List of RGJ advisors 2023/2024

Name:	Assoc. Prof. Dr.Athorn Vora-ud		
Program:	Physics	Department:	Physics
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Keywords: Transparent thin film, spintronic thermoelectrics, anomalous Nernst effect

Summary of research: The concept of this project is investigation on spintronic thermoelectric based on the transparent thin film materials. This project, we will select transparent thin film as a high spin current based on the spintronic thermoelectric effect such as; $Y_2Fe_5O_{10}$ (YIG) and transparent conduction layer with In/Ga-doped ZnO (IGZO) within large electrical conductivity and transparency [1]. Moreover, the spintronic thermoelectric effect will be combined with the perovskite solar cell within a new approach. Based on the potential of thermoelectric research group (SNRU) to development of excellent on spintronic thermoelectric thin film and excellent of perovskite solar cell research group (Sweden), they will be achieved to hybridization between spintronic thermoelectric/perovskite solar cell thin films. Due to last 2 years ago, Mr. Soe Ko Ko Aung (PhD. student) from SNRU went to Upsala University, then he had successfully to development the perovskite solar cell to be achieved the efficiency around 16% [2-3]. This is first collaboration between SNRU (Thailand) and Upsala University (Sweden). The hybridization of thermoelectric and photovoltaic were purposed on thin films, two dominant mechanisms to realize heat- and light-to-electricity conversation. The hybrid thermoelectric–photovoltaic thin film devices will be fabricated by using co-magnetron sputtering process onto the multi-layer thin film platform. We expect to the hybrid spintronic thermoelectric thin film will be improved the perovskite solar cell to be achieved the performance more than 16%.

References

[1] A. Vora-ud, A.T.T. Pham, D.C. Truong, S. Thoawankeaw, H.T. Lai, T.B.N. Le, N.M.Q. Tran, M. Insawang, P. Muthitamongkol, M. Horprathum, M. Kumar, S. Park, G.J. Snyder, T. Seetawan, T.B. Phan, *Chem. Eng. J.* 465 (2023) 142954. (IF= 16.7)

[2] S.K.K. Aung, A. Vijayan, T. Seetawan, G. Boschloo, *Sol. RRL 6* (2022) 21007. (IF= 9.173)

[3] S.K.K. Aung, A. Vijayan, M. Karimipour, T. Seetawan, G. Boschloo, *Electrochimica Acta* 443 (2023) 141935 (IF= 6.6)

การกรอกรายละเอียดในแบบฟอร์มนี้ ต้องดำเนินการให้ครบถ้วนตามความเป็นจริง หากตรวจสอบพบว่ามีการปกปิดหรือเป็นเท็จ วช. ขอสงวนสิทธิ์ที่จะไม่พิจารณาสนับสนุนและจะเป็นผู้ไม่มีสิทธิ์รับทุน วช. เป็นเวลา ๓ ปี

แบบเสนอโครงการวิจัย (Research Project)
ประกอบการเสนอขอทุนอุดหนุนการวิจัยของสำนักงานการวิจัยแห่งชาติ (วช.)
โครงการปริญญาเอกกาญจนาภิเษก (คปก.) ภายใต้ความร่วมมือไตรภาคีไทย-สวีเดน
ประจำปีงบประมาณ ๒๕๖๗

๑. **ชื่อโครงการวิจัย** Investigation on spintronic thermoelectric based on the transparent thin film

๒. **ชื่อ-สกุล อาจารย์ที่ปรึกษา** รองศาสตราจารย์ ดร.อาธรณ์ วรอัด (Assoc. Prof. Athorn Vora-ud; PhD)
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๓. **กลุ่มสาขาวิทยาศาสตร์พื้นฐานที่สมัคร** (เลือกเพียง ๑ กลุ่ม)

☐ ชีววิทยา (Biology) ☐ เคมี (Chemistry)

☑ ฟิสิกส์ (Physics) ☐ คณิตศาสตร์ (Mathematics)

๔. **ผู้ใช้ประโยชน์ (Research stakeholders)** (กรณีมีความร่วมมือฯ) เช่น ความร่วมมือของหน่วยงานภาครัฐ (เช่น กระทรวง กรม)/เอกชนที่ร่วมสนับสนุนทุนวิจัย เช่น MOU เป็นต้น

☐ มี.....*(โปรดระบุชื่อความร่วมมือ และหน่วยงาน)*.....

