論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Spin-related Phenomena in BiSb Topological Insulator - Ferromagnet Bilayers
著者(和文)	NGUYENKhang H D
Author(English)	Khang Huynh Duy Nguyen
出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第11274号, 授与年月日:2019年9月20日, 学位の種別:課程博士, 審査員:ファム ナムハイ,中川 茂樹,間中 孝彰,山田 明,宮島 晋介,田中 雅明
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第11274号, Conferred date:2019/9/20, Degree Type:Course doctor, Examiner:,,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	電気電子 系 コース	申請学位（専攻分野）： Academic Degree Requested	博士 (工学) Doctor of
学生氏名： Student's Name	Nguyen Huynh Duy Khang	指導教員（主）： Academic Supervisor(main)	Pham Nam Hai
		指導教員（副）： Academic Supervisor(sub)	

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

In this thesis, various spin-related phenomena in BiSb-ferromagnet (FM) bilayers were investigated for spintronic applications based on topological insulators (TIs). Here, the key results are highlighted as follows.

In chapter 1, the thesis background was introduced. The primary concepts of spin spintronics and its applications were reviewed. Spin-orbitronics was introduced as a novel concept that aims to utilize the spin-orbit interaction (SOI) in spintronic devices and has expanded spintronic materials to much broader spectra where spin devices utilize not only magnetic materials but also nonmagnetic materials with strong SOI. Toward exploring new materials with strong SOI, TIs and BiSb in particular appear as promising candidates. The motivation and outline of this thesis were introduced.

In chapter 2, fundamental physics of SOI was introduced. SOI-related effects, such as the Rashba-Edelstein effect, the spin Hall effect (SHE), the topological Hall effect (THE) were reviewed as new ideas that can help improve or even completely change spintronic device technologies. These ideas inspire my researches of spin-related phenomena in BiSb-ferromagnet bilayers as the main topic in the rest parts of thesis.

In chapter 3, the fabrication process of BiSb/FM bilayer thin films and characterization techniques were described in details. The thin film fabrication based on molecular beam epitaxy and real-time monitoring by reflection high energy electron diffraction played the main role in fabrication process. For sample characterizations, different types of measurement, such as X-ray diffraction measurement, magnetotransport measurement, magneto-optical measurement, magnetization measurement and atomic force microscopy measurement were briefly introduced.

In chapter 4, growth of MnGa thin layer with high perpendicular magnetic anisotropy (PMA) on BiSb thin film despite their differences in the crystal symmetry and lattice constant were achieved. The high PMA in BiSb/MnGa bilayers was confirmed by magnetic circular dichroism, anomalous Hall effect, and magnetization measurements.

In chapter 5, the large spin Hall effect in BiSb thin film was investigated in various BiSb/MnGa bilayers. A huge spin-orbit field of 2.3 kOe/(MA/cm^2) was observed at room temperature. This value is much larger than those of heavy metals and other TIs by at least an order of magnitude. The estimated spin Hall angle θ_{SH} of 52 is the largest value as reported so

far. Comparing with other spin Hall material, BiSb shows the big advantage of large θ_{SH} and high electrical conductivity. In term of spin Hall conductivity which is considered as the figure merit for spin Hall materials, BiSb outperforms the nearest competitor (Pt) and other TIs by at least an order of magnitude. Finally, the ultra-low current density of 1.5 MA/cm^2 for spin-orbit-torque (SOT) magnetization switching was demonstrated in BiSb/MnGa bilayers, even though the MnGa ferromagnet used in this work has higher PMA energy by an order of magnitude than those used in previous room-temperature SOT magnetization switching experiments.

In chapter 6, the THE in BiSb topological insulator / MnGa bilayers with an additional annealing step was observed and provided a firm evidence for the existence of skyrmions. By combining the strong SOI of BiSb and the small magnetization of MnGa, a large critical interfacial Dzyaloshinskii-Moriya-Interaction (DMI) energy (D_s = 5.1 pJ/m) was achieved by controlling the annealing temperature of the MnGa template. Moreover, field-free ground-state skyrmions were observed for the first time at room temperature even under absence of an external magnetic field which is also consistent with micromagnetic simulations. These results confirm that BiSb topological insulator can generate not only large SOT, but also huge interfacial DMI for generation and manipulation of skyrmions.

In chapter 7, the large unidirectional magnetoresistance (UMR) in $Ga_{0.91}Mn_{0.09}As/Bi_{0.9}Sb_{0.1}$ bi-layers was reported. The observed UMR ratio is many orders of magnitude larger than those observed in metallic bi-layers and other TIs/CoFeB heterostructures. In addition, the large UMR ratio was found to originate from the magnon scattering mechanism, while the spin-dependent scattering mechanism plays a very small role. These results provide helpful insight into spin transport in strong spin-orbit-coupled systems and can open the door to realistic applications, such as two-terminal magnetic storage and spintronic devices based on UMR.