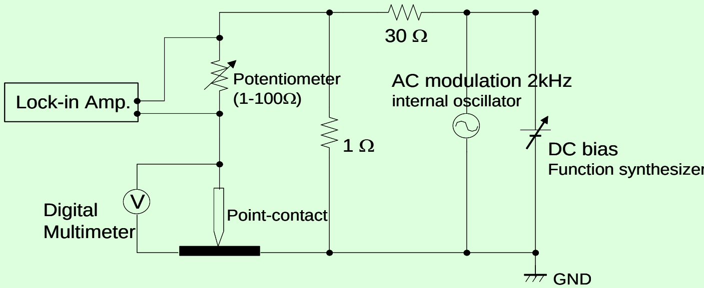
Ternary alloys	P	Ref.
Co_2MnSi	56	
Co_2MnGe	58	
Co_2MnSn	60	
Co_2MnAl	60	
Co_2MnGa	60	
Co_2CrAl	62	
Co_2FeAl	59	
Co_2FeSi	60	
Co_2FeGa	58	
Co_2CrGa	61	
Co_2TiSn	57	
Co_2VAl	48	
Fe_2VAl	56	

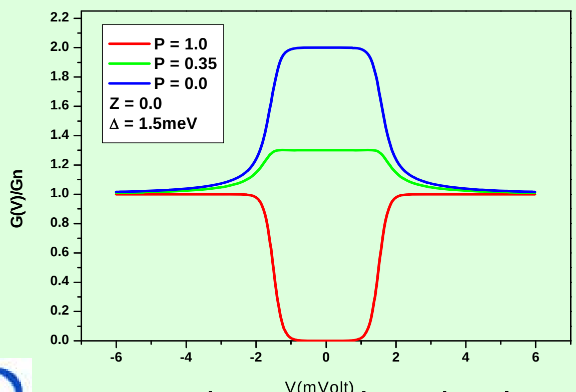
Quaternary alloys	P	Ref.
$Co_2Mn(Ge_{0.75}Ga_{0.25})$	74	
$Co_2Mn(Ga_{0.5}Sn_{0.5})$	72	
$Co_2Fe(Si_{0.75}Ge_{0.25})$	70	
$Co_2FeGa_{0.5}Ge_{0.5}$	68	
$Co_2(Cr_{0.02}Fe_{0.98})Ga$	67	
$Co_2MnGeSn$	67	
$Co_2(Mn_{0.95}Fe_{0.05})Sn$	65	
$(CoFe)_2MnGe$	65	
$Co_2(Mn_{0.5}Fe_{0.5})Ga$	65	
$Co_2(Cr_{0.02}Fe_{0.98})Si$	65	
$Co_2MnTiSn$	64	
$Co_2MnAl_{0.5}Sn_{0.5}$	63	
$Co_2MnGa_xSi_{1-x}$	63	
$Co_2FeAlGa$	63	
$Co_2MnSiGe$	63	
$Co_2(Mn_{0.5}Fe_{0.5})Si$	61	
$Co_2Mn(Al_{0.5}Si_{0.5})$	60	
$Co_2FeGa_{0.5}Si_{0.5}$	60	
$Co_2Fe(Al_{0.5}Si_{0.5})$	60	

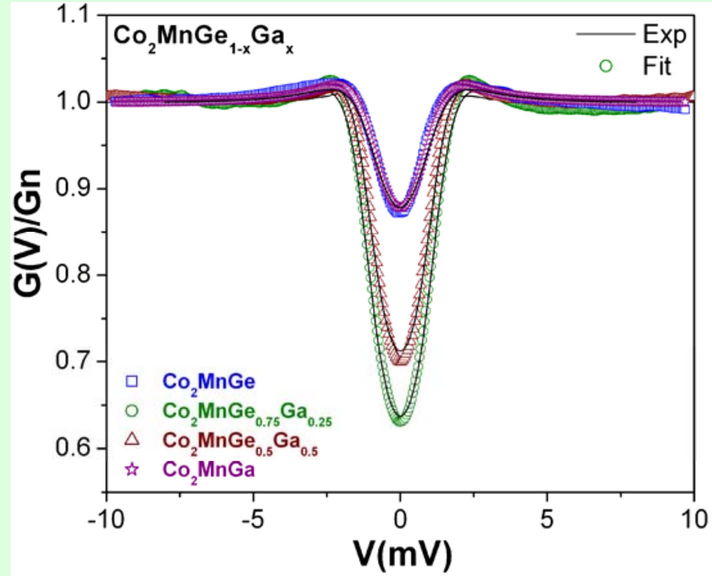
Point contact Andreev reflection (PCAR)

