北京大学量子材料科学中心

International Center for Quantum Materials, PKU

Seminar

Multi-level state and unidirectional switching driven by spin-orbit torque

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Venue: Room W563, Physics building, Peking University

地点：北京大学物理楼，西563会议室

Abstract

With ultra-fast writing capacity and high reliability, the spin-orbit torque is regarded as a promising alternative to fabricate next-generation magnetic random access memory. However, the three-terminal setup can be challenging when scaling down the cell size. In addition, the thermal stability is another concern.

Here we demonstrate two types of layer structures to address these issues. Demonstrated in a variety of non-volatile memories, multilevel storage is an effective remedy to overcome the obstruction of three-terminal setup. However, initialization process for achieving multilevel storage is often inevitable and costs prolonged write latency and wasted power consumption. By engineering multi-domain formation in Co/Pt multilayers, we demonstrate how initialization-free multilevel storage can be achieved by spin-orbit torque switching. With the appropriate number of repeated Co/Pt layers, the multi-domain states become energetically favorable and can be manipulated with precision by spin-orbit torques. It is rather remarkable that, by modulating the writing pulse conditions, we can precisely control the final magnetization states, independent of the initial configurations. The initialization-free multilevel memory advances the spin-orbit-torque MRAM to higher storage density for practical applications.

In addition, we will also demonstrate that the current-pulse-induced perpendicular exchange bias can significantly relieve the concern of thermal stability. The switching of the exchange bias direction is induced by the spin-orbit torque when passing current pulses through the Pt/Co system with an inserted IrMn antiferromagnetic layer. Manipulating the current-pulse-induced exchange bias, spin-orbit-torque switching at zero field between states with unidirectional anisotropy is achieved and the thermal agitation of the magnetic moment is strongly suppressed. The spin-orbit torque mechanism provides an innovative method to generate and to control the exchange bias by electrical means, which enables us to realize the new switching mechanism of highly stable perpendicular memory cells.

References:

(1) Initialization-Free Multilevel States Driven by Spin–Orbit Torque Switching, Kuo-Feng Huang, Ding-Shuo Wang,, Ming-Han Tsai,, Hsiu-Hau Lin, and Chih-Huang Lai, Adv. Mater. 29, (2017),1601575

(2) Spin-orbit-torque MRAM: from uniaxial to unidirectional switching, Ming-Han Tsai, Po-Hung Lin, Kuo-Feng Huang, Hsiu-Hau Lin, and Chih-Huang Lai, arXiv:1706.01639

About the speaker

Prof. Lai received his Ph.D. in Materials Science and Engineering from Stanford University in 1997. He then joined Read-Rite Co. and worked on TMR and GMR heads. He became an Assistant Professor in National Tsing Hua University (NTHU) in 1998. Prof. Lai is currently Dean of College of Engineering in NTHU and Tsing Hua Chair Professor. His research works focus on magnetic materials, spintronic devices and CIGS thin film solar cells. He has published more than 200 peer-reviewed SCI papers and obtained more than 30 patents. He is a MRS-Taiwan Fellow.