Coexistence of superconductivity and spin-orbit splitting in $Sn_{1-x}In_xTe$ thin film

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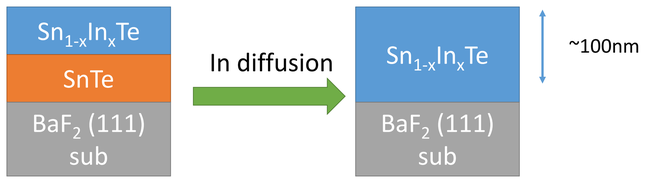
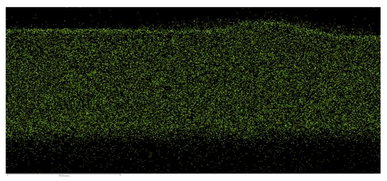
Introduction

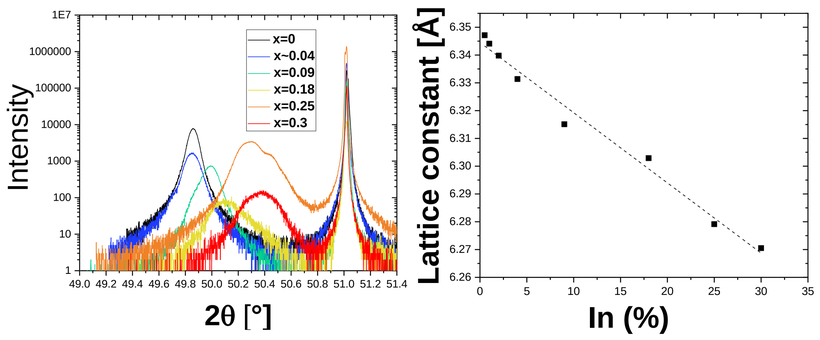
- SnTe is a topological crystalline insulator. [1] [2]
- It has been recently found that by In doping, $Sn_{1-x}In_xTe$(SIT) can be superconducting and also maintains its topological surface states.[3] However, the non-trivial character of superconductivity in SIT remains debated. Most previous research of SIT was focused on single crystals. The growth and analysis of SIT thin films are necessary to search for boundary Majorana states. In this work we report the growth of SIT film and the characterization by XRD, TEM and magneto-transport.

Sample growth

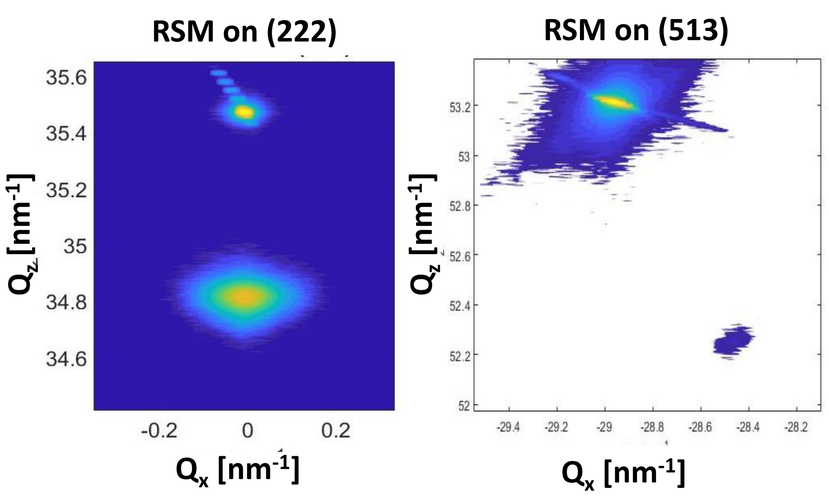


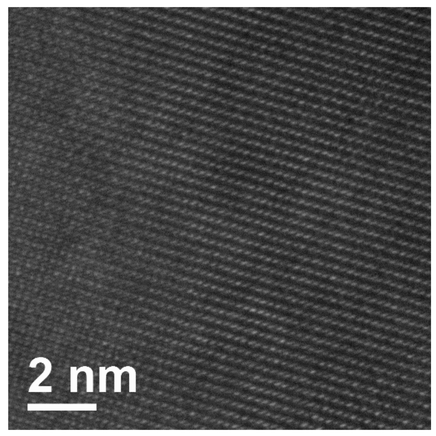


Sample is ~100nm. In diffuses all the way into SnTe buffer layer. We obtain a homogeneous $Sn_{1-x}In_xTe$.



