The structure induced magnetic susceptibility peak to dip transition in the $MoSe_{2-x}Te_x$

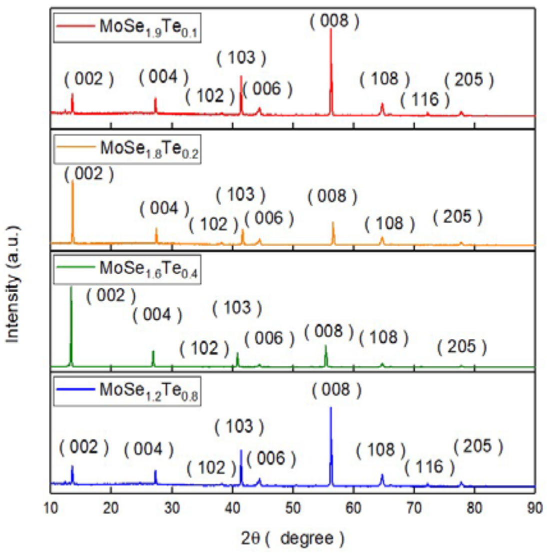
Shiu-Ming Huang,[1, 2], Fu-En Cheng,[1] Pin-Cing Wang,[1] Kuan-Ting Liu,[3] and Mitch Chou[3, 2],
1)Department of Physics, National Sun Yat-Sen University, Kaohsiung 80424, Taiwan
2)Center of Crystal Research, National Sun Yat-Sen University, Kaohsiung 80424, Taiwan
3)Department of Materials and Optoelectronic Science, National Sun Yat-Sen University, Kaohsiung 80424, Taiwan

Abstract

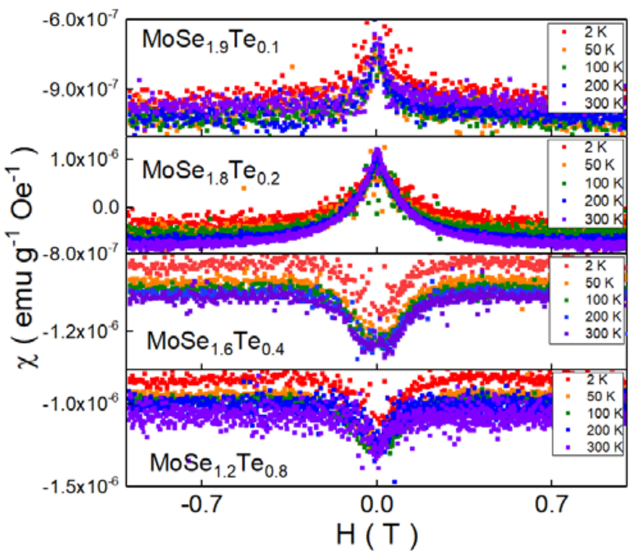
- Singular paramagnetic susceptibility peaks at zero magnetic field are reported in various kinds of topological materials. It is speculated to originate from the spin texture at the Dirac point of the topological surface state.
- The temperature independent magnetic susceptibility peak and dip were observed in the MoSe2−xTex. The magnetic susceptibility peak accompanies with ferromagnetism which originates from two electrons spin parallelly stay at 4d orbit in the 1T@2H structure. It exhibits no relation between magnetic susceptibility dip and ferromagnetism. This originates from two electron spin-anti-parallelly stay at the 4d orbit in the 2H structure and forms a diamagnetism. The magnetic susceptibility peak to dip transition is understood as transition of ferromagnetism to diamagnetism that originates from the disappear of the 1T@2H phase.

Experiment method

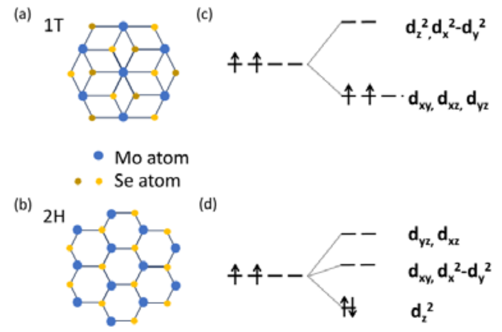
The chemical vapor transport (CVT) is adopted to grow molybdenum diselenide doped with tellurium $MoSe_{2-x}Te_x$ single crystal. The sample was evacuated to a pressure of 10^{-3} torr. The first step is to synthesize the raw materials into polycrystalline powder. The sample was slowly heated to 600 ° C over 95 hours. Secondly, the sample was annealed at 1050°C for 96 hours. Finally, the annealed polycrystalline materials were sealed into a 20 cm silica tube. It was then placed in the two-zone furnace, raised the temperature to 1020 ° C, and gradually decreased to 980 ° C in 170 hours.



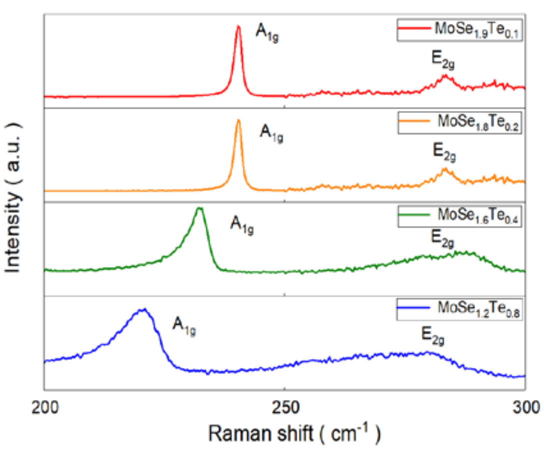
The X-ray diffraction peaks in the $MoSe_{2-x}Te_x$ single crystals. The peak position is consistent with the database of $MoSe_2$.



