Orbital Ordering Transition in Sr$_2$VO$_4$

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**Introduction**

Layered perovskites are well-known to exhibit various intriguing physical phenomena; two celebrated examples include high temperature d-wave superconductivity in La$_{2-x}$Sr$_x$CuO$_4$ (LSCO),[1] and low-temperature p-wave superconductivity in Sr$_2$RuO$_4$.[2] The search for exotic physics in s=1/2 systems has led to the synthesis of analogous materials which retain the K$_2$NiF$_4$ structure. Sr$_2$VO$_4$, which has similar s=1/2 V$^{4+}$ ions as Cu$^{2+}$, has been an elusive target for study due to the difficulty in producing single phase samples. The impetus to synthesize Sr$_2$VO$_4$ originates from a recent LDA calculation which predicts orbital ordering at T ~ 100 K.[3] This energy scale plays a role in properties of the related materials LSCO and Sr$_2$RuO$_4$ – the former has a structural transition, and the formation of a pseudogap as a function of doping, and the latter has a subtle c/a ratio change near 100 K. Until this work, no experimental evidence has been presented on the predicted orbital ordering in tetragonal Sr$_2$VO$_4$.

**Results and Discussion**

The world’s first samples of tetragonal Sr$_2$VO$_4$ were prepared in the Quantum Materials Laboratory at the NHMFL. The predicted orbital ordering transition at $T_{00} = 97$ K was observed through a characteristic drop in the DC susceptibility.[4] Using the new high resolution low temperature x-ray diffraction system at the NHMFL, the chemical structure was elucidated as a function of temperature to observe the magnetoelastic coupling of the lattice. The orbital ordering process was discovered to occur in stages – at $T = 122$ K, there is the onset of short-ranged ordering, followed by the coexistence of two phases as $T_{00}$ is approached from above. Below the transition, there exists only one tetragonal phase with an elongated c-axis and shortened a-axis, consistent with the LDA calculations of occupied orbitals oriented predominantly along the c direction.[3]

**Conclusions**

The synthesis and characterization of Sr$_2$VO$_4$ has verified the predicted orbital ordering at 97 K. Future doping studies will be performed to elucidate the rich phase diagram of this material by inducing holes upon the V$^{4+}$ sites. Experiments are already underway to probe the transition with pressure measurements, followed by neutron scattering studies of the magnetic behavior on single crystals.

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**References**

[1] For a review, see M. Imada et al., Rev. of Mod. Physics 70, 1039 (1998).