2021年度　提案書（**Web公開用**）　　作成者：　杜　野（東北大CSIS）

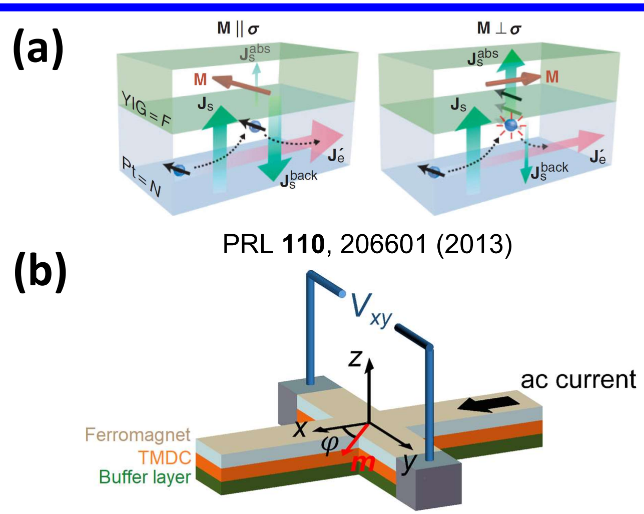
研究プロジェクト名：　Spin transport in transition-metal-dichalcogenide (TMDC)/ferromagnet bilayers

概要： <u>Current-induced spin-orbit torques</u> are promising for the efficient control of local magnetizations in spintronic devices. Recent studies suggest that <u>transition-metal-dichalcogenide (TMDC)</u> is not only a good candidate for generating spin-orbit torques, but also a key ingredient to promote field-free magnetization switching. <u>However, up to now, the underlying physics for the TMDC-based magnetic hetero-structures has remained elusive.</u> Specifically, the mechanism of the TMDC-based spin-orbit torques is not clear yet. Here in this proposal, we aim to <u>1) prepare TMDC-based magnetic hetero-structures and 2) study the origin of current-induced spin-orbit torques.</u>

コアメンバー：　新田グループ（Tohoku Univ.）、境グループ（QST）

期待される研究成果：

- High-quality TMDC/ferromagnet bilayers will be prepared upon proper buffer layers.
- The spin Hall magneto-resistance will be studied as an initial probe of charge-spin conversion in the system.
- The current-induced spin-orbit torques will be examined in such hetero-structures to study the origin.



Figs. (a) Physical process of magnetoresistance originating from spin Hall effect. (b) Schematic demonstration of harmonic Hall technique for the spin-orbit torque study.

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概要： The spin transport properties in transition-metal-dichalcogenide (TMDC)/ferromagnet bilayers have received increasing attention in recent years because of novel physics arising from the local symmetry breaking. Particularly, the charge-spin current conversion in TMDC/ferromagnet is a promising topic because of potential applications in MRAM. However, up to now, the physical origin of the charge-spin current conversion has remained elusive. In this work, we aim to prepare TMDC-based magnetic hetero-structures and to study the spin-orbit torques of such hetero-structures.

研究成果（実施状況）：

1. **We have successfully prepared thin TMDC films on top of graphene buffer layer on a sapphire substrate. Both TMDC and graphene show good crystallinity.**
2. **We have successfully measured and analyzed the current-induced spin-orbit torques in ferromagnet (FM)/graphene bilayers by using the in-plane harmonic Hall measurements (Fig. 1). The obtained damping-like and field-like torques scale with applied current (Fig. 2).**
3. **The current-induced spin-orbit torques in graphene/TMDC/ferromagnet tri-layer samples will be studied in the future.**

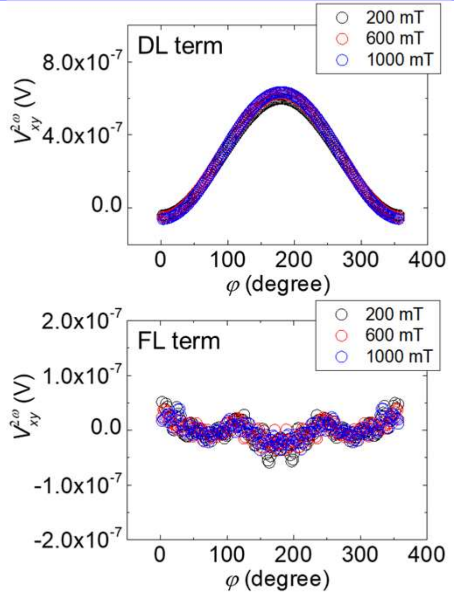

Fig. 1 Damping-like and field-like terms of the 2nd harmonic signals.

