

## Tomoyasu Taniyama

### 1. Research Highlights

#### 1) Spin filtering effect at ferromagnet/semiconductor interfaces under optical spin orientation

Spin injection from a ferromagnet into a semiconductor is one of the most critical issues for developing spintronic devices. In this study, we have investigated the issue of spin injection utilizing the unique metal-insulator transition of  $\text{Fe}_3\text{O}_4$ . While  $\text{Fe}_3\text{O}_4$  shows a metallic behavior at room temperature, the metal-insulator transition, so called Verwey transition, occurs at 120 K, below which  $\text{Fe}_3\text{O}_4$  is a ferrimagnetic insulator. Therefore, as a thin  $\text{Fe}_3\text{O}_4$  layer is grown on a semiconductor, it works as an insulating spin filter below 120 K, indicating a high efficiency of spin injection into the semiconductor. We have fabricated a spin-LED structure consisting of a 10-nm-thick  $\text{Fe}_3\text{O}_4$  layer on an AlGaAs/GaAs quantum well and demonstrated a spin polarization of over 40 % in the quantum well, analyzing the circular polarization of light emission from the quantum well. This demonstration clearly reveals that the use of an insulating spin filter is very effective for increasing the spin injection efficiency.

#### 2) Resonant spin transmission in ferromagnet/semiconductor interfaces

Spin filter effect is a very useful means for characterizing the spin polarization of electrons in a semiconductor. In order to use spin filtering effect, it is crucially important to gain information about spin dependent transmission across ferromagnet/semiconductor interfaces. In this study, we characterized the spin dependent transmission across an Fe/AlGaAs/GaAs quantum well interface measuring helicity dependent photocurrent. A clear dip feature was observed in the bias dependence of the helicity dependent photocurrent, where even the sign of the helicity dependent photocurrent was reversed. The appearance of the dip can be understood in terms of spin dependent tunneling processes via interface resonant states. This observation indicates that the spin dependence of electron spin transmission probability can be manipulated by applying bias voltage at the interface and it may be used as a means to characterize the spin polarization in semiconductor.

#### 3) Resonant spin transmission in ferromagnet/semiconductor interfaces

Control of the magnetic anisotropy of a ferromagnet is very important to design spintronic devices. Here, we have studied the magnetic anisotropy of ferromagnet/ferroelectric heterostructures where interface strain plays an important role in the magnetic anisotropy. We grew an epitaxial Fe or FeGa layer on  $\text{BaTiO}_3(001)$  using MBE technique and measured changes in the in-plane magnetic anisotropy at the structural phase transition temperatures of  $\text{BaTiO}_3$  from the tetragonal phase to orthorhombic phase and from the orthorhombic phase to rhombohedral phase. A clear variation of the magnetic anisotropy from the four-fold symmetry to two-fold symmetry was observed. This demonstration of the symmetrical change in the magnetic anisotropy enables us to control the magnetization orientation by changing the interface strain. Also, we have demonstrated the modulation of magnetic anisotropy in an Fe/piezoelectric  $\text{BaTiO}_3$  structure by applying electric voltage.

### 2. Original Articles

- 1) T. Naito, I. Suzuki, M. Itoh, and T. Taniyama, "Effect of Spin Polarized Current on Magnetic Phase Transition of Ordered FeRh Wires", *J. Appl. Phys.* **109**(7) (2011) 07C911-1-3. [selected for the Volume 23, Issue 14, Nanomagnetism and Spintronics of Virtual Journal of Nanoscale Science & Technology]
- 2) Y. Shirahata, E. Wada, M. Itoh, and T. Taniyama, "Inversion of Spin Dependent Photocurrent at  $\text{Fe}_3\text{O}_4$ /modulation Doped GaAs Heterointerfaces", *J. Appl. Phys.* **109**(7) (2011) 07E105-1-3.