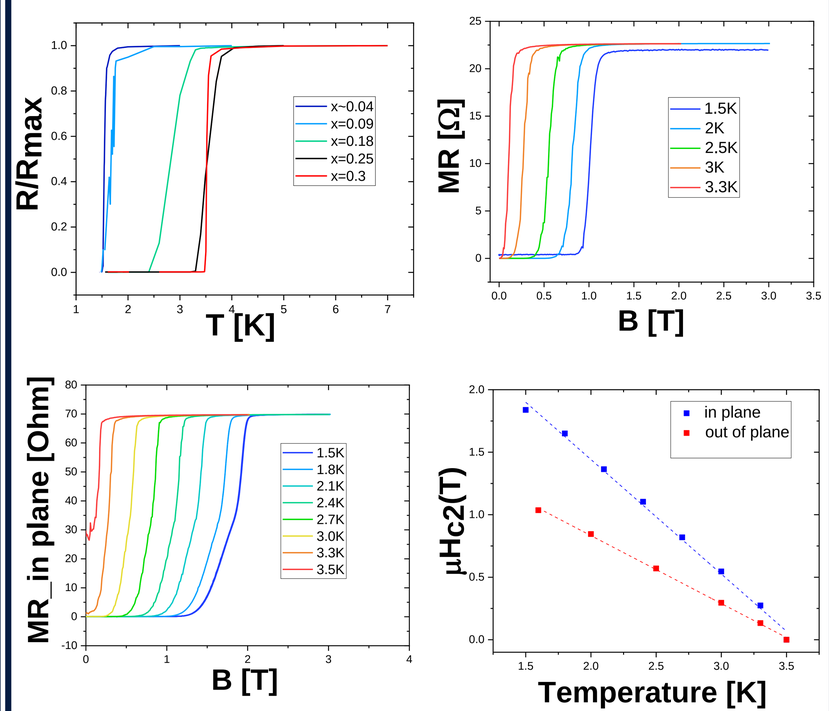
High-resolution XRD of samples with different In concentration (determined by EDX) . The lattice contant roughly follows Vegard's law.





No sign of different phases or In clusters in Reciprocal Space Map in (222) and (513) plane of $Sn_{0.91}In_{0.09}Te$. The calculated lattice constant is c=6.314Å, a=6.310Å, indicating a in-plane compressive strain from the substrate. TEM image shows a uniform film well oriented in (111) direction.

Superconductivity

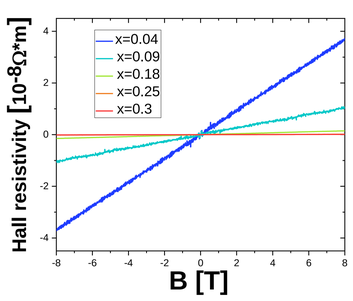


The temperature dependence of the critical field shows an anisotropic behavior. It can be fit with 3D Ginzburg-Landau theory:

$$\mu_0 H_{c2}^{\perp} = \mu_0 H_{c2}^{\perp}(0)[1 - \frac{T}{T_c}]$$

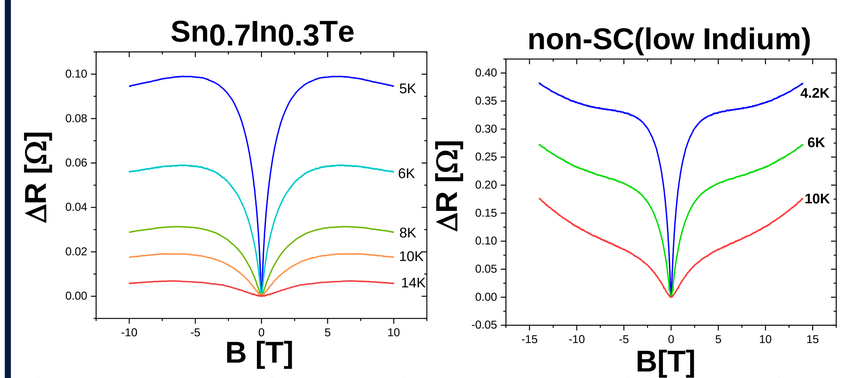
$$\mu_0 H_{c2}^{||} = \mu_0 H_{c2}^{||}(0)[1 - \frac{T}{T_c}]$$