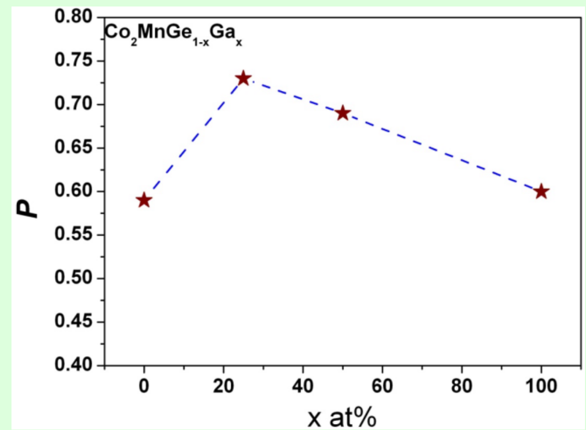










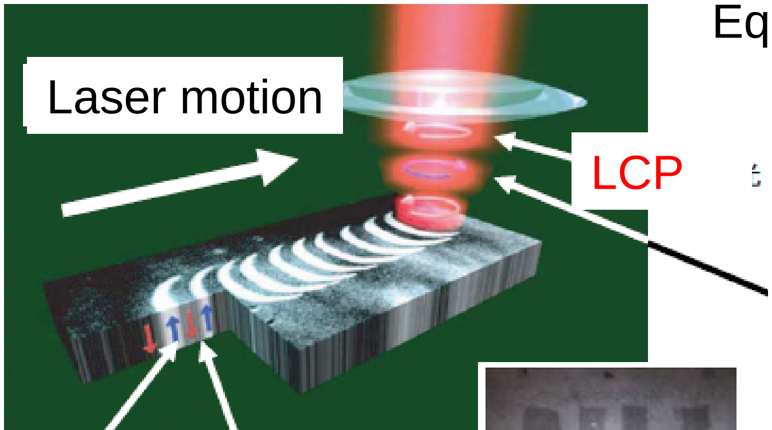


$Co_2MnGe_{0.75}Ga_{0.25}$ shows highest P

Light-Induced ultrafast magnetization reversal

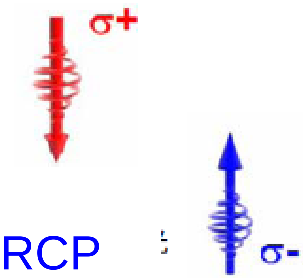
- The response time of magnetization reversal is usually limited by the spin dynamics which follow Landau-Lifshitz-Gilbert equation.
- By a collaboration of Nihon Univ. group and Radbout Univ. group, ultrafast magnetization switching (less than ps) was accomplished in the vicinity of the compensation point of MO-recording media.

Demonstration of direct magneto-optcal recording by circular polarization modulation



Up spin,　Down spin

Equivalent magnetic field produced by photon



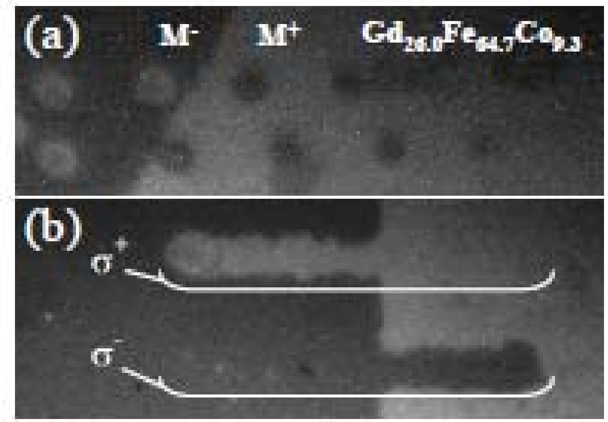
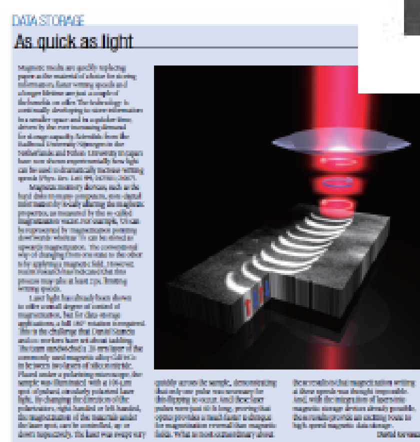


