北京大学量子材料科学中心

International Center for Quantum Materials, PKU

Weekly Seminar

Atomic scale imaging of spin, charge and lattice by achromatic electron microscopy

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Time: 4:00Pm, Sep. 19, 2018 (Wednesday)

时间：2018年09月19日 （周三）下午4:00

Venue: Room W563, Physics building, Peking University

地点：北京大学物理楼，西563会议室

Abstract

The atomic-level knowledge of local spin configuration of the magnetic materials is of great importance to predict and control their physical properties, in order to meet the challenges of ever-increasing demands on performance of functional materials. However, it is highly challenging to experimentally characterize magnetic properties of such materials with atomic scale spatial resolution.

The leading techniques in spatially resolved magnetic imaging are magnetic exchange force microscopy and spin polarized scanning tunneling microscopy. However, as they are surface sensitive, very little information can be obtained regarding bulk or buried materials. The X-ray magnetic circular dichroism (XMCD) combined with photoelectron emission microscopy (PEEM) technique is a very attractive alternative because it has the spatial resolution as high as the polarized x-ray beam size besides element specific feature, as it is less surface sensitive and can be used to look at the interior of the thin films. However, the length scale of magnetic contrast using highly brilliant left and right circularly polarized X-ray beams is around 15nm.

The best option to push the spatial resolution of the spectromicroscopies lies in the electron beam equivalent technique electron energy-loss magnetic chiral dichroism (EMCD) [1], which is also called electron magnetic circular dichroism. Physically, XMCD and EMCD shares the same underlying physics in which the angular momentum transferred during X-ray absorption or inelastic electron scattering can selectively excite magnetic sublevels in atoms. The structured electron beams generated through interference of suitably phased plane waves can produce beams with orbital angular momentum. Electron beams can be easily focused compared with X-rays, allowing for atomic scale magnetism to be probed. Previously, we have found a strong EMCD signal in transition metal oxides allowing them to use standing wave methods to identify the different spin states of Fe atoms with site specificity [2].

In principle EMCD can offer higher spatial resolution and greater depth sensitivity due to the short de Broglie wavelength and penetration of high-energy electrons compared to XMCD. Recently by using EMCD and achromatic electron microscopy, we are able to access the magnetic circular dichroism with unit-cell resolution and even with atomic resolution [4,5]. Combining with advanced capability of structural and chemical imaging by using aberration-corrected transmission electron microscopy, all the information including magnetic polarization, atomic configurations, chemical states can be simultaneously accessed from the very same sample region. In the examples of complex oxides including Sr_2FeMoO_6, $NiFe_2O_4$ [3], we would like to show how to achieve local atomic-scale magnetic, chemical and structural information and understand the structure-property relationship of these magnetic materials at the atomic level.

1. Schattschneider, P. *et al.* Detection of magnetic circular dichroism using a transmission electron microscope. *Nature* **441,** 486–488 (2006).
2. Z. Q. Wang, X. Y. Zhong*****, R. Yu, Z. Y. Cheng, J. Zhu*, Quantitative experimental determination of site-specific magnetic structures by transmitted electrons. *Nature Communications*, 4 (2013), 1395,.
3. Z. C. Wang, A. H. Tavabi, L. Jin, J. Rusz, D. Tyutyunnikov, H. B. Jiang, Y. Moritomo, J. Mayer, R. E. Dunin-Borkowski, R. Yu, J. Zhu and X. Y. Zhong*. Atomic scale imaging of magnetic circular dichroism by achromatic electron microscopy. *Nature Materials*. 17 (2018) 221-225.

About the speaker

钟虓龑，清华大学材料学院，北京电子显微镜中心，副研究员。2006 年获清华大学博士学位。2006-2010 年，美国阿贡国家实验室博士后，2010 年 1 月至今在清华大学材料学院北京电子显微镜中心工作。多年来一直从事高空间分辨分析电子显微学研究，特别在电子磁圆二色谱、电子能量损失谱、像差校正与微区电子衍射技术等方面，在实验研究方法与理论模拟上积累了一定经验。国际上首先发展了发展原子尺度磁圆二色谱测量方法，发展占位分辨电子磁圆二色谱技术定量测量磁矩，相关成果发表在Nature Materials, Nature Communications等杂志。