MAGNETIC ORDER AND SUPERCONDUCTIVITY IN RUTHENATES, RUTHENOCUPRATES, AND OTHER LAYERED OXIDES

Abstract

by

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There exist several classes of materials that simultaneously exhibit superconductivity and anomalous magnetic order, where both effects are homogeneous throughout the material. No cohesive explanation for this "apparent ferromagnetism" has ever been published. In the $\text{Ln}_{1-x}\text{Ce}_x\text{Sr}_2\text{Cu}_2\text{MO}_10$ and in the $\text{LnSr}_2\text{Cu}_2\text{RuO}_8$ ($\text{Ln} = \text{Ln,Y}$; M=Ru,Nb) families of materials, it is shown via diffraction, SQUID magnetometry, and electron spin resonance that the metamagnetism in these materials is due to CuO$_2$ ferromagnetic order in the $ab$-plane, with adjacent layers stacked ferromagnetically; this CuO$_2$ magnetic order coexists with superconductivity in these materials. The implications of this on models of high-$T_c$ superconductivity may be profound.

Another controversial class of superconducting material, $\text{Ba}_2\text{LnRu}_{1-x}\text{Cu}_x\text{O}_6$ (Ln=Ln,Y) is examined and the compound $\text{Ba}_2\text{YRu}_{1-x}\text{Cu}_x\text{O}_6$ is shown to be superconducting with simultaneous Cu magnetic order at temperatures near that of YBCO, without CuO$_2$ planes. The magnetic and crystal structures of several members of the Ln series are examined by SQUID magnetometry, electron spin resonance, and x-ray and neutron diffraction, with discovery of simultaneous superconductivity and Cu magnetic order in only $\text{Ba}_2\text{DyRu}_{1-x}\text{Cu}_x\text{O}_6$. 
A third related class of materials, $\text{La}_2\text{CuMO}_6$ (M=Ru,Nb,Ti,Ir,Sn) is also examined for superconductivity. The magnetic structure of these materials is investigated by diffraction and SQUID magnetometry, and new high-temperature synthesis techniques are performed that dramatically improve the structural and magnetic properties of the compound $\text{La}_2\text{CuRuO}_6$; electron spin resonance has identified Cu antiferromagnetism in this material for the first time. Hole doping (with Ba or Sr) and electron doping (with Ce or Th) fails to generate superconductivity in this material. The high-temperature synthesis techniques are unsuccessful in processing of other members of the $\text{La}_2\text{CuMO}_6$ family due to the stability of $\text{La}_2\text{M}_2\text{O}_7$-type compounds at high temperatures. The compound $\text{La}_2\text{CuSnO}_6$ forms distinct CuO$_2$ and SnO$_2$ chemical layers, yet shows no superconductivity.