図 2　光励起超高速磁化反転

Complete magnetization by
40 fs irradiation of CP.
Reversal without ext. field

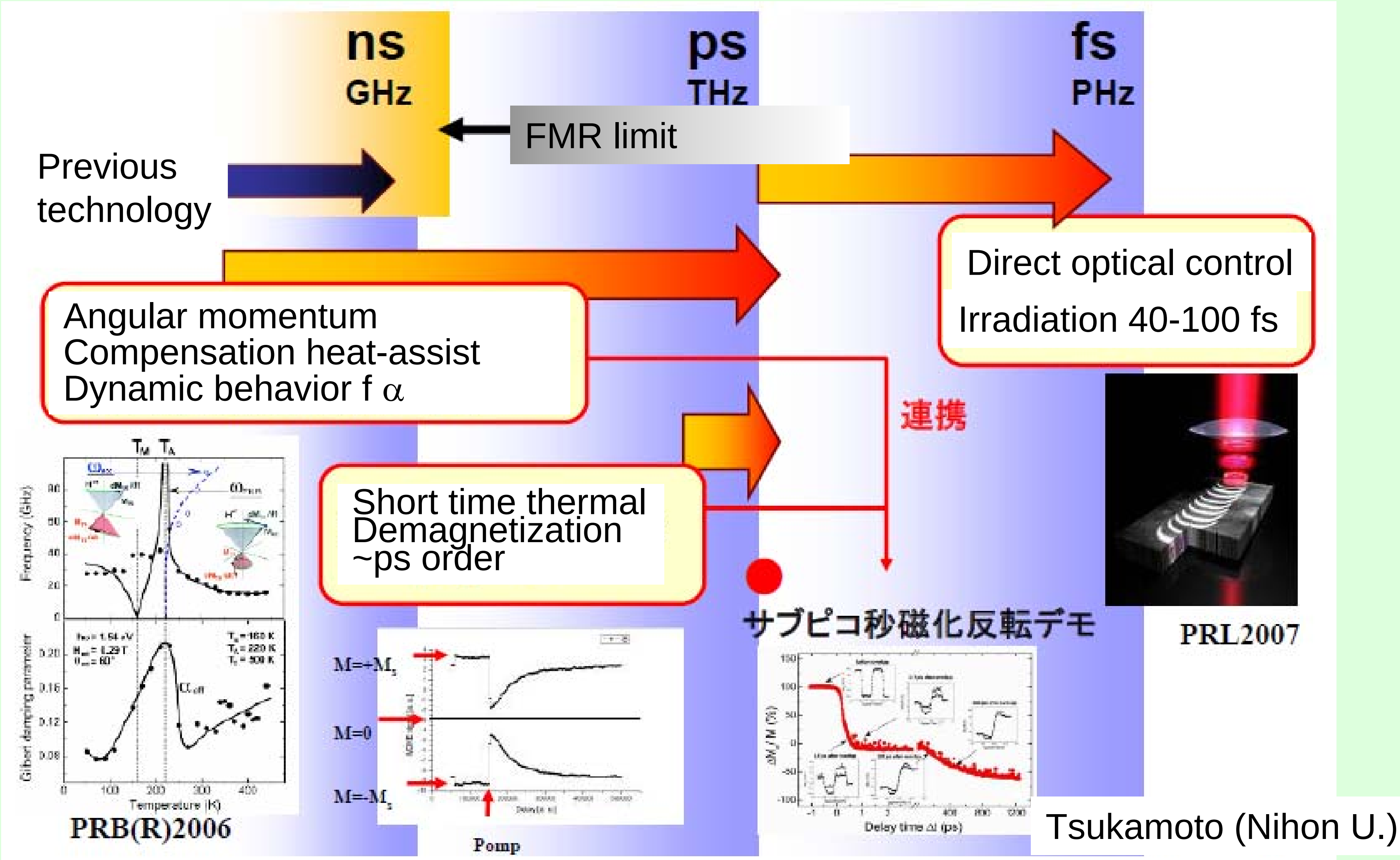
PRL 99, 047601 (2007) 7月26日掲載

Nature Photonics 9月号


DATA STORAGE
As quick as light

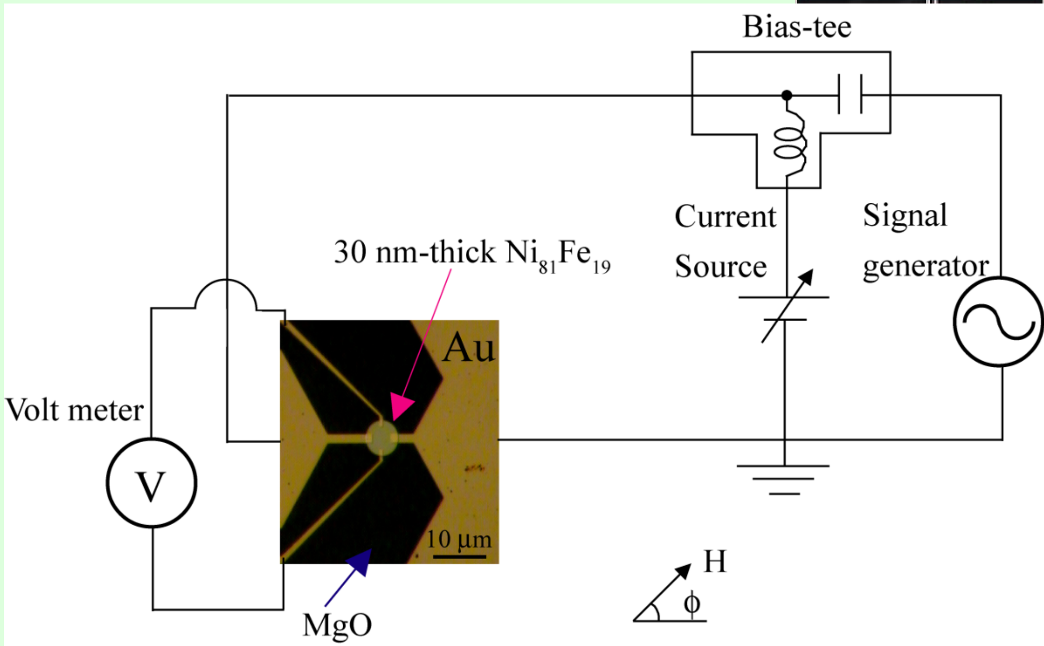
Science、Physics today他

Direct optical spin control



Finding new magnetic phenomena for meta-materials

- Yamaguchi discovered microwave-induced DC voltage generation in ferromagnetic nanowire and explained the phenomenon in terms of coupling between spin-precession and electric transport.

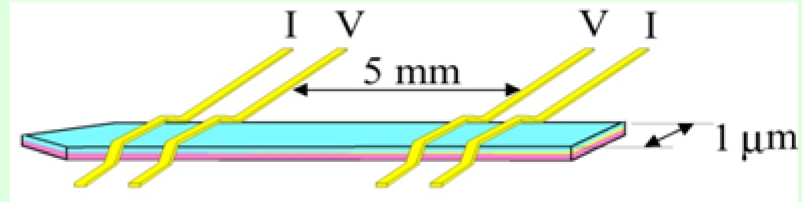


・Dynamic motion of magnetic vortices in feromagnetic Fe19Ni81 disk via was discovered the rectification effect. The self-bistability state was detected experimentally, which is consistent with the physical model.

