Low Temperature MBE Growth and Characterization of (111) $Sn_{1-x}Mn_xTe$ Thin Epitaxial Layers Obtained with Additional Te Flux

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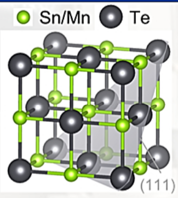
Introduction / Motivation

Topological crystalline insulators:

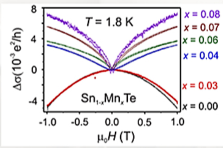


→ SnTe is an archetypical topological crystalline insulator

Material: Ternary $Sn_{1-x}Mn_xTe$:

→ Transition metal Mn-doped SnTe is a ferromagnet

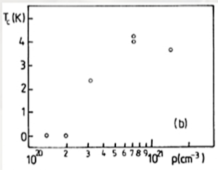
→ RKKY exchange interaction



R. Adhikari et al., PRB 100, 134422 (2019)

Motivation

→ Predicted coexistence of topological insulator, magnetism, and ferroelectricity. Combined with superconductor can be useful in superconductor spintronics.



T.Story, et al., PRL 56, 777 (1986)

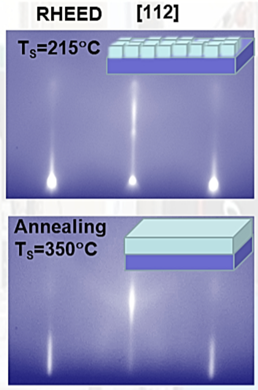
Goal of present work

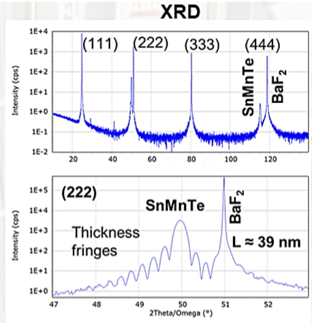
→ Growth of thin (111) $Sn_{1-x}Mn_xTe$ epilayrs by MBE. Study how Te excess affects structure and magnetic properties of the epilayers.

Two step growth

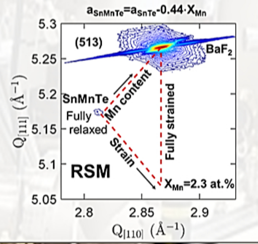
MBE growth

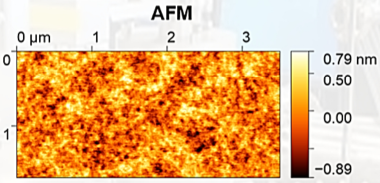
- Veeco GENxplor, SnTe, Mn, Te sources
- (111) BaF_2 substrates
- The initial layer with rough surface was formed by the rapid coalescence of *Volmer-Weber* islands to minimaze elastic strains
- Subsequent rapid annealing step at a higher temperature was used to minimise the film surface energy
- *in-situ* RHEED revealed evolution of pattern due to surface smoothering
- AFM confirms atomically smooth surface (RMS roughness ~ 275 pm)
- XRD, only (111) orientation, no strains detected from asymmetric RSM



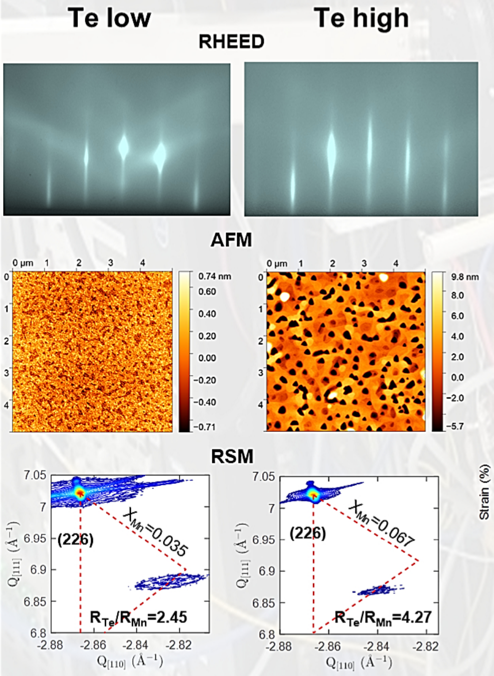


W. Li et al., J. Materiomics 1, 307 (2015)

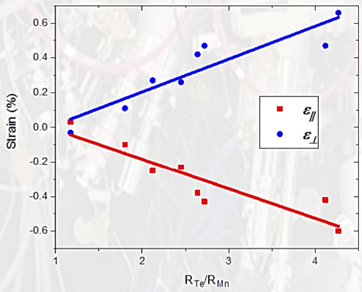




Te flux influence



- $Sn_{1-x}Mn_xTe$ films, x_{Mn} = 0 ÷ 0.07, 20-50 nm thickness
- RHEED and AFM revealed drastic increase of surface roughness when R_{Te}/R_{Mn} > 2
- From RSMs we found that excess of Te induces a tetragonal distortion of the crystal structure, in-plane compressive strains up to -0.6 % introduced
- Systematic reduction of lattice constant with Mn doping was also observed