- 3) I.Suzuki, T. Naito, M. Itoh, T. Sato, and T. Taniyama, "Clear Correspondence between Magnetoresistance and Magnetization of Epitaxially Grown Ordered FeRh Thin Films", *J. Appl. Phys.* **109**(7) (2011) 07C717-1-3.
- 4) E. Wada, Y. Shirahata, T. Naito, M. Itoh, M. Yamaguchi, and T. Taniyama, "Inversion of Spin Photocurrent due to Resonant Transmission", *Phys. Rev. Lett.* **105**(15) (2010) 156601-1-4. [selected for the Volume 22, Issue 16, Nanomagnetism and Spintronics of Virtual Journal of Nanoscale Science & Technology]
- 5) E. Wada, Y. Shirahata, T. Naito, M. Itoh, M. Yamaguchi, and T. Taniyama, "Spin Polarized Electron Transmission into GaAs Quantum Well across Fe<sub>3</sub>O<sub>4</sub>: Optical Spin Orientation Analysis", *Appl. Phys. Lett.* **97**(17) (2010) 172509-1-3. [selected for the Volume 22, Issue 20, Nanomagnetism and Spintronics of Virtual Journal of Nanoscale Science & Technology]
- 6) T. Takakura, M. Piore-Ladriere, T. Obata, Y. S. Shin, R. Brunner, K. Yoshida, T. Taniyama, and S. Tarucha, "Triple Quantum Dot Device Designed for Three Spin Qubits", *Appl. Phys. Lett.* **97**(21) (2010) 212104-1-3. [selected for the Volume 22, Issue 23, Electronic Structure and Transport of Virtual Journal of Nanoscale Science & Technology]
- 7) D. Fu, M. Endo, H. Taniguchi, T. Taniyama, M. Itoh, and S. Koshihara, "Ferroelectricity of Li-doped silver niobate (Ag,Li)NbO<sub>3</sub>", *J. Phys.: Cond. Matt.* **23** (2011) 075901-1-7.
- 8) T. Shimizu, T. Era, H. Taniguchi, D. Fu, T. Taniyama, and M. Itoh, "Phonon Dynamics in BiFeO<sub>3</sub> studied by Raman Scattering", *Ferroelectrics* **403** (2010) 187-190.
- 9) T. Taniyama, Y. Shirahata, M. Itoh, P. Sharma, M. Fukuhara, and A. Inoue, "Magnetic Anisotropy of Glassy Ferromagnet/Ferroelectrics Heterostructures", *Proc. Visual-JW2010* (2010) 306-307.
- 10) M. M. Uddin, E. Wada, Y. Shirahata, and T. Taniyama, "Fe/MgO Tunnel Barrier Contact for Electrical Spin Injection into GaAs for Semiconductor Spintronics Applications", *Proc. Natl. Conf. Mater. Sci. & Tech. for Sustainable Development: Bangladesh Perspective*, (2010) 42-45.
- 11) S. Kimura, Y. Narumi, N. Terada, Y. Tanaka, M. Iwaki, K. Katsumata, M. Hagiwara, K. Kindo, Z. He, T. Taniyama, M. Itoh, H. Toyokawa, T. Ishikawa, and H. Kitamura, "Field Induced Lattice Deformation in a Quasi-One-Dimensional Antiferromagnet BaCo<sub>2</sub>V<sub>2</sub>O<sub>8</sub>", *J. Phys. Soc. Jpn.* **79**(4) (2010) 043706-1-4.
- 12) H. Yamaguchi, S. Yasin, S. Zherlitsyn, K. Omura, S. Kimura, S. Yoshi, K. Okunishi, Z. He, T. Taniyama, M. Itoh, and M. Hagiwara, "Novel Phase Transition Probed by Sound Velocity in Quasi-One-Dimensional Ising-like Antiferromagnet BaCo<sub>2</sub>V<sub>2</sub>O<sub>8</sub>", *J. Phys. Soc. Jpn.* **80** (2011) 033701-1-4.

### 3. Conference presentations

#### International Conference

- 1) Y. Shirahata, T. Nozaki, M. Itoh, and T. Taniyama, "Interfacial Strain Induced Magnetic Anisotropy of Epitaxial Fe<sub>3</sub>O<sub>4</sub>/BaTiO<sub>3</sub> Heterostructures", International Conference of Asian Union of Magnetism Societies (ICAUMS2010) (Jeju, Korea) (Poster)
- 2) I.Suzuki, M. Itoh, and T. Taniyama, "Magnetic Anisotropy of Epitaxial FeGa/BaTiO<sub>3</sub>(001) Heterostructure", International Conference of Asian Union of Magnetism Societies (ICAUMS2010) (Jeju, Korea) (Poster)