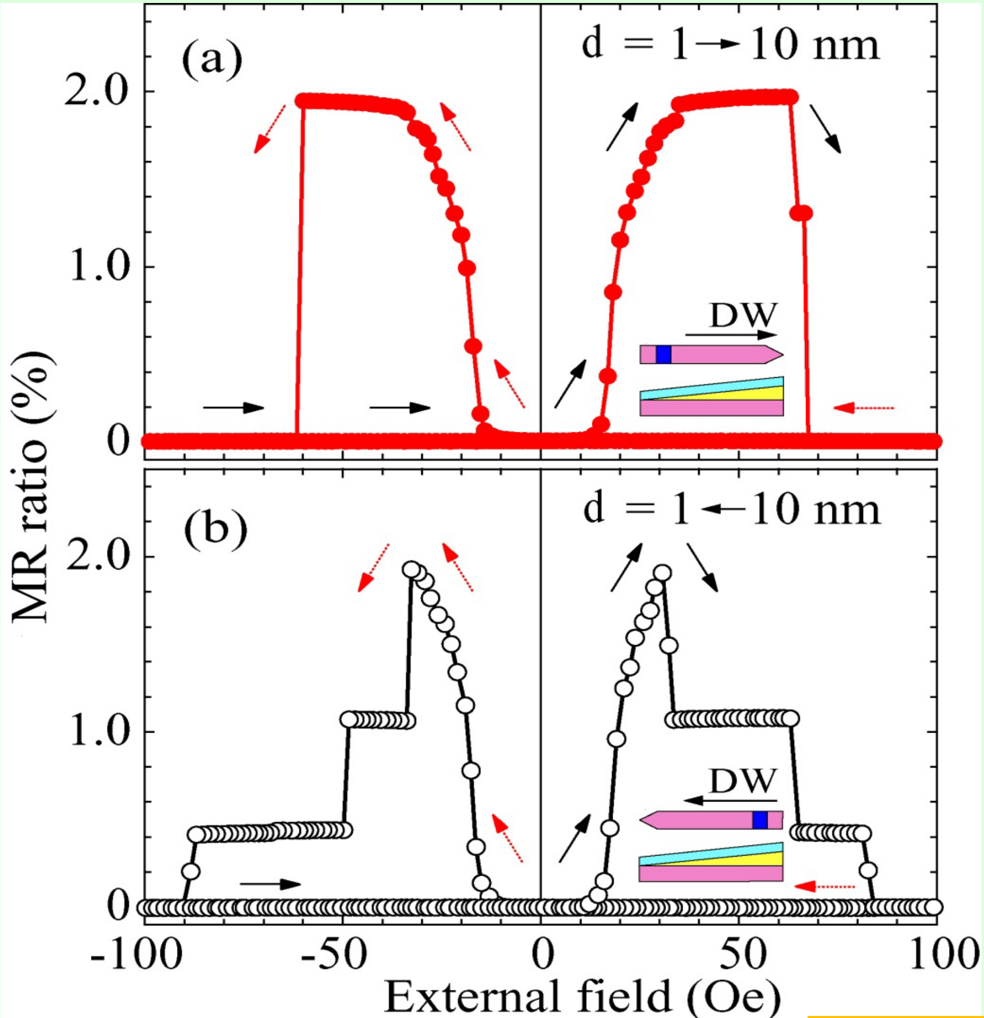
Observation of new spin-latchet effect

- The quantum interference effect in th FM/NM/FM structure was successfully modulated through modulation of boundary conditions. The periodic potential can be measured as a force by detecting thw wall motion. The wall motion was found one-way!

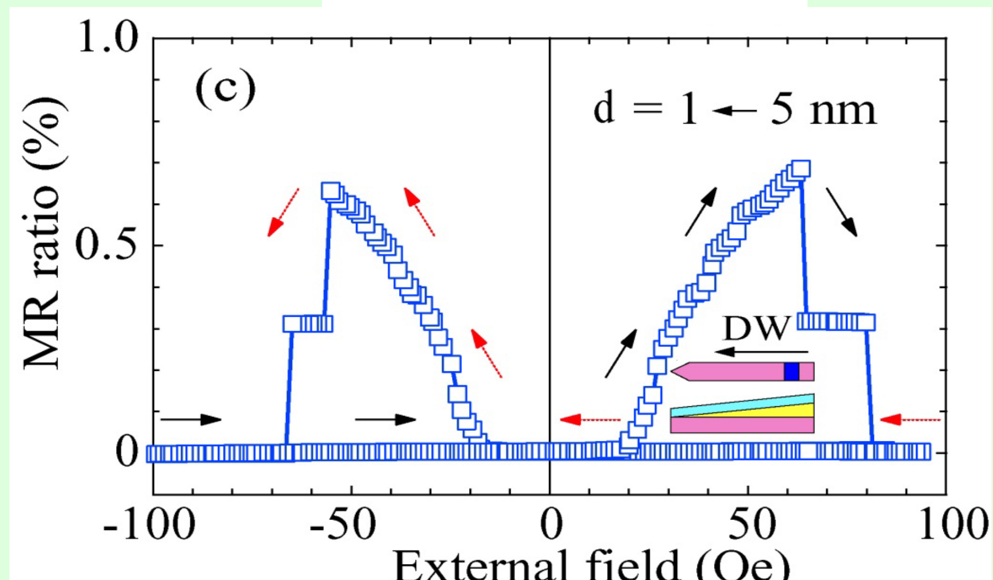
Domain wall motion in spatially modulated GMR nanowire



Wall motion in pinned layer
(a)Left to right ⇨ abrupt inversion
(b)Right to left ⇨ step-like



Pinning by potential



APEX **3**, 093004 (2010).

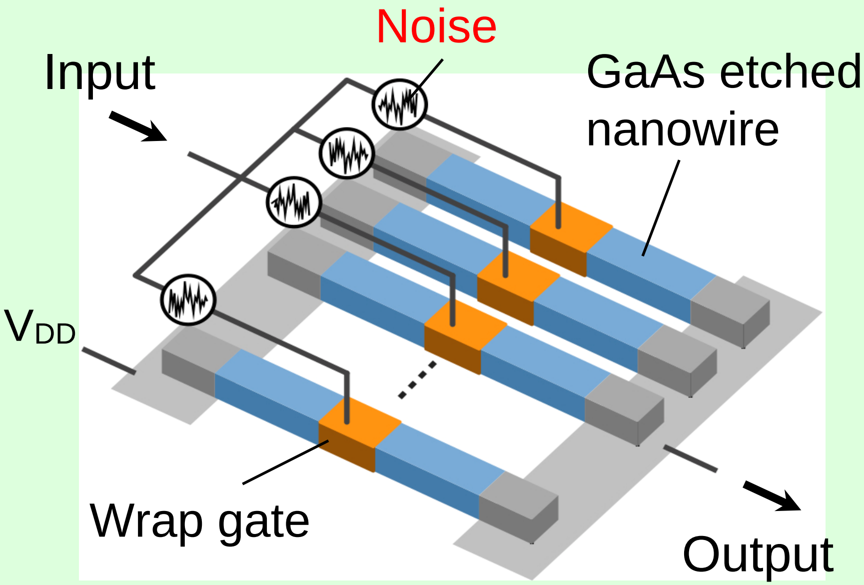
Variation of potential dips due to change in inclination