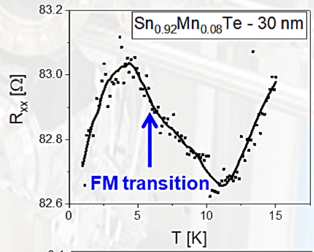
Lattice parameters, elastic strains of $Sn_{1-x}Mn_xTe$ epilayers determined from asymmetric RSMs and their carrier concentration as a function of Te/Mn evaporation rate ratio.

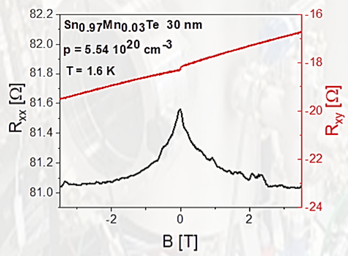
Sample	R_{Te}/R_{Mn}	X_{Mn}, %	d, Å	Q_x, $Å^{-1}$	Q_z, $Å^{-1}$	$a_{\parallel}$, Å	$a_{\perp}$, Å	a_0, Å	$\varepsilon_{\parallel}$, %	$\varepsilon_{\perp}$, %	p, cm^{-3}
G061122a	1.17	3.5	230	2.8159258	5.1761223	6.311	6.308	6.309	0.03	-0.03	1.2e+20
G091322A	1.8	4.5	500	2.821443	6.896322	6.299	6.312	6.305	-0.10	0.11	
G073022a	2.12	3.5	500	2.8234415	6.880176	6.294	6.327	6.310	-0.25	0.27	2.2e+20
G073122b	2.45	3.5	335	2.823216	6.881234	6.295	6.326	6.310	-0.23	0.26	5.8e+20
G080522a	2.64	3.7	200	2.827562	6.8710605	6.285	6.335	6.309	-0.38	0.42	5.5e+20
G080322b	2.72	3.4	300	2.828452	6.866116	6.283	6.340	6.310	-0.43	0.47	
G110422B	4.12	7.2	411	2.8359126	6.88461	6.267	6.323	6.293	-0.42	0.47	
G112322A	4.27	6.7	400	2.8397523	6.868955	6.258	6.337	6.296	-0.60	0.66	

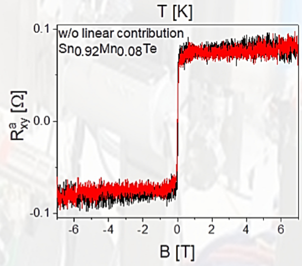
Transport Characterization

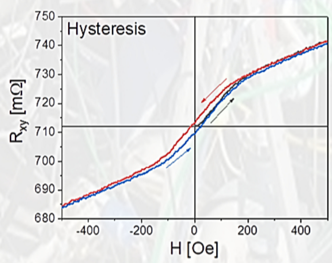
- Critical behavior $R_{xx}(T)$ at low temperatures, close to paramagnet – ferromagnet transition
- Addition of Te increases hole concentration and decreases mobility due to presence of disorder
- AHE, negative MR, WL and hysteresis are observed in Mn-doped samples as evidence of ferromagnetism
- All the samples demonstrate low coercivity of several Oe
- High field linear slope was subtracted from Hall curve to obtain AHE contribution

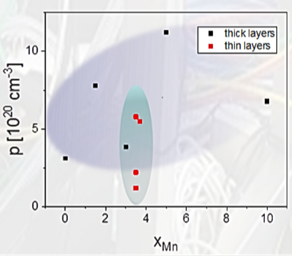
Silver paste was used for contacts











Summary of the results

- ✓ High quality thin epilayers of FM TCI $Sn_{1-x}Mn_xTe$ (x_{Mn} = 0 - 0.07) were successfully prepared on BaF_2 (111) substrates by MBE.
- ✓ The films with smooth surface of 20 -100 nm thickness , were grown by a two-step method involving initial low-temperature deposition followed by high-temperature annealing.
- ✓ This strain can be tuned by varying the Te content, which potentially might affect ferroelectric properties $Sn_{1-x}Mn_xTe$.
- ✓ Transport investigations revealed ferromagnetism in obtained samples.
- ✓ The obtained results pave the way for application this material in low temperature spintronic applications.

Acknowledgements

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