Atomic scale magnetic, chemical, and structural imaging of functional oxides

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The atomic-level knowledge of the local spin configuration of magnetic materials is of great importance to predict and control their physical properties. However, it is highly challenging to experimentally characterize the magnetic properties of such materials with atomic-scale spatial resolution. One of the best options to push the spatial resolution of magnetic imaging lies in the electron energy-loss magnetic chiral dichroism [1], which is also called electron magnetic circular dichroism (EMCD). Physically, X-ray magnetic circular dichroism (XMCD) and EMCD share 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 the 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 can access the magnetic circular dichroism with atomic plane resolution 3]. Combined with the advanced capability of structural and chemical imaging by using aberration-corrected transmission electron microscopy, all the information including magnetic polarization, atomic configurations, and chemical states can be simultaneously accessed from the very same sample region. In the examples of complex oxides e.g. Sr_2FeMoO_6 [3], nanocomposite $Sr_2Fe_{1+x}Re_{1-x}O_6$ [4], and antiphase boundary of $NiFe_2O_4$ [5], we would like to show how to achieve atomic-scale magnetic, chemical and structural information and understand the structure-property relationship of these magnetic materials at the atomic level.[6]

References

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