☑ ไม่มี

๕. **คำสำคัญ (Keyword) ของโครงการ**

Transparent thin film, spintronic thermoelectrics, anomalous Nernst effect

๖. **ความสำคัญและที่มาของปัญหาที่ทำการวิจัย (Problem statement and significance of research)**

The conversion of heat to electricity is knowns as thermoelectric phenomena. This is involving with electron transport when the temperature gradient is applied to the sample. The efficiency of thermoelectric device is depending on figure of merit (ZT) which is needed to reduce the thermal conductivity (κ) and electrical resistivity (ρ) as shown in eq. (1) [1-2]. To reduce these parameters, the semiconductor materials is the best choice for observing.

$$ZT = \frac{S^2}{\rho\kappa} \quad (1)$$

where S is represented the Seebeck coefficient which is come from voltage (ΔV) per temperature different (ΔT). However, the spin conversion by thermal is observed by Uchida K. et. al. in 2008 [ref] which is known as spin Seebeck effect [ref]. The configuration of SSE is represented in Fig.1b. The sample configuration is fabricated from the hybrid structure between ferromagnetic materials (FM) which is acting for spin injector and paramagnetic materials (PM) which is acting for spin detector. The temperature gradient ($\boldsymbol{\nabla T}$) is applied to the sample in z-axis while the magnetic field H is applied in x-axis. The spin polarization ($\boldsymbol{\sigma}$) in FM is aligned parallel to H. When the $\boldsymbol{\nabla T}$ is applied, the spin dynamic is moved and injected to PM. By inverse spin Hall effect (ISHE), the spin current ($\boldsymbol{J_s}$) is conversed to charge current ($\boldsymbol{J_c}$) and then the voltage different (ΔV) can be detected across the sample as seen in eq. (2) [3].

$$E_{ISHE} \propto J_S \times \sigma \tag{2}$$

where E_{ISHE} is the electric field which is generated from ISHE conversion. Since the first observed SSE in ferromagnetic metal [ref], there are also detected in semiconductor [ref] and insulator [ref] ferromagnetic materials, respectively. As the advantage of SSE in insulator, the consideration to reduce the thermal conductivity (κ) and electrical resistivity (ρ) is possible to find out. Because the thermal conductivity (κ) is low in ferromagnetic insulator which is acting for spin injector while electrical resistivity (ρ) is also still low in paramagnetic metal which is acting on spin detector.

This project will be investigated on spintronic thermoelectric based on the transparent thin film materials. Transparent thin film was selected from a high spin current based on the spintronic thermoelectric effect such as; $Y_2Fe_5O_{10}$ (YIG) and transparent conduction layer with In/Ga-doped ZnO (IGZO) within large electrical conductivity and transparency [1]. When achieved, we will hybridization between spintronic thermoelectric/perovskite solar cell thin films for a new approach.

๗. ทฤษฎี/สมมุติฐานของโครงการ (Hypothesis)

The magnetic properties of IGZO/YIG thin film were measured by vibration sample microscope (VSM) with Physical Property Measurement System (PPMS®Versalab™). For spin conversion detection, the effect of magnetic field dependence is observed by varying H in x-axis while the temperature gradient ($\boldsymbol{\nabla T}$) is fixed and applied in z-axis. Then, the ISHE voltage is measured in y-axis. Moreover, the temperature dependence was also measured by fixing the

magnetic field at 300 mT and then varying the temperature difference as 0K, 3K, 6K, 9K and 12K, respectively. However, when the FM is used for spin detector instead PM, the anomalous Nernst effect (ANE) will be occurred with e. (2). When the temperature gradient (∇T) is not parallel to magnetization (M), the electric field from ANE (E_{ANE}) will generated.

$$E_{ANE} \propto \nabla T \times M \tag{3}$$

๘. วัตถุประสงค์ของโครงการ (Objectives)

To investigation on spintronic thermoelectric based on the transparent thin film materials to combination between spintronic thermoelectric/perovskite solar cell thin films.

๙. การทบทวนวรรณกรรม/ผลงานวิจัยที่เกี่ยวข้อง (Literature Review)

A new approach, the spintronics is a new electronic technology, which actively exploits the spin degree of freedom of electrons as shown in Fig. 1 [1]. To develop novel principles to drive electric and magnetic devices and to save their energy consumption, a lot of research on spintronics has been conducted all over the world. In this field, a spin counterpart of the Seebeck effect the spin Seebeck effect (SSE) was discovered in 2008. The SSE refers to the generation of 'spin voltage' as a result of a temperature gradient in ferromagnetic or ferrimagnetic materials.