Stochastic Resonance

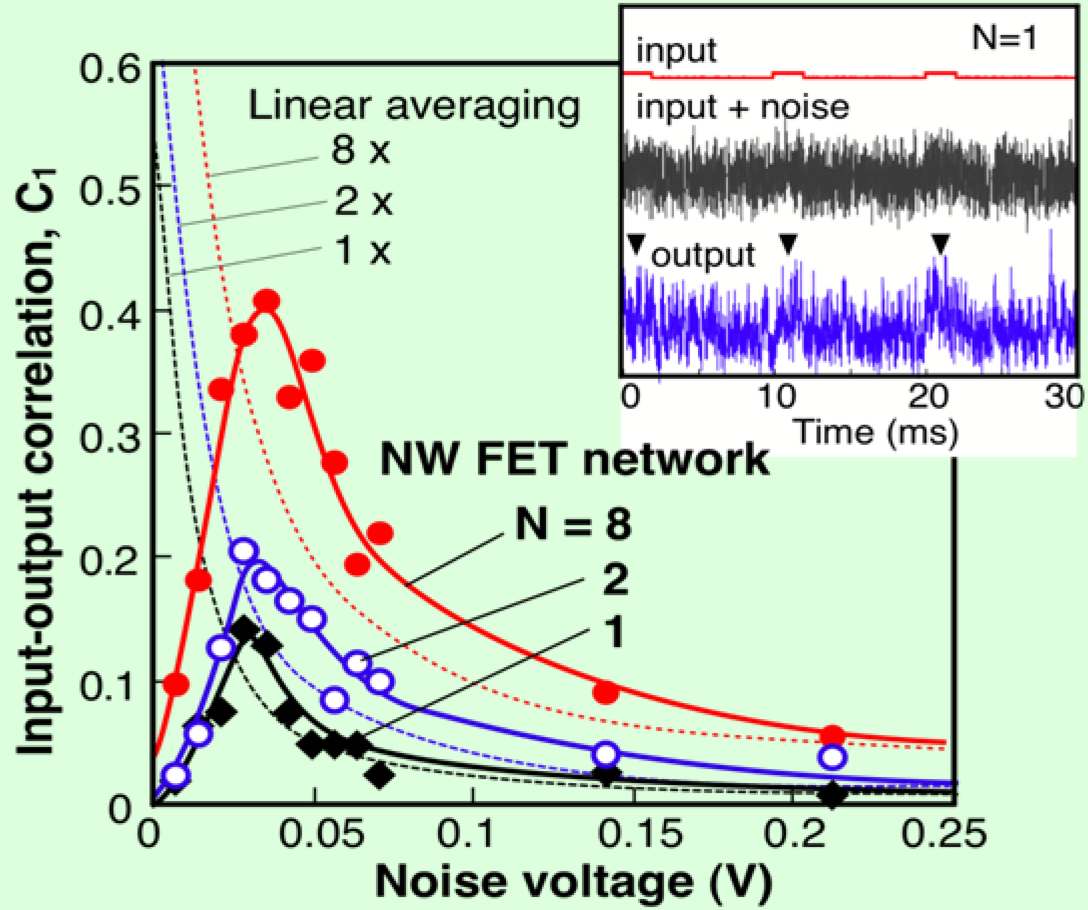
- Novel semiconductor nanodevices utilizing "stochastic resonance"[i] and their integration are now under investigation to realize state-of-the-art electronics hardware for noise-robust information processing. The stochastic resonance is a phenomenon that noise enhances response of a system, which plays an important role in nature and living things. Kasai designed, fabricated and characterized artificially controllable nanodevices in which the stochastic resonance takes place electrically. He integrated on semiconductor nanowire network structure to realize functionality for noise-robust information processing.[ii]
-

- [i] A. Bulsara and L. Gammaitoni: Physics Today 49 (1996) 39.
- [ii] S. Kasai and T. Asai: Appl. Phys. Express 1 (2008) 083001.

Stochastic Resonance in Nanowire FET Network



S.Kasai et al., Appl. Phys. Express 1, 083001 (2008)



Stochastic resonance (SR) is a phenomenon that many bio-systems use to enhance their response in noisy environment.

The SR was realized in GaAs nanowire FET networks and enhanced weak-signal detection was successfully demonstrated.

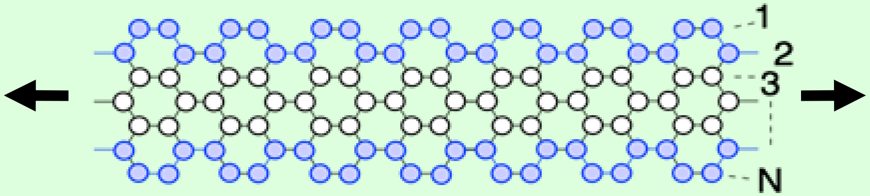
Si and Ge Nanowire for Surrounding Gate Transistors

- Advances in performance and integration through conventional scaling of device geometries are now reaching their practical limits in planar MOSFETs. To overcome the limiting factors in planar MOSFETs, vertical structural arrangements called surrounding gate transistors (SGT) have been suggested as the basis for next-generation semiconductor devices. Fukada studies one dimensional Si and Ge semiconductor nanowires which are expected for the components in SGT.[i]
-

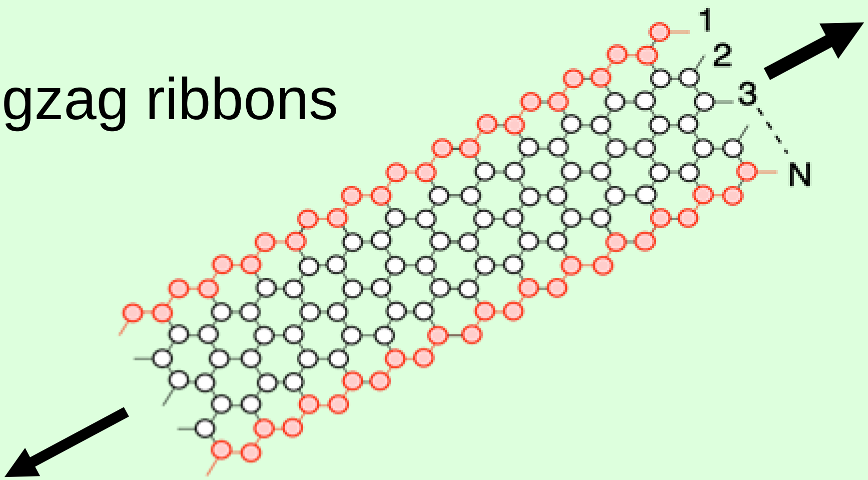
[i] N. Fukata, M. Mitome, Y. Bando, M. Seoka, S. Matsushita, K. Murakami, J. Chen, and T. Sekiguchi: Appl. Phys. Lett. 93 (2008) 203106.

