On the paramagnetic-like susceptibility peaks at Zero Magnetic Field in WSe2−xTex single crystals

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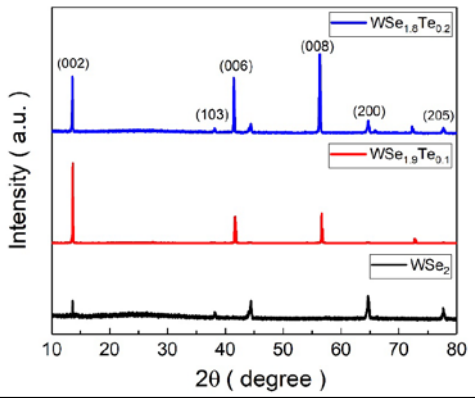
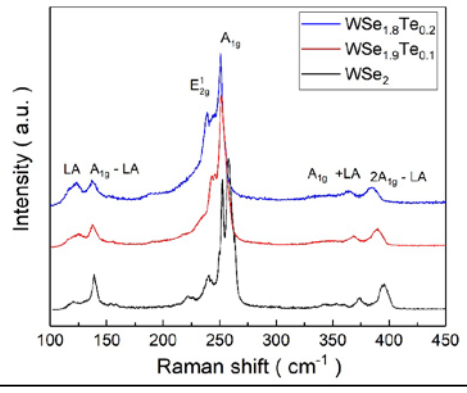
Motivation

- The temperature independent paramagnetic peaks at zero magnetic fields have been observed in various kinds of topological materials.
- All experimental and theoretical works speculate this behavior originates from the singularity spin texture at Dirac point topological surface state.
- Our previous experimental work in topological insulators without Dirac point support this behavior should not originate from the Dirac point of surface state and subvert all previous experimental and theoretical conclusions.
- To further exam and clarity this behavior, the magnetic characteristics of the WSe2−xTex single crystal were performed.
- Our results imply that the weakly temperature-dependent paramagnetic-like susceptibility peak originates from weak lattice distortion.

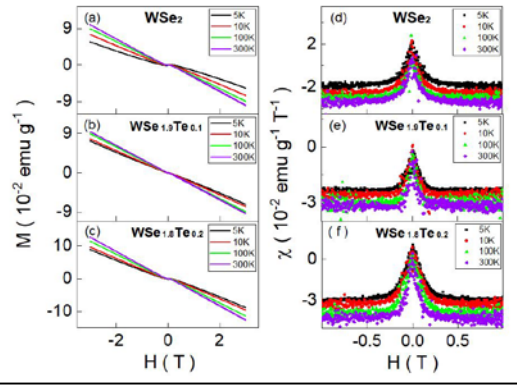
Results and Discussions



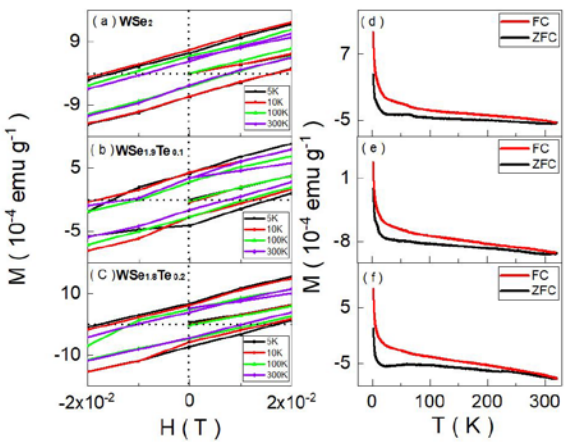
The XRD spectra of the WSe2, WSe1.9Te0.1 and WSe1.8Te0.2 single crystals. The peak positions are consistent with the database of the WSe2 crystal. The shift of the diffraction peaks to lower angles in the crystal with more Te atoms replacement reflects an enlargement of the lattice constants with increasing Te content.



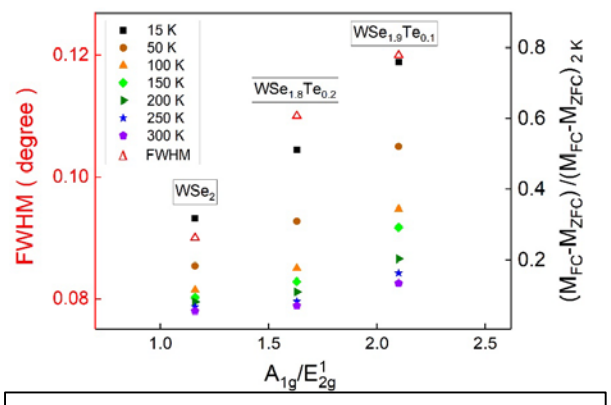
The Raman spectra of the WSe2, WSe1.9Te0.1 and WSe1.8Te0.2 single crystals. Peaks shift to lower Raman shift in samples with more Te-atom replacement.