- 3) T. Shimizu, D. Fu, H. Taniguchi, T. Taniyama, and M. Itoh, "Phonon Dynamics and Phase Transition in  $Ba_{1-x}Ca_xTiO_3$  Studied by Raman Scattering", 3rd International Congress on Ceramics (ICC3) (Osaka, Japan) (Poster)
- 4) T. Taniyama, M. Itoh, P. Sharma, M. Fukuhara, and A. Inoue, "Switching of Magnetization Process of Glassy Ferromagnetic Films Caused by Interfacial Strain", 55th Annual Conference on Magnetism & Magnetic Materials (MMM2010) (Atlanta, Georgia, USA) (Poster)
- 5) E. Wada, K. Watanabe, Y. Shirahata, M. Itoh, M. Yamaguchi, and T. Taniyama, "Efficient Spin Injection from  $Fe_3O_4$  into GaAs Triggered by Verwey Transition", 55th Annual Conference on Magnetism & Magnetic Materials (MMM2010) (Atlanta, Georgia, USA) (Poster)
- 6) Y. Shirahata, T. Nozaki, H. Taniguchi, M. Itoh, and T. Taniyama, "Switching of Magnetic Anisotropy due to Interfacial Strain at  $Fe/BaTiO_3$ ", 55th Annual Conference on Magnetism & Magnetic Materials (MMM2010) (Atlanta, Georgia, USA) (Poster)
- 7) Y. Shirahata, E. Wada, M. Itoh, and T. Taniyama, "Inversion of Spin Dependent Photocurrent at  $Fe_3O_4$ /Modulation Doped GaAs Heterointerfaces", 55th Annual Conference on Magnetism & Magnetic Materials (MMM2010) (Atlanta, Georgia, USA) (Poster)
- 8) I. Suzuki, T. Naito, M. Itoh, T. Sato, and T. Taniyama, "Clear Correspondence between Magnetoresistance and Magnetization of Epitaxially Grown Ordered  $FeRh$  Thin Films", 55th Annual Conference on Magnetism & Magnetic Materials (MMM2010) (Atlanta, Georgia, USA) (Poster)
- 9) T. Naito, I. Suzuki, M. Itoh, and T. Taniyama, "Effect of Spin Polarized Current on Magnetic Phase Transition of Ordered  $FeRh$  Wires", 55th Annual Conference on Magnetism & Magnetic Materials (MMM2010) (Atlanta, Georgia, USA) (Poster)
- 10) T. Naito, M. Itoh, and T. Taniyama, "Strain Driven Variations in Spin Polarization of  $Fe/Cu/Fe/BaTiO_3$  Trilayered Magnetic Wire Structures", 55th Annual Conference on Magnetism & Magnetic Materials (MMM2010) (Atlanta, Georgia, USA) (Poster)
- 11) Y. Shirahata, M. Itoh, and T. Taniyama, "Interface Related Magnetic Properties in Ferromagnetic-Semiconductor-Ferroelectric Hybrid Structures", 2010 Tokyo Tech - Asia Materials Week (Fuji, Japan) (Poster)
- 12) T. Taniyama, Y. Shirahata, M. Itoh, P. Sharma, M. Fukuhara, and A. Inoue, "Magnetic Anisotropy of Glassy Ferromagnet/Ferroelectrics Heterostructures" The International Symposium on Visualization in Joining & Welding Science (Visual-JW2010) (Osaka, Japan) (Poster)
- 13) M. H. Cho, H. Takashima, T. Taniyama, and M. Itoh, "Luminescent Properties of Europium Doped  $CaMoO_4$  Thin Film Prepared by Pulsed Laser Deposition", E-MRS 2010 Fall Meeting (Warsaw, Poland) (Oral Presentation)
- 14) Y. Yoneda, T. Obata, Y.-S. Shin, T. Takakura, T. Taniyama, and S. Tarucha, "Quantum Dot Devices with Micro-Magnet towards Stable Fast Spin Manipulations", The 6th International Conference on the Physics and Applications of Spin Related Phenomena in Semiconductors (PASPS-VI) (Tokyo, Japan) (Poster)
- 15) R. Brunner, M. Pioro-Ladriere, Y. Tokura, T. Obata, Y. -S. Shin, T. Taniyama, and S. Tarucha, "Towards the Realization of a Multiple Qubit System by using a Split Micromagnet Design",

30th International Conference on the Physics of Semiconductors (ICPS-2010) (Seoul, Korea)  
(Poster)

