



Weekly Seminar

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

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4:00

Venue: Room W563, Physics building, Peking University

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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 $\text{Sr}_2\text{FeMoO}_6$, 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. Ruzs, 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

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