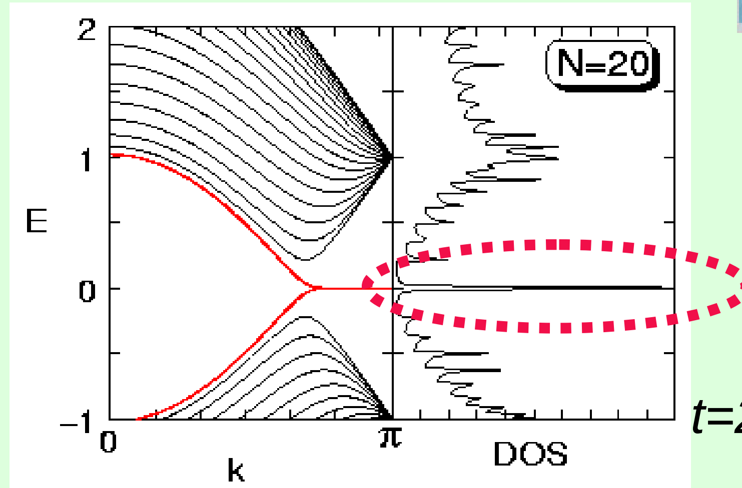
Graphene nanoribbons and strong nanoscale effect

Armchair ribbons

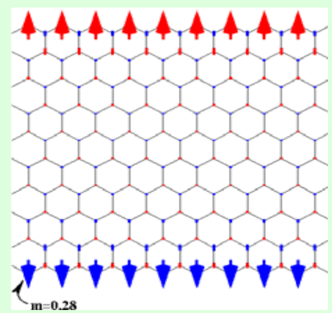


Zigzag ribbons

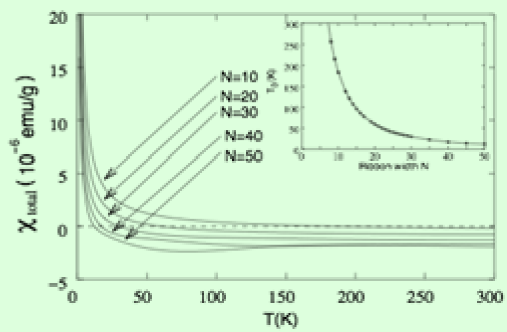




t=2.7eV



ferrimagnetic spin correlation



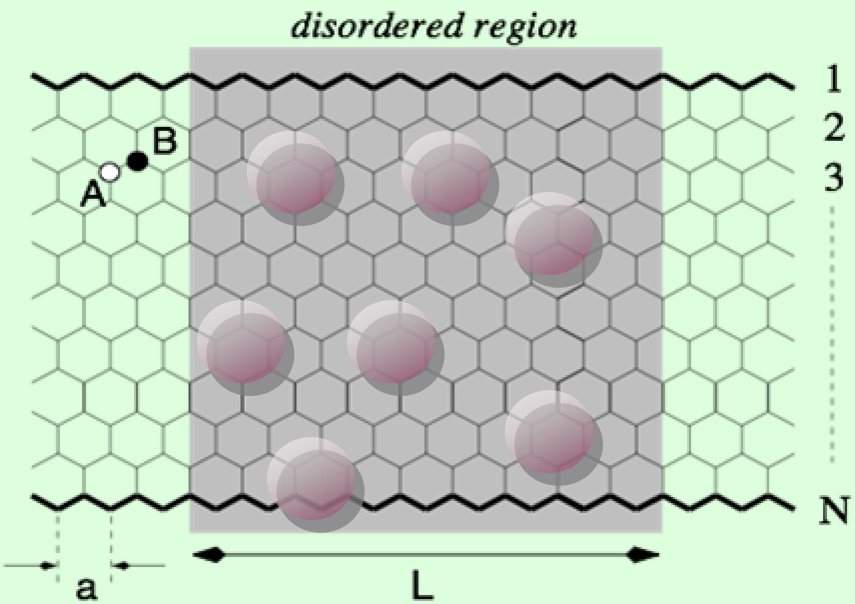
Crossover from dia- to para magnetism

New class of quantum wires

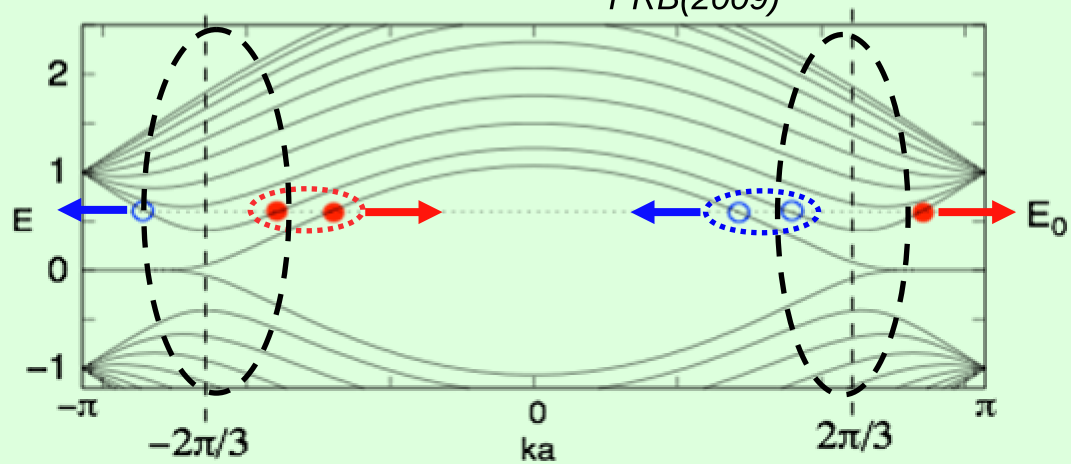
M. Fujita, K. Wakabayashi, K. Nakada, K. Kusakabe, *J. Phys. Soc. Jpn.* (1996).
K. Nakada, M. Fujita, et. al. *Phys. Rev.* B (1996).
K. Wakabayashi, M. Fujita, et. al., *Phys. Rev.* B (1999).

