Materials Science Division
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ISIS

Structure, magnetism and superconductivity in $RuSr_2{}^{160}GdCu_2O_8$

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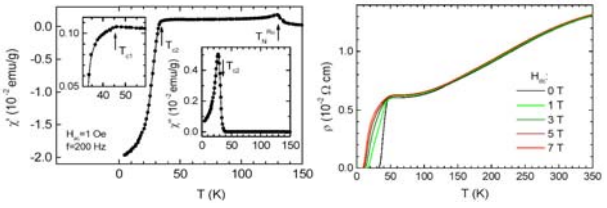
Introduction

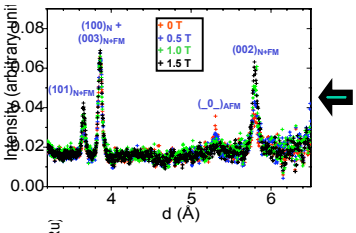
We have carried out a neutron diffraction and synchrotron X-ray diffraction investigation of polycrystalline $RuSr_2{}^{160}GdCu_2O_8$ (Ru-1212), which exhibits the unusual phenomenon of bulk ferromagnetism coexisting with superconductivity. The ferromagnetic moment most likely arises from a small canting of antiferromagnetically ordered Ru spins and the superconductivity arises in the CuO_2 planes, as in other layered cuprate superconductors. Samples can be changed from superconducting (SC), with T_c = 40 K, to non-superconducting (non-SC) through the choice of annealing conditions, with no apparent change in chemical composition. Here we compare the crystal chemistry and microstructures of SC and non-SC samples and present possible explanations for their behaviour.

Neutron diffraction experiments were carried out on the GEM diffractometer at ISIS using either a closed-cycle refrigerator or a cryomagnet, and synchrotron X-ray diffraction experiments were performed on beamline ID31 at ESRF.

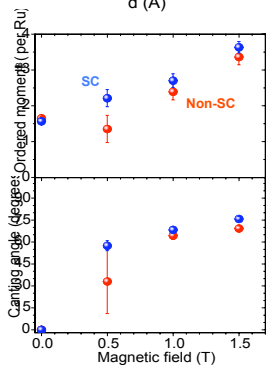


Left: Real part of AC magnetic susceptibility as a function of temperature for SC sample. The magnetic ordering temperature T_N is indicated. Right inset shows imaginary part of susceptibility indicating onset of superconductivity at ~40 K.

Right: Electrical resistivity as a function of temperature for SC sample under applied magnetic fields. High fields destroy superconductivity.

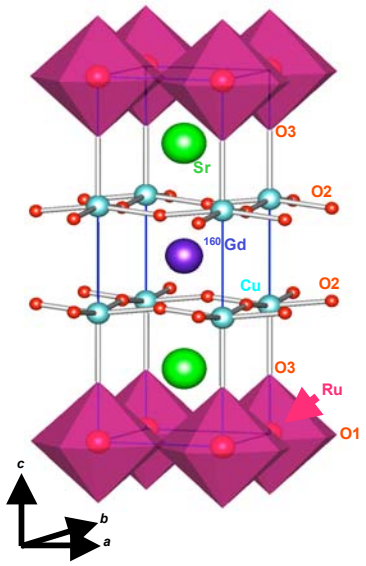


Neutron diffraction profiles of SC Ru-1212 measured with and without applied magnetic field. As the applied field is increased, the intensity of the antiferromagnetic (AFM) peak decreases while the intensity of the ferromagnetic (FM) peaks increase.
(N) denotes nuclear peak.

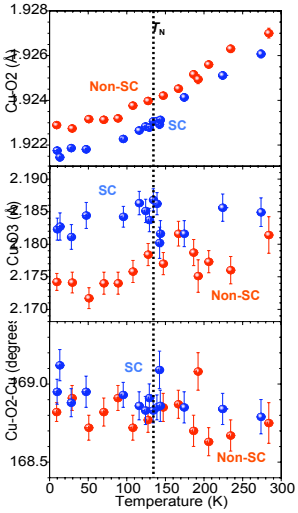


Above: Total ordered moment per Ru cation as a function of applied magnetic field.

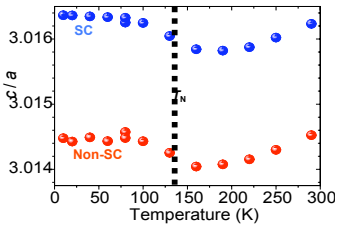
Below: Canting angle between AFM-ordered Ru spins, assuming that the FM moment arises purely from spin canting. At zero field no FM moment is measured, but the high residual absorption of the sample means that the lower limit for a measurable moment is ~0.4 μ_B per Ru.



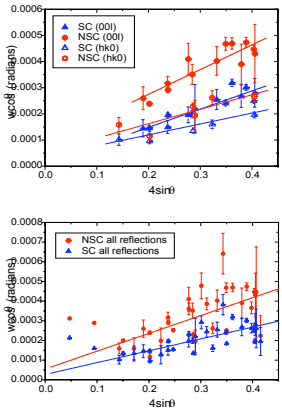
Crystal structure of Ru-1212. Space group is *P4/mmm* at all temperatures. The O1 atoms are disordered over two sites, giving an equal number of RuO_6 octahedra rotated in "clockwise" and "anticlockwise" fashion around the *c* axis.



Cu-O bond distances and Cu-O-Cu angles as a function of temperature. The difference between SC and non-SC samples can be explained by the different *c*/*a* lattice parameter ratios. Both samples show a small structural response near T_N.



Ratio of lattice parameters *c*/*a* as a function of temperature for SC and non-SC samples. The magnetic ordering temperature T_N is indicated. The difference might indicate a doping effect.



Williamson-Hall plots using synchrotron X-ray diffraction data collected at 295 K for (*hk*0) and (00*l*) reflections (upper) and all reflections together (lower), where 2_ is the peak position and *w* is the integral breadth of the peak. The slope of the line through the points is proportional to the strain of the sample.

The non-SC sample has a higher degree of strain than the SC sample, especially parallel to the *c* direction. This might indicate a higher proportion of stacking faults, with disorder inhibiting superconductivity.

Summary

- Ratio of lattice parameters *c*/*a* suggests that there may be a subtle doping effect that makes one sample superconducting and the other non-superconducting, in analogy to $YBa_2Cu_3O_{7-\_}$. However, no difference in oxygen content was detected, and the nature of any doping remains an open question.
- No significant difference in crystal structures between the SC and non-SC samples was observed. However, from an analysis of peak widths, the non-SC sample appears to have greater disorder than the SC sample.

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