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Raman Spectroscopic Investigation of Antiferromagnetic Ordering in 2-Dimensional van der Waals Materials

Magnetism in two-dimensional (2D) systems is an interesting topic of fundamental importance. There have been several important theoretical predictions on these systems. For example, the famous Mermin-Wagner theorem states that magnetic ordering at a finite temperature is not possible for isotropic Heisenberg-type ferromagnetic or antiferromagnetic two dimensional materials. On the other hand, the so-called Onsager solution predicts that 2D magnetic ordering is stable for Ising-type materials. Recent discovery of ferromagnetism in atomically thin materials [1,2] has renewed interest in this topic with very interesting results. Antiferromagnetic ordering, on the other hand, is much more difficult to study because the lack of net magnetism hinders easy detection of such phenomena, and bulk measurement tools such as neutron scattering cannot be used for atomically thin samples due to the small sample volume. Raman spectroscopy has proven to be a powerful tool to detect antiferromagnetic ordering by monitoring the characteristic changes in the Raman spectrum that correlate with the magnetic transition. In this talk, I will review recent achievements in the study of antiferromagnetism in 2 dimensions using Raman spectroscopy of transition metal phosphorus trisulfides, $TMPS_3$ (TM = Fe, Ni, Mn). This class of 2D van der Waals materials is a very useful platform to study 2D magnetic ordering because the type of magnetic ordering depends on the transition metal element whereas the crystal structures are the same. $FePS_3$ exhibits an Ising-type antiferromagnetic ordering down to the monolayer limit, in good agreement with the Onsager solution for 2-dimensional order-disorder transition. The transition temperature remains almost independent of the thickness from bulk to the monolayer limit, indicating that the weak interlayer interaction has little effect on the antiferromagnetic ordering. [4] On the other hand, $NiPS_3$, which shows an XXZ- or XY-type antiferromagnetic ordering in bulk, exhibits antiferromagnetic ordering down to 2 layers, but the magnetic ordering is suppressed in the monolayer limit. [5] $MnPS_3$, which is a Heisenberg-type antiferromagnet, also shows magnetic ordering down to 2 layers [6].

References

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