The macroscopic properties of magnetic materials, thin films and nanosystems are intimately related to their atomic structure and the presence of defects, interfaces, etc. Electron energy loss spectroscopy (EELS) in the aberration corrected scanning transmission electron microscope (STEM) allows simultaneous exploration of structure, chemistry and electronic properties in real space with atomic resolution. Furthermore, derived techniques such as electron magnetic chiral dichroism allow studies of magnetization in real space [1]. These techniques combine to provide a unique tool to understand systems such as the La$_{0.7}$Sr$_{0.3}$MnO$_3$/SrTiO$_3$ (LSMO/STO) ferromagnetic/insulating superlattices where unexpected behaviors such as a magnetic moment on Ti atoms have been measured. EELS images show that charge transfer takes place due to the presence of an extra interfacial La$_{0.7}$Sr$_{0.3}$-O plane [2]. In this talk we will review applications of STEM-EELS to such systems and show how interface charge transfer explains the observed ferromagnetism. Other examples to be described include the sensitivity of the EELS fine structure to the spin state of atoms [3]. For example, Co ions in A$_{1-x}$B$_x$CoO$_3$ perovskites (where A and B are divalent/trivalent elements) exhibit a competition between the crystal field splitting and Hund’s-rule exchange energy in the 3d states, which determines the spin state of the individual Co ions. These materials provide an ideal test bed to explore how environmental effects, such as O vacancies or impurities, affect the resulting Co spin state. The ordering of O vacancies along with the presence of epitaxial strain in these compounds can stabilize a superlattice in the Co spin state which can be measured by EELS [4]. This example shows how column-by-column spectroscopy offers the possibility of atomic resolution mapping of spin states.

References