- 16) Y. Shirahata, E. Wada, M. Itoh, and T. Taniyama, "Spin Filtering Effect at Fe<sub>3</sub>O<sub>4</sub>/Modulation Doped GaAs Interfaces", 2nd International Symposium on Advanced Magnetic Materials and Applications (ISAMMA 2010) (Sendai, Japan)(Poster)
- 17) T. Taniyama, R. Kakinuma, T. Naito, and M. Itoh, "Electric Field Driven Switching of Magnetic Domain Structures in Fe dots/BaTiO<sub>3</sub> Heterostructures", 2nd International Symposium on Advanced Magnetic Materials and Applications (ISAMMA 2010) (Sendai, Japan) (Oral)
- 18) T. Shimizu, D. Fu, H. Taniguchi, T. Taniyama, and M. Itoh, "Phonon Dynamics in Ba<sub>1-x</sub>Ca<sub>x</sub>TiO<sub>3</sub> Studied by Raman Scattering", The 10th Russia/CIS/Baltic/Japan Symposium on Ferroelectricity (RCBJSF-10) (Yokohama, Japan)(Poster)
- 19) T. Nozaki, Y. Shirahata, M. Itoh, and T. Taniyama, "Strain-induced Magnetic Anisotropy of Fe<sub>3</sub>O<sub>4</sub>/BaTiO<sub>3</sub> Heterostructures Studied by Magneto-optical Kerr Effect", 4th International Conference on the Science and Technology for Advanced Ceramics (STAC-4) (Yokohama, Japan) (Poster)
- 20) R. Brunner, Y. -S. Shin, T. Obata, T. Kubo, Y. Tokura, M. Pioro-Ladriere, K. Yoshida, T. Taniyama, and S. Tarucha, "Spin SWAP in a Scalable Qubit System including a Split Micro-Magnet", Quantum Dot 2010 (Nottingham, UK) (Oral)

#### **Domestic Conference**

- 1) 白幡 泰浩, 和田 詠史, 磯崎 俊之, 伊藤 満, 谷山 智康, "強磁性薄膜/GaAs(001)における円偏光励起スピン偏極電子伝導の励起波長依存性", 日本物理学会第66回年次大会(2011年)(新潟市、新潟大) (ポスター発表)
- 2) 鈴木 一平, 内藤 朋之, 伊藤 満, 谷山 智康, "界面歪によるFeRh薄膜の磁気特性への影響", 日本物理学会第66回年次大会(2011年)(新潟市、新潟大) (ポスター発表)
- 3) 内藤 朋之, 伊藤 満, 谷山 智康, "強誘電体BaTiO<sub>3</sub>上のFe/Cu/Co構造の磁気抵抗特性", 日本物理学会第66回年次大会(2011年)(新潟市、新潟大) (ポスター発表)
- 4) 清水 荘雄, 符 徳勝, 谷口 博基, 谷山 智康, 伊藤 満, "強誘電体Ba<sub>1-x</sub>Ca<sub>x</sub>TiO<sub>3</sub>における相転移機構", 日本物理学会第66回年次大会(2011年)(新潟市、新潟大) (ポスター発表)
- 5) 小幡 利顕, ロランドブルナー, 申 潤錫, ミシェルビオロラドリエル, 都倉 康弘, 久保敏弘, 吉田 勝治, 谷山 智康, 樽茶 清悟, "不均一磁場を利用した2スピンキュービットとスピンエンタングル状態", 日本物理学会第66回年次大会(2011年)(新潟市、新潟大) (口頭発表)
- 6) 趙 明姫, 谷山 智康, 谷口 博基, 伊藤 満, 高島 浩, "PLD法によるCaMoO<sub>4</sub>:Eu薄膜作成と蛍光特性", 2011年春季第58回応用物理学関係連合講演会(厚木市・神奈川工科大) (口頭発表)
- 7) 星野 晃大, 清水 荘雄, 谷口 博基, 谷山 智康, 阿藤 敏行, 伊藤 満, 稲熊 宜之, "PLD法によるMnTiO<sub>3</sub>の薄膜成長と相制御", 2011年春季第58回応用物理学関係連合講演会(厚木市・神奈川工科大) (口頭発表)