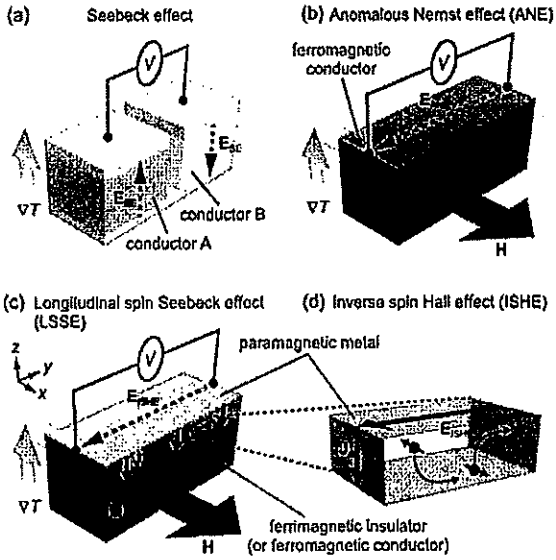

Figure 1. (a)–(d) Schematic illustrations of the conventional Seebeck effect (a), anomalous Nernst effect (ANE) (b), longitudinal spin Seebeck effect (LSSE) (c), and inverse spin-Hall effect (ISHE) (d). ESE, EANE, and EISHE denote the electric fields generated by the Seebeck effect, ANE, and ISHE, respectively [1].

๑๐. ระเบียบวิธีวิจัย (Methodology)

1) Synthesis and optimization of IGZO and YIG transparent thin films by using RF magnetron sputtering method onto Quartz and polyimide substrates.

2) Characterization of crystal structure, chemical composition and microstructure of IGZO and YIG transparent thin films as synthesized onto Quartz and polyimide substrates.

3) Study on electronic properties and thermoelectric properties of IGZO and YIG transparent thin films as synthesized onto Quartz and polyimide substrates.

4) Fabrication the hybrid spintronic thermoelectric/perovskite solar cell transparent thin film module prototype onto Quartz and polyimide substrate by using RF magnetron sputtering method.

5) Measurement of efficiency of spintronic thermoelectric/perovskite solar cell transparent thin film module by solar simulator method.

6) Study possibility of spintronic thermoelectric/perovskite solar cell transparent thin film generator application for energy harvesting from the sun light.

8) Discussion, conclusion, report, and progress to concept of commercial products.

๑๑. ขอบเขตของการวิจัย (Scope of the study)

1) Characterization of crystal structure, chemical composition, and microstructure by using XRD, SEM&EDX and TEM techniques, respectively.

2) Electronic properties and thermoelectric properties were carried by hall effect measurement and ZEM-3 methods, respectively.

3) Fabrication the hybrid spintronic thermoelectric/perovskite solar cell transparent thin film module prototype.

๑๒. ผลผลิต (Output) ผลลัพธ์ (Outcome) และ ผลกระทบ (Impact) ที่คาดว่าจะได้จากการวิจัย

1) The hybrid spintronic thermoelectric/perovskite solar cell transparent thin film module prototype.

2) One paper per year of international journal publications in ISI and SCOPUS (Q1) and then total less than three papers.

3) One person of International doctoral degree (Ph.D.).

Short Curriculum vitae of RGJ advisors 2023 (Assoc.Prof. Dr.Athorn Vora-ud)

Given Name	Athorn	Family Name	Vora-ud
Organization	Sakon Nakhon Rajabhat University	Department	Program of Physics
Division	Faculty of Science and Technology	Title/Position	Assistant Professor
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Professional education

Name of Institution	Year/Period of study	Field of study	Degree and Year of completion
Sakon Nakhon Rajabhat University, Thailand	2012–2017	Physics	Ph.D. (2017) (RGJ#15 scholarship)
Sakon Nakhon Rajabhat University, Thailand	2009–2012	Physics	M.Sc. (2012) (TGIST scholarship)
Sakon Nakhon Rajabhat University, Thailand	2005–2009	Physics	B.Sc. (2009) (YSTP scholarship)

Professional positions held

Year	Position
2017 - 2018	**Lecturer** in Program of Physics, Faculty of Science and Technology, Nakhon Rajabhat University (SNRU)
2017-Present	**Head of Thin Film Laboratory,** Center of Excellence on Alternative Energy (CEAE), Research Development Institute (RDI), Sakon Nakhon Rajabhat University (SNRU)
2019-2021	**Assistant Professor** in Program of Physics, Faculty of Science and Technology, Nakhon Rajabhat University (SNRU)
2021-Present	

