Spin Density Wave in Molecular Conductor Nanoparticle Assemblies

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Introduction

Despite decades of research, the quasi 1-D $(TMTSF)_2PF_6$ charge transfer salt has continued to attract interest due to the rich physics and phenomena present in the material. For example, in bulk, a metal-insulator transition is observed at T_{SDW} ~ 12 K in all three crystal axis directions due to the formation of spin density waves. The antiferromagnetic ordering is pronounced in the second most conducting *b*-axis, where a spin-flop transition is observed at magnetic fields above 0.3 T at 4 K. These are expected to occur in bulk crystals. However, it is unclear how these characteristics are affected as we approach the nanoparticle length scales comparable to the coherence lengths ~ 30 nm. Here, we report our investigation of the transport and magnetic properties of $(TMTSF)_2PF_6$ nanoparticles. It is remarkable that the spin density waves persist with identical T_{SDW}, accompanied by other similar functional features.

Experimental

Four-point transport is done on both the randomized nanoparticle assemblies and single crystals using the adhesive stamp electrodes [1] in a He^4 PPMS system. SQUID measurements are done on compacted nanoparticle powders in He^4 MPMS system at the Physics Department at Florida State University.

Results and Discussion

Due to the random orientation of the nanoparticles, comparative analysis between the bulk and the nanoparticle systems are done in terms of averages. In Fig. 1a, a clear metal-insulator transition is observed at ~ 12 K for both the single crystals and nanoparticle assemblies. The apparent lower activation energies of the nanoparticles suggest the presence of non-stoichiometric components contributing to the overall transport signal. The spin-flop transition is also observed above 0.3 T with a more gradual transition than that of the bulk crystals (Fig. 1b).

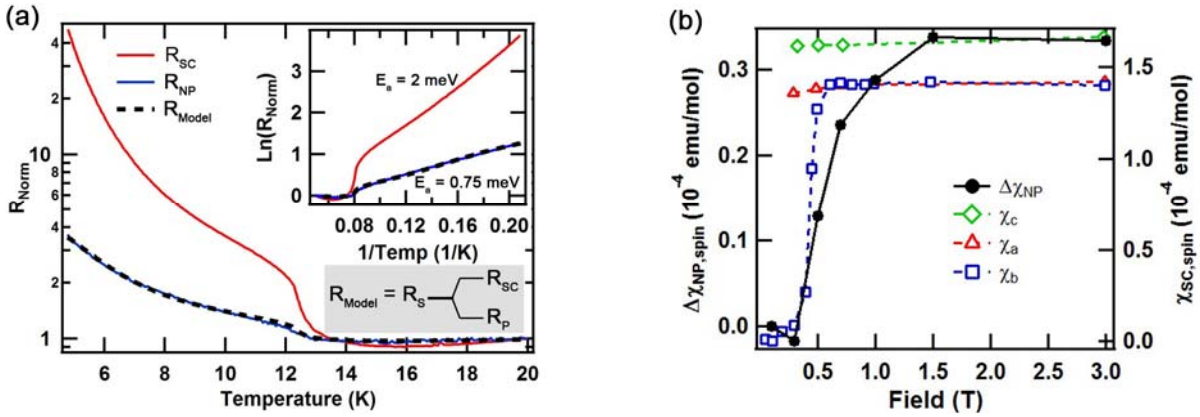

Fig 1. Comparative analysis of bulk and nanoparticle $(TMTSF)_2PF_6$. (a) Averaged temperature dependent transport revealing the persistence of the spin density wave metal-insulator transition at ~ 12 K. Top inset: Arrhenius plot showing the apparent lower nanoparticle activation energy. Lower inset: Series-parallel model used to fit the nanoparticle data. (b) Field dependent susceptibility showing similar spin-flop onset with more gradual transition than that of the bulk.

Conclusions

The persistence of the spin density waves in the nanoparticle systems, which are observed from two independent probes, is intriguing and suggests that the nanoparticle assemblies may interact collectively as a single body. However, more work is required ideally on a single nanoparticle to further clarify the functional differences.

Acknowledgements

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References

[1] E. Steven, E. Jobiliong, P. M. Eugenio, and J. S. Brooks, Rev. Sci. Instrum. **83**, 046106 (2012).