Yu HE

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Research Interests

Magnetism and superconductivity are two inherently exclusive order parameters in nature; however, at the nanoscale, they are anticipated to coexist and interact synergistically. My research focuses on investigating novel spin-related transport properties at two-dimensional magnetic/superconducting nanointerfaces through thin film material growth and nanofabrication. This includes the generation, injection, and detection of supercurrent without energy dissipation, as well as the magnetic modulation of the superconducting phase. In particular, I try to develop innovative spin-related low-temperature storage devices, such as superconducting magnetic tunnel junctions and magnetic Josephson junctions, hoping to further drive the evolution of traditional spintronic devices toward extremely low power consumption (aJ/bit).

Education

Beihang University *Beijing, China*

PhD student in Electronic Science and Technology *Sept 2023 - Current*

- **Supervisors: Prof. Guang Yang** and Prof. Haozhe Yang
- **Courses:** Introduction to Low Temperature Storage and Quantum Computing

Beihang University *Beijing, China*

M.E. in Electronic Science and Technology *Sept 2021 - Sept 2023*

- **Supervisors: Prof. Haiming Yu** and Prof. Guang Yang
- **Courses:** Matrix Theory, Introduction To Solid State Physics, Modern Semiconductor Device Physics, Theory of Magnetism, Magnetic Property Measurement Technologies, Introduction To Micro-Nano Fabrication Technology, Spin Dynamics(Jean-Philippe Ansermet, EPFL)

Northwestern Polytechnical University *Xi'an, China*

B.E. in Electronics and Information Engineering *Sept 2017 - July 2021*

- **Supervisors: Prof. Ping Kwan Johnny Wong**
- Won the Outstanding Student Scholarship of the School of Electronics and Information of Northwestern Polytechnical University in 2019-2020 academic year

Research Projects

Quantitative Study of Geometry-Dependent Superconducting Diode Effect in Nb Nanowires *Beijing, China*

Leading project affiliated at Beihang University *June 2024 - Ongoing*

- **Project Description**: This project focuses on investigating the nonreciprocal transport phenomenon in asymmetric structured Nb nanowires. Unlike conventional s-wave superconductors, these constricted nanowires can function in a nonreciprocal manner under a perpendicular magnetic field, with the superconducting-to-normal metallic phase transition depending on the polarity of the bias current. Our research aims to characterize the superconducting diode effect (SDE) through second harmonic measurements. Additionally, by designing experiments and proposing theoretical frameworks, we will quantitatively analyze the impact of asymmetric geometric constraints on SDE effects and explore potential underlying physical mechanisms.
- **My Tasks**: Based on existing published work, I derive a theory of nonlinear resistors for harmonic measurements. For device fabrication, a Nb layer is deposited onto SiO_2 (300 nm)/Si substrates using DC magnetron sputtering. Electron-beam lithography is then employed to pattern custom Hall bar devices, incorporating asymmetric structures with various geometric constraints along the current channel. Cryogenic measurements are performed using a Physical Properties Measurement System (ColdTUBE from MultiFields Technology), along with external Keithley 6221 and Keithley 2182 instruments for DC measurements, and an SR830 for AC measurements. This project is ongoing and will benefit from additional experimental and theoretical enhancements.
- **Supervisor: Prof. Guang Yang** and Prof. Haozhe Yang.

Research on Spin-Triplet Transport at FM/SC Interfaces with Varying Barrier Thickness *Beijing, China*

Leading project affiliated at Beihang University *Aug 2023 - Ongoing*

- **Project Description**: This project explores novel phenomena arising from the interplay of fundamental symmetry breaking and relativistic spin-orbit coupling in quantum materials, with a particular focus on the interface between ferromagnets and conventional s-wave superconductors. The study centers on the Sub.//PtCo/MgO system, provided by our cooperative partners at the Institute of Physics, Chinese Academy of Sciences (IoP-CAS, Beijing), and fabricated via molecular beam epitaxy (MBE). In this system, the PtCo alloy exhibits perpendicular magnetic anisotropy, while the MgO barrier forms a distinctive wedge-shaped structure. The research aims to investigate the spin-orbit fields at the ferromagnet/superconductor interface, which may offer experimental evidence of spin-triplet Andreev reflection and induced spin-triplet superconductivity. These phenomena are vital for advancing superconducting spintronics and for realizing topologically protected Majorana bound states.
- **My Tasks**: In this project, the Nb layer is deposited onto the Sub.//PtCo/MgO stack structures using DC magnetron sputtering. The samples are then patterned into arrays of Hall bar devices through standard electron beam lithography (EBL) and ion beam etching (IBE) techniques. The current channel is oriented perpendicular to the wedge direction, resulting in a varying MgO barrier thickness across the widths of the different Hall bar devices. Cryogenic measurements are conducted using a Physical Properties Measurement System (ColdTUBE from MultiFields Technology) with external Keithley 6221 and Keithley 2182 instruments. This project is still ongoing and requires some experimental and theoretical supplements.
- **Supervisor: Prof. Guang Yang**.