	Associate Professor in Program of Physics, Faculty of Science and Technology, Nakhon Rajabhat University (SNRU)

2020-Present	PhD. Curriculum Chairperson in Program of Physics, Faculty of Science and Technology, Nakhon Rajabhat University (SNRU)
2020-Present	Associate Editor of Journal of Materials Science and Applied Energy

Researcher Data Base (Web of Science)

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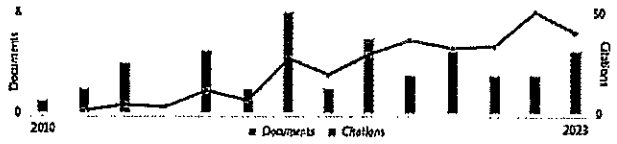

- Scopus Author ID: **36009437900**
- H-index: **9**
- Total citations: **290**

List of Project in Higher than TRF Academic Scholar

1. Year 2018-2020 (18 months); project title "Thermoelectric Cooling System for Turbo Molecular Pump", supported by **Thailand Research Fund (TRF)** through the **Next Generation Automotive and Smart Electronics Industry Program** within the Research Grant: RDG6150086. **(Principal investigator)**

- Budget total: 2,294,450 bath

2. Year 2022-2025 (3 years); project title "Data-driven computational design of high-performance thermoelectrics in atomic layers and topological materials", supported by National Research council of Thailand (NRCT) through the e-ASIA Joint Research Program (e-ASIA JRP) within the Research Grant: B16F650001. (Co-investigator)

- Budget total: 5,000,000 bath

Key publications in Scopus = 49)

– List of the past 5 years; 2023-2019 (Selected in Q1/Q2)

1. A. Vora-ud*, A.T.T. Pham, D.C. Truong, S. Thoawankeaw, H.T. Lai, T.B.N. Le, N.M.Q. Tran, M. Insawang, P. Muthitamongkol, M. Horprathum, M. Kumar, S. Park, G.J. Snyder, T. Seetawan, T.B. Phan, PhanTransparent-flexible thermoelectric module from In/Ga co-doped ZnO thin films, Chemical Engineering Journal 465, (2023) 142954. (Q1, IF= 16.7)
2. S. Thaowonkaew, M. Insawang, A. Vora-ud*, M. Horprathum, P. Muthitamongkol, S. Maensiri, M. Kumar, T.B. Phan, T. Seetawan, Effect of substrate rotation and rapid thermal annealing on thermoelectric properties of Ag-doped Sb_2Te_3 thin films, Vacuum 211, (2023) 111920. (Q1, IF= 4.11)
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5. 2. D.C. Truong, S. Thaowonkaew, P. Muthitamongkol, M. Horprathum, M. Kumar, T.B.N. Le, A.T.T. Pham, T. Seetawan, A. Vora-ud*, T.B. Phan, Relaxation of residual stress-controlled thermopower factor in transparent-flexible Ti-doped ZnO thin films, Ceramics International 48, (2022) 2605-2613. (Q1, IF= 5.532)
6. A. Vora-ud*, K. Cha-ar-mart, W. Kasemsin, S. Boongerdrum, T. Seetawan, Transparent Thermoelectric Properties of Copper Iodide Thin Films, Physica B: Condensed Matter 625, (2022) 413527-5. (Q1, IF= 2.988)
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8. A. Vora-ud*, S. Thaowonkaew, J. Khajonrit, K. Singsoog, P. Muthitamongkol, C. Chananonnawathorn, N. Chanlek, M. Horprathum, S. Maensiri, T. Seetawan, Rapid Thermal Annealing induced the c-axis (00 l) Preferred Orientation and the p-type Thermoelectric Properties of Bi-Sb-Te Thin Films, Thin Solid Films 706, (2020) 138094-5. (Q2, IF= 2.358)
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12. A. Vora-ud, T. Seetawan, M. Kumar, Experimental and theoretical study of thermoelectric properties of rhombohedral **$GeSb_5Te_{10}$ thin films**, **Materials Science and Engineering B** 250, (2019) 114439-7. **(Q1, IF= 3.507)**

13. A. Vora-ud*, M. Horprathum, M. Kumar, P. Muthitamongkol, C. Chananonnawathorn, B. Saekow, I. Nualkham, S. Thaowonkaew, C. Thanachayanont, T. Seetawan, Effect of Ag mixing in thermoelectric **$Ge_2Sb_2Te_5$ thin films**, **Materials Letters** 234, 229–232 (2019). **(Q1, IF= 2.687)**