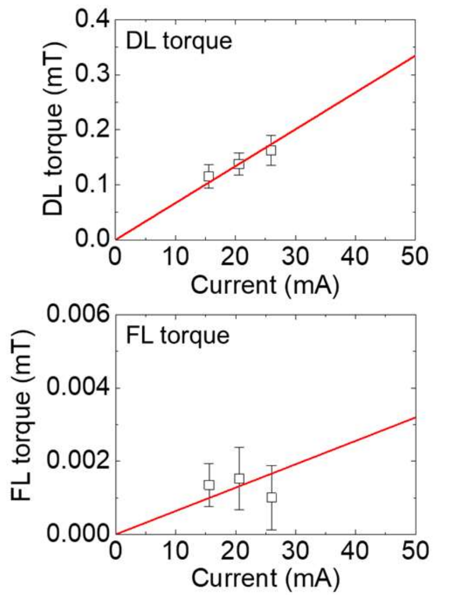

Fig. 2 Damping-like and field-like torques in FM/graphene bilayers.

主要発表論文等：

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概要： The current-induced spin-orbit torque (SOT) has been demonstrated as an efficient method to control local magnetic moments via electric means. Recently, the transition-metal-dichalcogenide (TMDC) was proposed to be a promising candidate as the SOT generator. In this proposal, we aim to prepare the TMDC materials upon proper ferromagnet (FM), and to study the related spin transport properties.

研究成果(実施状況)：

1. **We have prepared the FM single layer and FM/graphene bilayers as an initial step, because graphene layer is found to be helpful to promote the TMDC growth.**
2. **Magneto-transport properties have been studied for FM and FM/graphene samples (Fig. 1). Relatively low resistivity below 10 μΩ cm and high intrinsic anomalous Hall conductivity of ~700 Ω^{-1} cm^{-1} have been obtained as shown in Fig. 1(a) and 1(d), suggesting excellent sample quality.**
3. **We have studied the temperature dependent SOT in both FM and FM/graphene samples, the results are under discussion.**
4. **Our current study of spin transport in FM and FM/graphene samples provides a solid background for the preparation of FM/graphene/TMDC and for the study of spin transport in such tri-layers. We plan to prepare FM/graphene/TMDC tri-layers and to study the spin transport properties in the future.**

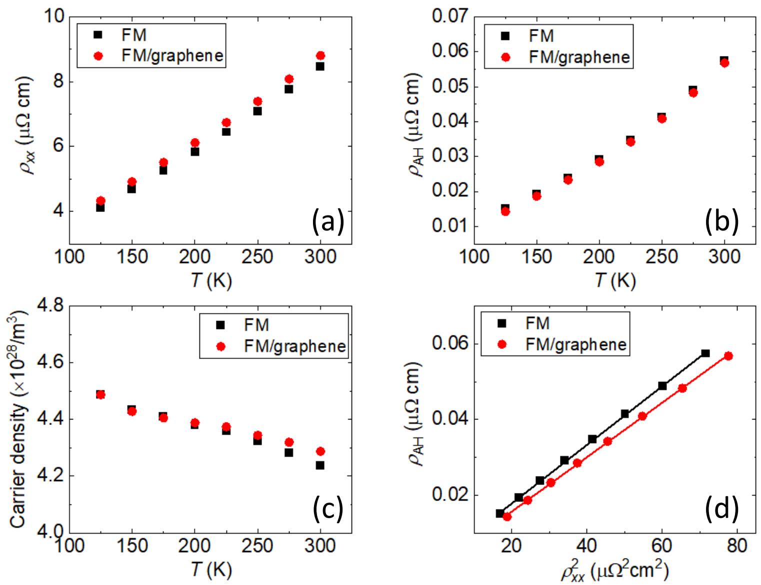

Fig.1 Temperature dependence of (a) longitudinal resistivity, (b) anomalous Hall resistivity, (c) carrier density and (d) anomalous Hall scaling for FM single layer and FM/graphene bilayers (FM thickness: 10 nm).

主要発表論文等：