We can estimate the superconducting coherence length ξ_{ab}(in plane) and ξ_c(out of plane). The extracted values are 12.9nm and 7.6nm separately. We conclude that our film lies in between 2D and 3D, and shows a quasi-3D superconducting behavior.

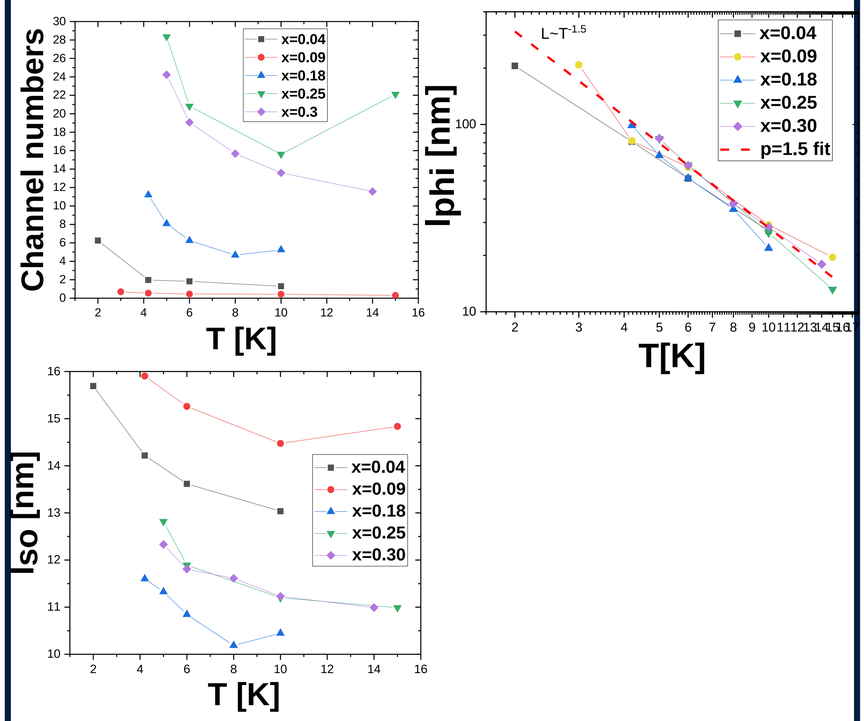


The extremely low Hall resistivity will give a single carrier density over 10^{24} cm^{-3}, which is even larger than the atomic density. Thus we believe that In actually acts as an electron donor. The low Hall slope is caused by the coexistence of electrons and holes that all have low mobility.

Weal localization & antilocalization



The coexistence of WAL and WL in SC samples may indicate that carriers from trivial spin-orbit split states may play a dominant role in the superconducting state. We can fit with full 2D HLN model[4], and the result is shown as figures below:



- The high channel numbers indicate that the superconducting fluctuations gives a large contribution below 10K, especially for samples with Tc=3.5K. In fact it can be well fitted when taking the fluctuation term into account. [5]
- In the region of T/Tc>4, the effect of WAL/WL is dominant. This is satisfied for x=0.04 and x=0.09 above 6K.

Conclusion

- We have grown uniform $Sn_{1-x}In_xTe$ film and measured its quantum coherent properties. The realization of these thin films enables new types of measurements to search for topological superconductors.
- WAL and WL coexist in SC SIT samples, indicating that electrons from trivial spin-orbit split states may play a dominant role in the superconducting state. More measurement need to be performed to find the origin of a possible spin-splitting, which is important to clarify the pairing mechanism for superconductivity.[6]

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