- 8) 有岡 孝祐, 谷口 博基, 谷山 智康, 伊藤 満, "Pb(Fe<sub>2/3</sub>W<sub>1/3</sub>)O<sub>3</sub>-PbTiO<sub>3</sub>の光起電力効果に関する研究", 2011年春季第58回応用物理学関係連合講演会(厚木市・神奈川工科大)(口頭発表)
- 9) 星野 晃大, 清水 荘雄, 谷口 博基, 谷山 智康, 阿藤 敏行, 伊藤 満, 稲熊 宜之, "PLD法によるMnTiO<sub>3</sub>薄膜作成と構造制御", 日本セラミックス協会2011年年会(浜松市・静岡大)(口頭発表)
- 10) 谷山 智康, "磁性薄膜/半導体量子井戸ヘテロ界面を介したスピン輸送の光学的検出", 酸化物特異構造の形成と機能創発ワークショップ(横浜)(招待講演)
- 11) 内藤 朋之, 鈴木 一平, 伊藤 満, 谷山 智康, "FeRh/Co細線におけるスピン注入II", 日本物理学会2010年秋季大会(堺市、大阪府立大)(ポスター発表)
- 12) 鈴木 一平, 内藤 朋之, 伊藤 満, 谷山 智康, "FeRh磁性電極を持つトンネル接合における磁気抵抗", 日本物理学会2010年秋季大会(堺市、大阪府立大)(ポスター発表)
- 13) 白幡 泰浩, 野崎 泰一郎, 伊藤 満, 谷山 智康, "Fe<sub>3</sub>O<sub>4</sub>エピタキシャル薄膜の磁気異方性の不整合歪み効果", 日本物理学会2010年秋季大会(堺市、大阪府立大)(ポスター発表)
- 14) 野崎 泰一郎, 内藤 朋之, 白幡 泰浩, 伊藤 満, 谷山 智康, "強磁性体/強誘電体ヘテロ構造における電圧誘起磁区構造変化", 日本物理学会2010年秋季大会(堺市、大阪府立大)(ポスター発表)
- 15) 内藤 朋之, 伊藤 満, 谷山 智康, "強誘電体BaTiO<sub>3</sub>上のFe/Cu/Fe構造の磁気抵抗特性", 日本物理学会2010年秋季大会(堺市、大阪府立大)(ポスター発表)
- 16) 清水 荘雄, 符 徳勝, 谷口 博基, 谷山 智康, 伊藤 満, "ラマン散乱によるBa<sub>1-x</sub>Ca<sub>x</sub>TiO<sub>3</sub>の構造転移の研究", 日本物理学会2010年秋季大会(堺市、大阪府立大)(ポスター発表)
- 17) 酒井 雄樹, 中島 将吾, 石川 隆昭, 神原 陽一, 的場 正憲, 谷山 智康, 伊藤 満, "Coカゴメ格子を持つシャンド鉱型金属強磁性体Sn<sub>2</sub>Co<sub>3</sub>S<sub>2</sub>の電子状態と物性制御要因", 日本物理学会2010年秋季大会(堺市、大阪府立大)(ポスター発表)
- 18) 的場 正憲, 酒井 雄樹, 川田 琢磨, 中井 隼也, 中島 将吾, 名越 英二, 神原 陽一, 谷山 智康, 伊藤 満, "Coカゴメ格子を持つシャンド鉱型金属強磁性体Sn<sub>2</sub>Co<sub>3</sub>S<sub>2</sub>の電子状態と磁気体積効果", 日本物理学会2010年秋季大会(堺市、大阪府立大)(ポスター発表)
- 19) 米田 淳, 小幡 利頭, 申 潤錫, 高倉 樹, 谷山 智康, 樽茶 清悟, "磁場を自己補償できる微少磁石型量子ドットEDSRサンプルの開発と実践", 日本物理学会2010年秋季大会(堺市、大阪府立大)(口頭発表)
- 20) 谷山 智康, "スピン偏極の外的制御とチューナブルスピン源の創製", 2010年秋季第71回応用物理学学会学術講演会(長崎市、長崎大)(招待講演)
- 21) 和田 詠史, 白幡 泰浩, 内藤 朋之, 伊藤 満, 山口 雅史, 谷山 智康, "GaAs量子井戸構造を用いたスピン注入円偏光発光とスピン依存光電流", 2010年秋季第71回応用物理学学会学術講演会(長崎市、長崎大)(口頭発表)

- 22) 有岡 孝祐, 諏訪間 大, 星野 晃大, 清水 莊雄, 谷口 博基, 谷山 智康, 伊藤 満,  
"SrTiO<sub>3</sub> (110)上へのBaTiO<sub>3</sub>薄膜作製と物性評価", 2010年秋季第71回応用物理学会学術  
講演会 (長崎市、長崎大) (口頭発表)
- 23) 和田 詠史, 白幡 泰浩, 内藤 朋之, 伊藤 満, 山口 雅史, 谷山 智康, "スピン依存光電  
流の効率的検出とスパイク状符号反転", 日本磁気学会第34回学術講演会 (つくば市、  
つくば国際会議場) (口頭発表)
- 24) 白幡 泰浩, 野崎 泰一郎, 谷口 博基, 伊藤 満, 谷山 智康, "構造相転移に伴う  
Fe/BaTiO<sub>3</sub>ヘテロ接合の磁気異方性変化", 日本磁気学会第34回学術講演会 (つくば市、  
つくば国際会議場) (口頭発表)
- 25)  
谷山 智康, "異種材料複合化によるナノ磁性スピントロニクス", 日本磁気学会第34回ナノ  
マグネティックス専門研究会 (東京、化学会館) (招待講演)