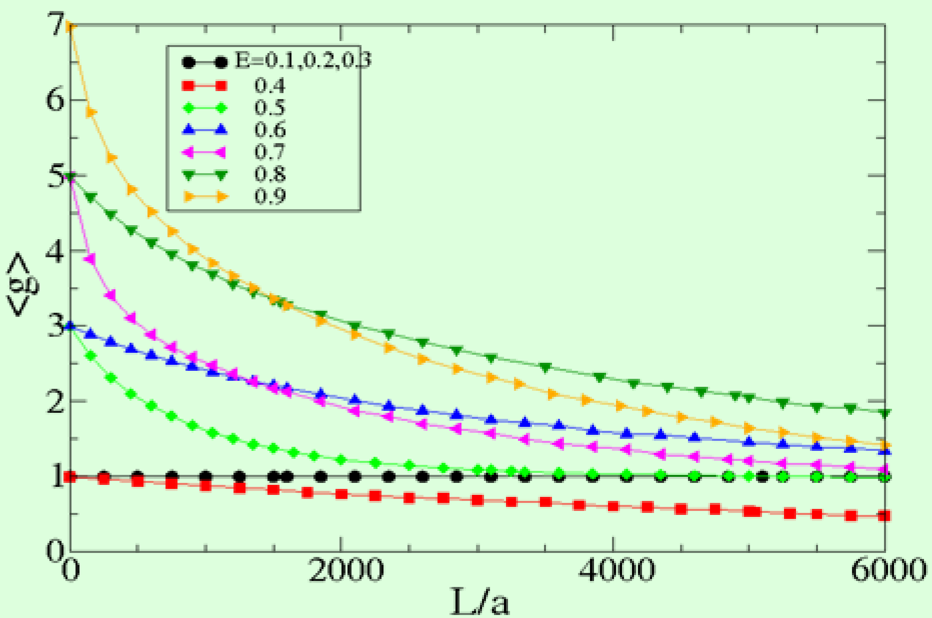
Wakabayashi

Perfectly Conducting Channel



K. Wakabayashi et. al., PRL(2007), Carbon(2009), PRB(2009)





dimensionless conductance:

$$g = \mathrm{Tr}\left(t^{\dagger}t\right)$$

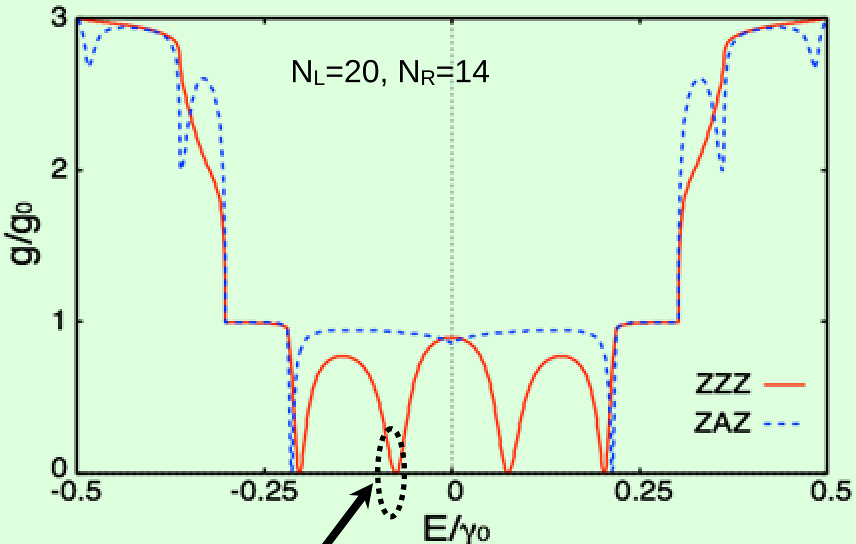
ensemble average for various impurity configuration

#of samples > 10000

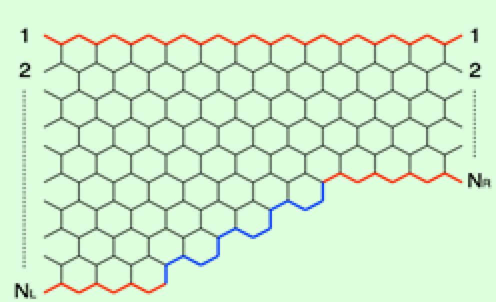
Averaged conductance <g> converges to 1.
Perfectly Conducting Channel

Absence of Anderson localization

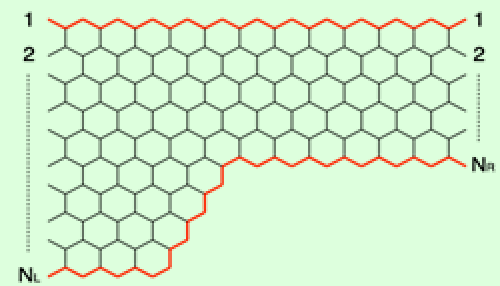
Electronic transport through graphene junction



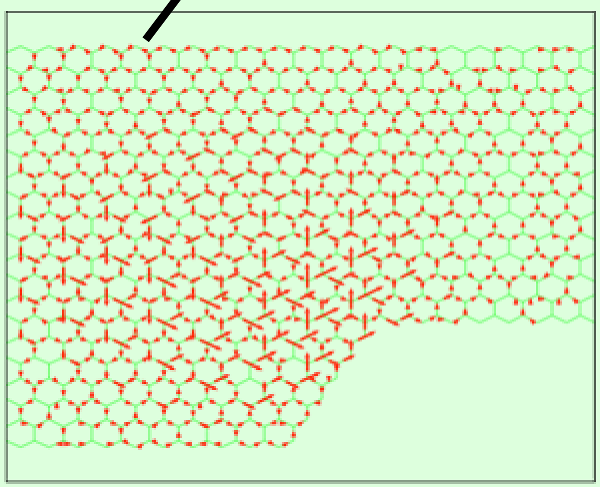
ZAZ



ZZZ



(1) Multiple zero conductance dips appear in ZZZ junction, which serve as the charge current switching.
(2) Visible condition at T=300K : W< 12.5nm



Internal circular current is induced at the
in the vicinity of zero conductance d

Lead	Junction	Position of anti-resonance
A	A	$E = 0$
	Z	$E = \pm\delta$:
Z	A	$E = \pm\Delta_1, \Delta_2, \ldots$ just before 2ch. is opened in wider ribbon.
	Z	

A: armchair
Z: zigzag

App. Phys. Lett. (2009)

Organic transistors

- Flexible electronics made with organic transistors may enable technologies such as low-cost sensors on product packaging and electronic paper displays. Thanks to recent development in organic LED, organic electronics has become the matter of interest for practical use.
- However, organic materials show electrical performances far below inorganic semiconductors. Therefore it is necessary to improve electronic transport properties represented by the low carrier mobility. Yasuda of our team aims to fabricate high-performance organic field-effect transistors using enhanced intrachain carrier transport along uniaxially aligned π-conjugated polymers.[i]

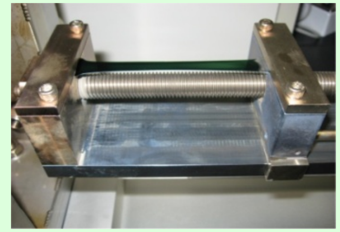
- [i] T. Yasuda, M. Saito, H. Nakamura, and T. Tsutsui: Chem. Phys. Lett. 452 (2008) 110.