Novel Magnetoresistance in EuS/Au/EuS Switches: From Localisation to Spin Scattering Crossover *Beijing, China*

Collaboration project with University of Cambridge *May 2023 - Aug 2023*

- **Project Description**: This project investigates the emergence of novel magnetoresistance phenomena in EuS/Au/EuS spin-switch structures, focusing on the transition from localization to spin scattering regimes. By varying the Au spacer thickness, we observe a crossover from quantum localization to giant magnetoresistance (GMR) driven by spin-dependent scattering. Additionally, the enhanced spin Hall magnetoresistance (SMR) further underscores the role of spin transport. Through detailed analysis of electrical transport in these heterostructures, where over 99% of current flows through the central Au interlayer, we demonstrate that the thickness of the Au spacer directly influences the system's crossover from localization to GMR. The research opens pathways to leveraging interfacial magnetic exchange fields for novel magnetoresistance effects, with significant implications for spintronic applications.
- **My Tasks**: In this project, I collaborated with Dr. Hisakazu Matsuki from Prof. Jason Robinson's group to conduct cryogenic measurements of angular-dependent magnetoresistance (ADMR) and Hall measurements on EuS/Au/EuS structures provided by Dr. Matsuki. After a series of discussions and a thorough literature review, particularly focusing on the work by Juan M. Gomez-Perez et al. in Nano Letters (2020), we demonstrated that the uniquely large G_i at the EuS/Au interfaces significantly modifies electronic transport, allowing for a crossover to GMR as the thickness of the Au layer increases. In addition to the cryogenic measurements, I took the lead in enhancing the measurement system, which involved developing LabVIEW programs to automate the process, resulting in high efficiency in data collection. This collaborative work has deepened my understanding of low-temperature transport measurements while gaining insights into the theory of low-temperature transport in magnetic superconducting material systems through relevant literature research.
- **Supervisor: Prof. Guang Yang** and Prof. Jason W. A. Robinson; cooperated with Dr. Hisakazu Matsuki.

Molecular Regulation of Two-dimensional Ferromagnetic Crystals *Xi'an, China*

Leading project affiliated at Northwestern Polytechnical University *Oct 2020 - June 2021*

- Funded by the Natural Science Foundation of Chongqing (General Program)
- **Project Description**: This project aims to study the structure, electronic states, and magnetism of organic/two-dimensional material systems, in order to obtain their basic characteristics and regulate their interface design schemes. Part of the research has been incorporated into my undergraduate thesis
- **My Tasks**: As a graduation thesis research project for undergraduate students under the funding framework of the Natural Science Foundation of Chongqing (General Program), A first-principles study of the structural, electronic and magnetic properties of the pristine bulk CoRhCrAl quaternary Heusler alloy and its (111), (001) and (110)-oriented thin films were performed by using VASP based on the density functional theory.
- **Supervisor: Prof. Ping Kwan Johnny Wong** and Prof. Wen Zhang; under the direct guidance of Dr. Iltaf Muhammad.

Skills

Programming	Python, C/C++, Matlab, LabView.
Laboratory skills	Thin Film Deposition, Nano-fabrication, Vacuum Technology, Material Characterization, Cryogenic Transport Measurement.
Miscellaneous	Linux, Shell (Bash/Zsh), LaTeX(Overleaf/VS Code), Data Analysis.

Publications

Journal Articles

Novel magnetoresistance in EuS/Au/EuS sandwich structures: from localisation to spin scattering crossover
H. Matsuki, G. Yang, J. Xu, Y. He, J. Li, A. Hijano, V. Golovach, N. Stelmashenko, F. S. Bergeret, J. W. A. Robinson
In preparation for submission (2024). 2024

Spin-Related Superconducting Devices for Logic and Memory Applications
Yu He, Jiaxu Li, Qiusha Wang, Hisakazu Matsuki, Guang Yang
ADVANCED DEVICES & INSTRUMENTATION (Dec. 2023). 2023

First-principles prediction of the half-metallicity in quaternary Heusler CoRhCrAl thin films

Iltaf Muhammad, Yu He, Anwar Ali, Wen Zhang, Ping Kwan Johnny Wong
Physica Scripta (June 2022). 2022

Conference Proceedings

Yu He, Iltaf Muhammad, Wen Zhang, Ping Kwan Johnny Wong. *First-principles Prediction of the Half-metallicity in Quaternary Heusler CoRhCrAl Thin Films*. The 2021 Around-the-Clock Around-the-Globe Magnetics Conference. 2021.

Languages

English Professional proficiency
Chinese Native proficiency