VIETNAM NATIONAL UNIVERSITY, HANOI
VNU UNIVERSITY OF ENGINEERING AND TECHNOLOGY

SOCIALIST REPUBLIC OF VIETNAM
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INFORMATION ON DOCTORAL THESIS

1. Full name: Phan Hai..... 2. Sex: Male

3. Date of birth: 13/06/1990..... 4. Place of birth: Quang Binh

5. Admission decision number: 778/QĐ-CTSV dated 21st August, 2017

6. Changes in academic process:

- Decision on extending the study period No. 561/QĐ-ĐT, dated 28th August, 2020 of the Rector of the University of Engineering and Technology, Vietnam National University, Hanoi. The extension period is 1 years.
- Decision on extending the study period No. 803/QĐ-ĐT, dated 29th October, 2021 of the Rector of the University of Engineering and Technology, Vietnam National University, Hanoi. The extension period is 1 years.
- Decision on returning PhD students to their locality/work agency No. 1179/QĐ-ĐT, dated 29th November, 2022 of the Rector of the University of Engineering and Technology, Vietnam National University, Hanoi.
- Adjustment of the PhD thesis title according to decision number: 2078/QĐ-ĐHCN dated 30th September, 2024. The old thesis title, "Study on the fabrication of nanogenerator using triboelectric technology" has been changed to the new title, "Study on the triboelectric effect based on micro-nanostructured Al and PVC/PTFE materials for green energy development".

7. Official thesis title: Study on the triboelectric effect based on micro-nanostructured Al and PVC/PTFE materials for green energy development

8. Major: Nano materials and devices 9. Code: 9440126.01QTD

10. Supervisors: Assoc. Prof. Dr. Pham Duc Thang

11. Summary of the new findings of the thesis:

a. Aims and objectives:

- Fabricating the nanostructured PTFE and PVC triboelectric materials, and experimenting for triboelectric effect.

- Designing and producing TENG and multi-directional vibration TENG (MV-TENG) structures which operate in vertical contact separation mode for energy harvesting from single/multiple direction mechanical sources.

b. Research methods:

This thesis is conducted based on the theoretical research and experimental techniques, such as:

- Fabrication and modification: fabrication PVC nanofiber membranes by electrospinning techniques, etching and surface modification of PTFE film by ICP-RIE technique, fabrication of micro/nano structured Al by electrochemical corrosion and Q-switched laser technique.
- Study on the microstructures of the fabricated materials surface: using scanning electron microscopy and surface roughness measurement system.
- Study on designing and producing TENG structures: the vertical contact separation mode TENGs were fabricated by using Al, PVC and PTFE, and convert mechanical energy from single/multiple direction mechanical sources into electricity.

c. Results:

- The fabrication of PVC nanofiber membranes by electrospinning techniques, etching and surface modification of PTFE film by ICP-RIE technique, fabrication of micro/nano structured Al by Q-switched laser technique have been studied.
- The designing and producing TENG in vertical contact separation mode based on PTFE/Al triboelectric materials has been carried out. This TENG investigation indicated the optimal fabrication conditions for the Q-switched laser technique (d = 20 µm, v = 1000 mm/s, and P = 15 W). The maximal electrical signals of this TENG are V_{OC} = 148 V and I_{SC} = 9.6 µA.
- The new MV-TENG structure in vertical contact separation mode using a PTFE/Al triboelectric material pair has been developed. This generator can be used for converting from multidirectional mechanical vibrations to electrical energy. In this MV-TENG, depending on the direction of motion, the values of V_{OC} ranging from 57 V to 97 V and I_{SC} ranging from 6.2 µA to 6.5 µA have been obtained.

12. Practical applicability, if any: The potential in develop the applications for mechanical-to-electrical energy conversion; harvesting energy from mechanical energy sources with a suitably designed structure

13. Further research directions, if any: Research on new TENG structures for harvesting energy from wind and water flow motion

14. Thesis-related publications:

a) Hai Phan, P.N. Hoa, H.A. Tam, P.D. Thang, N.H. Duc (2020), "Multi-directional triboelectric nanogenerator based on industrial Q-switched pulsed laser etched Aluminum film", *Extreme Mechanics Letters*, 40, 100886.

b) Hai Phan, P.N. Hoa, H.A. Tam, P.D. Thang (2021), "Q-switched pulsed laser direct writing of aluminum surface micro/nanostructure for triboelectric performance enhancement", *Journal of Science: Advanced Materials and Devices*, 6(1), 84-91.

c) Phan Hải, Phan Nguyễn Hòa, Hồ Anh Tâm, Phạm Đức Thắng (2021), "Máy phát điện ma sát nano: Một giải pháp năng lượng tiềm năng", *Tạp chí Khoa học Đại học mở Thành phố Hồ Chí Minh – Kỹ thuật và Công nghệ,* 17, 43.

d) Phan Hải, Phan Nguyễn Hòa, Hồ Anh Tâm, Nguyễn Hữu Đức, Phạm Đức Thắng (2022), Nghiên cứu chế tạo thử nghiệm máy phát điện ma sát nano dựa trên hai vật liệu Teflon và nhôm công nghiệp", *Tạp chí Khoa học và Công nghệ Việt Nam (bản B)*, 64, 32.

Date: ……..……..	Date: ……..……..
SUPERVISOR	**PHD STUDENT**
Assoc. Prof. Dr. Pham Duc Thang	**Phan Hai**