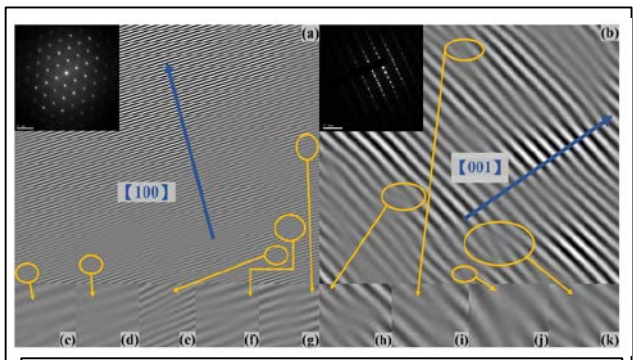
3 (a)-(c) show the magnetization as a function of magnetic field. They show paramagnetism at low magnetic field and diamagnetism at high magnetism at different temperatures. The diamagnetism is negatively proportional to the magnetic field. (d)-(f) show susceptibility peaks at a function of magnetic field. It reveals peaks at zero magnetic field, and the susceptibility peaks show weak temperature dependence from 5 K to 300 K.



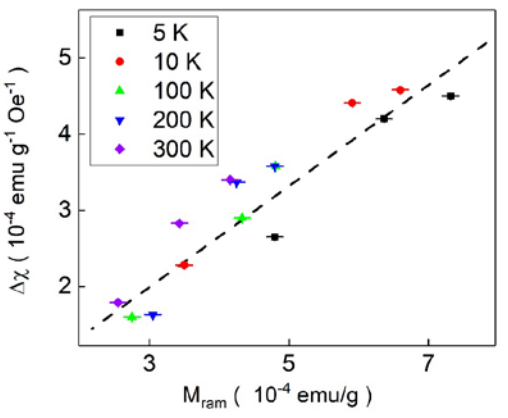
(a)-(c) show the magnetization as a function of magnetic field. It reveals magnetic hysteresis loops, and the coercive field is roughly 0.02 T. (d)-(f) show the temperature-dependent magnetization of field-cooled and zero-field-cooled processes. It splits from 330 K to 2 K. (a)-(f) support the ferromagnetic characteristic in the WSe2−xTex single crystals.



The full width at half maximum (FWHM) of the X-ray diffraction peak (002), and the normalized magnetic moment difference of field-cooled and zero-field-cooled processes as a function of A1g/E12g. Both follow the same tendency and are positive in the A1g/E12g. Larger lattice dislocation leads to larger FWHM. These results imply the element replacement distorts the lattice and enhances intrinsic ferromagnetism.



(a)-(b) The high-resolution transmission electron microscope image of the WSe2 single crystals in different axes and planes. The insets are the reciprocal lattice image of selected area electron diffraction patterns of the WSe2 single crystals in different axes and planes.
(c)-(k) reveal lattice dislocation of the WSe2 single crystals at several locations in different axes and planes.



The paramagnetic-like susceptibility peak height as a function of remanent magnetization of hysteresis loops in the WSe2−xTex single crystals at different temperatures. The susceptibility peak height is proportional to the remanent magnetization of hysteresis loops. This supports that the observed weakly temperature-dependent paramagnetic-like susceptibility peak originates from intrinsic ferromagnetism.

Conclusions

A weakly temperature-dependent paramagnetic-like susceptibility peak at zero magnetic field is observed in WSe2−xTex with only marginal amount of ferromagnetic impurities.
The ferromagnetic hysteresis loop, and the magnetic moment splitting between zero-field-cooled and field-cooled processes indicates ferromagnetism in the samples.
The paramagnetic-like susceptibility peak height is proportional to the remanent magnetic moment of hysteresis loops. High-resolution transmission electron microscope image supports that the observed ferromagnetic feature originates from lattice distortion.
These results imply that the weakly temperature-dependent paramagnetic-like susceptibility peak originates from weak lattice distortion.