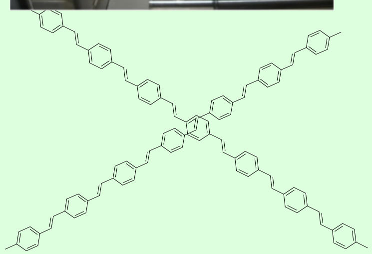
Yasuda

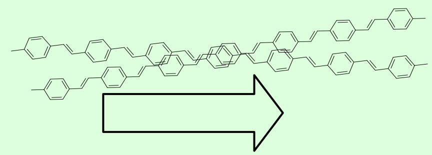
Increase of Conductivity in Stretch-Oriented π-Conjugated Polymers

Yasuda

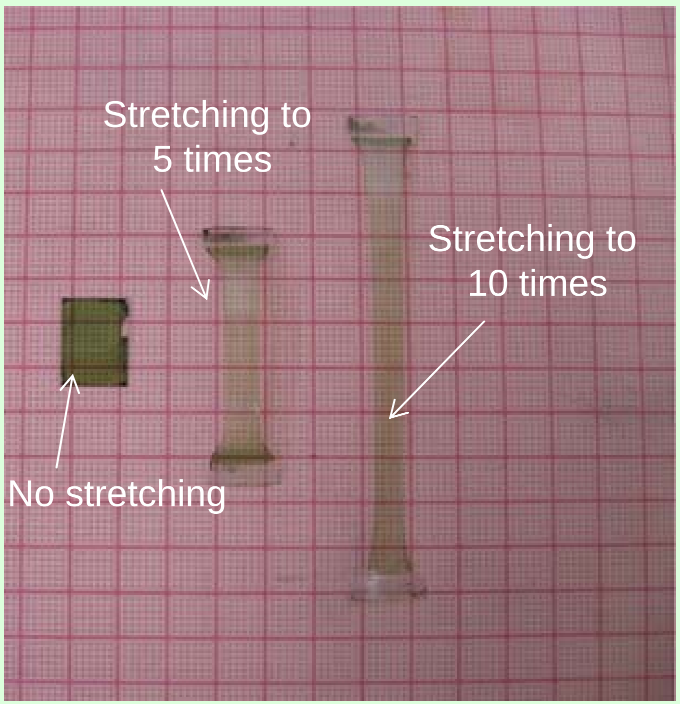
Stretch







Increasing carrier mobility along π-conjugated main chain



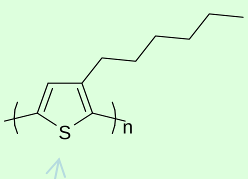
Sample	Conductivity (S/cm)
No stretching	6.5×10^{-2}
Stretching to 5 times	2.0
Stretching to 10 times	12.3
Stretching to 15 times	71.5

x 1100

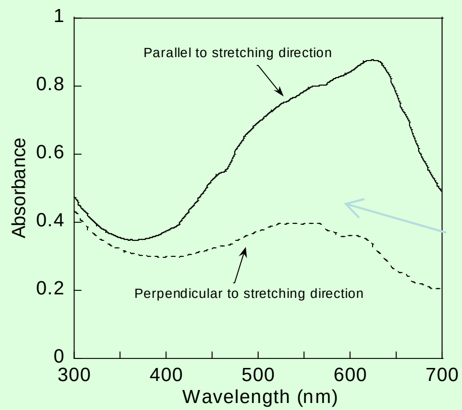
The conductivity in the stretched polymer is larger by a factor of 1100 compared to that in the no stretched polymer.

Organic Field-Effect Transistors Based on Stretch-Oriented π-Conjugated Polymer

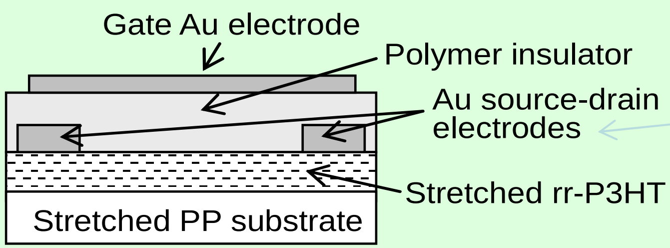
We fabricated OFETs based on a stretch-oriented polymer film from a relatively modern π-conjugated polymer, regioregular poly(3-hexylthiophene), and investigated the anisotropic carrier transport properties in the OFETs.



Regioregular poly(3-hexylthiophene) (rr-3HT)



Absorption spectra of aligned polymer layer when light is polarized parallel and perpendicular to the stretching direction. This figure provides clear evidence that π-conjugated chains are highly oriented parallel to the stretching direction.



Schematic cross section of OFET based on stretch-oriented π-conjugated polymer

Sample	Hole mobility（cm^2/Vs）
Current flow parallel to the stretching direction	2.7×10^{-3}
Current flow perpendicular to the stretching direction	8.0×10^{-4}

This result indicates that charge transport via the π-conjugated rr-P3HT chains is advantageous in the stretch-oriented rr-P3HT film.

T. Yasuda et al, J. Photopolym. Sci. Technol. (in press)

Yasuda

課題解決型基礎研究が
イノベーションを呼ぶ

- 以上紹介しましたさきがけ「次世代デバイス」の第1期生の成果を見ますと、すべて、課題解決の明確な目標の下、極めて深い基礎研究が行われ、新しいパラダイムを拓くような発見にむすびつき、デバイスイノベーションにむけての確かな手応えを得ることができたものと考えます。
- 第2期，第3期を総合して見ていただければ、今後のデバイスイノベーションの着実な一歩を踏み出したと評価いただけるものと確信しております。

夜のグラバー亭

ご静聴ありがとうございました。