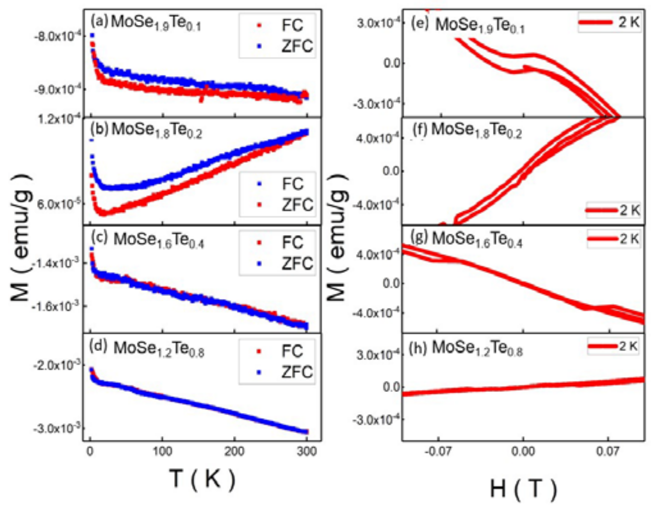
The weak temperature dependent magnetic susceptibility peaks in $MoSe_{1.9}Te_{0.1}$ and $MoSe_{1.8}Te_{0.2}$, and magnetic susceptibility dips in $MoSe_{1.6}Te_{0.4}$ and $MoSe_{1.2}Te_{0.8}$.



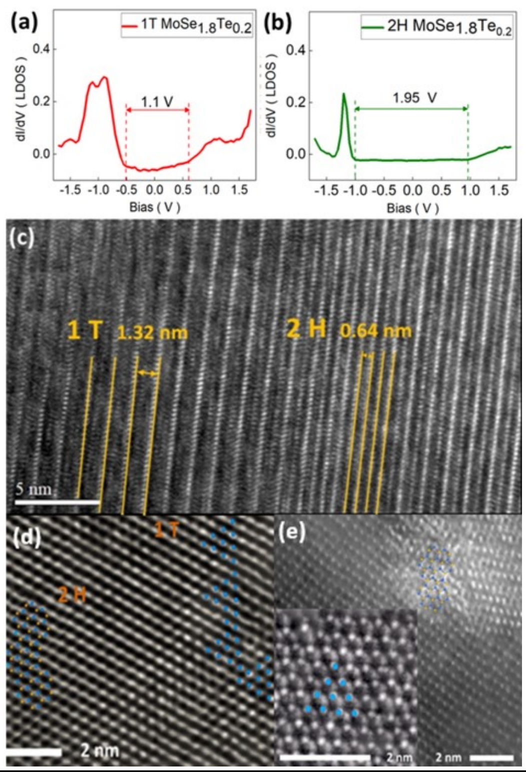
The occupation of electrons in the Mo 4d orbits in the 1T and 2H phase under external magnetic field.



The Raman spectrum of the $MoSe_{2-x}Te_x$ single crystals.
The Raman shift frequency of A_{1g} and E^1_{2g} is labeled.
The two Raman shift frequency peaks are consistent with the peak position of 2H phase in the $MoSe_{2-x}Te_x$.



(a)-(d) show the field-cool (FC) and zero-field cool (ZFC) curves and (e)-(h) shows hysteresis loop of $MoSe_{2-x}Te_x$.
It exhibits that FC and ZFC curves splitting and hysteresis loops in the $MoSe_{1.9}Te_{0.1}$ and $MoSe_{1.8}Te_{0.2}$. In contrast, the FC and ZFC curves overlap, and no hysteresis loop in the $MoSe_{1.6}Te_{0.4}$ and $MoSe_{1.2}Te_{0.8}$.



(a)and (b) Scanning tunneling spectroscopy shows the different bandgap of the metallic phase, 1T, and semiconductor phase, 2H of $MoSe_{1.8}Te_{0.2}$.
(c) The HRTEM image in side view mode. It shows 1T and 2H phases of $MoSe_{1.8}Te_{0.2}$.
(d) The HRTEM image in the plan view mode. It shows both 1T and 2H phases in $MoSe_{1.9}Te_{0.1}$.
(e) The HRTEM images of $MoSe_{1.8}Te_{0.2}$ in plan view mode. It shows 1T phase and the insect image shows the 2H phases.

Conclusions:

- The temperature independent magnetic susceptibility peak and dip are observed in the MoSe2−xTex.
- The magnetic susceptibility peak accompanies with the ferromagnetism. In contrary, no ferromagnetism characteristic in the system exhibiting magnetic susceptibility dip.
- The high resolution tunneling electron microscope and scanning tunneling spectroscopy support that existence of the 1T@2H phase in the MoSe1.9Te0.1 and MoSe1.8Te0.2 which exhibit the magnetic susceptibility peak. In contrary, no 1T phase is detected in the MoSe1.6Te0.4 and MoSe1.2Te0.8 which exhibiting the magnetic susceptibility dip.
- The magnetic susceptibility peak to dip transition is understood as crossover transition of ferromagnetism to diamagnetism that originates from the disappear of the 1T@2H phase.
- These behavior could be understood as that two electrons spin align parallelly in Mo 4d orbit in the 1T phase and leads to ferromagnetism. On the hand, two electron spin align anti-parallelly in Mo 4d orbit in the 2H phase and exhibits diamagnetism.
- Contrast to spin texture model, the temperature independent susceptibility peak might be the characteristic of ferromagnetism from the spin orientation of different material structures.