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 : Ho Anh Tam.............................. 2. Sex: Male ....
3. Date of birth: June 01, 1987 .... 4. Place of birth: Quang Binh ....
5. Admission decision number: 778/QĐ-CTSV dated August 21, 2017, of the Rector of the University of Engineering and Technology, Vietnam National University, Hanoi
6. Changes in academic process:

Extended study period of 02 years (24 months) according to Decision No. 561/QĐ-ĐT dated August 28, 2020, of the Rector of the University of Engineering and Technology.

Return to the agency/locality according to Decision No. 1179/QD-DT dated November 29, 2022, of the Rector of the University of Engineering and Technology.

7. Official thesis title: Research on fabricating an integrated system of high-sensitivity magneto-impendence sensors and microfluidic channels for applications in the biomedical field.
8. Major: Nanomaterials and Nanodevices .... 9. Code: 944012601.QTD....................
10. Supervisors:

Assoc. Prof. Dr. Do Thi Huong Giang

Prof. Dr. CheolGi Kim

11. Summary of the **new findings** of the thesis:

This thesis focuses on researching and fabricating high-sensitivity, micro and nano-sized planar magnetoimpedance (MI) sensors, operating in low frequency and wide magnetic field ranges, for integration with microfluidic channel systems to detect magnetic nanoparticles in biomedical applications.

The research subjects of this thesis are: soft magnetic ribbon material $Fe_{90.88}Si_{4.13}C_{4.99}$ with a thickness of 20 µm, commercially available, shaped by wet chemical etching assisted by laser engraving technology; PDMS and PMMA materials used in the fabrication of microfluidic channels; and Fe_3O_4 magnetic nanoparticles synthesized by co-precipitation method using PVP as an activator, used for testing the integrated system.

Research methods used in this thesis:

- *MI sensor fabrication*: Utilizing 20 µm thick FeSiC soft magnetic ribbon combined with laser micromachining technology to create micro/nano sensor structures with linear, meander, and polygonal spiral shapes.
- *Material optimization by laser heat treatment*: Adjusting laser power to create nanocrystalline structures with controllable grain sizes, aiming to enhance the magnetoimpedance effect.
- *Simulation and measurement*: Employing Mumax^3 and OOMMF simulation software for micromagnetic structure analysis, combined with experimental measurements to evaluate the magnetoimpedance effect and magnetic particle detection capability.
- *Sensor integration with microfluidic systems*: Using laser etching and wet etching techniques to fabricate PDMS microfluidic channels, followed by experimental measurements of Fe_3O_4 magnetic particle solutions.

Main results and new contributions of the thesis:

- *Optimized sensor fabrication*: A circular spiral MI sensor (CSR60) with an edge width W = 60 µm achieved a magnetoimpedance effect of ~120%, a sensitivity of 0.85 %/Oe, a lowest resonant frequency f_r = 750 MHz, an excitation magnetic field of ~50 Oe, a resolution at the 10^{-3} Oe threshold, and complete isotropy with the measured magnetic field.
- *Enhanced MI effect through laser heat treatment*: With a laser power of approximately 2%, the magnetoimpedance effect increased 2.5 times, reaching 250%, while also improving soft magnetic properties.
- *Magnetization process simulation*: The thesis simulated the micromagnetic structure, domain patterns, and domain wall formation, helping to scientifically explain the magnetoimpedance effect mechanism.
- *Successful integrated microfluidic system*: The system achieved a magnetic field resolution of 10^{-3} Oe, a sensitivity of 0.82 Ω/µemu, and a magnetic particle measurement error of ±1 µemu.
- *Application in biomedical diagnostics*: The sensor was tested in respiratory rate measurement, allowing for high-precision respiratory rate spectrum analysis, supporting respiratory health monitoring.

Regarding scientific and practical significance, the thesis has contributed to the development of MI sensor technology, fundamental research on micromagnetics, and the magnetoimpedance effect in micro/nano structures. In terms of practical applications, the experiments in this thesis are oriented towards biomedical applications, aiding in the detection of magnetic particles for disease diagnosis and non-invasive health monitoring. Technologically, the thesis develops methods for fabricating sensors and microchannels outside cleanroom environments, saving costs and time, and paving the way for commercialization.

The above achieved results have addressed the research objectives of the thesis. In particular, the successful integration of microfluidic channels and magnetic sensors for experimental measurements with magnetic nanoparticles holds significant implications for lab-on-a-chip applications. The development of cleanroom-free experimental fabrication methods based on laser technology is also highly significant in expanding the research capabilities of related fields.

12. Practical applicability, if any:

With high sensitivity and resolution, the circular spiral sensor has been tested to measure and analyze respiratory rate spectra, providing valuable information on respiratory-related pathological conditions, aiding in treatment monitoring and drug response effectiveness.

13. Further research directions, if any:

Further optimize the fabrication technologies used in the thesis to achieve higher quality and repeatability.

Research and experiment with different sensor configurations and materials to achieve sensors with optimal parameters for biomedical applications.

14. Thesis-related publications:

"Fabrication of microchannels by using the CO2 laser Galvo marking machine and thermo-mechanical sealing method"; VNU Journal of Science: Natural Sciences and Technology, Vol. 35, No. 2 (2019) 112-120.

"Research on the fabrication of microchannels for biomedical applications using laser technology," 12th National Conference on Solid State Physics and Materials Science, SPMS 2021, Hanoi National University Publishing House, volume 1, pages 88-92.

"Tuning rotational magnetization for high frequency magnetoimpedance in micro-patterned triangle spiral magnetic systems"; Journal of Science: Advanced Materials and Devices (2022/12/1), Volume 7, Issue 4, Pages 100514, Publisher Elsevier (ISI Q1, IF = 6.7).

Utility Solution Patent: *"Process for fabricating metal masks using a commercial Fiber Laser engraving machine, applied in sputtering techniques to fabricate millimeter-sized details",* number 3105 according to Decision No. 1023w/QD-SHTT, dated February 15, 2023.

"Design and manufacturing of thin film planar coil-based magneto-impedance sensors", The 4th International Workshop on Advanced Materials and Devices_ IWAMD 2023, EMD-P26, page 157.

"Planar omnidirectional magnetoimpedancebased sensors with micro-spiral patterns"; IEEE Sensors Journal, vol. 24, no. 24, pp. 40603-40613, 15 Dec.15, 2024. Publisher: IEEE (ISI Q1, IF = 4.3). DOI: 10.1109/JSEN.2024.3486315.

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