Molecular beam epitaxy growth of self-assembled $MnSb_2Te_4/Sb_2Te_3$ magnetic topological materials with very high Curie temperatures

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Abstract

When grown by molecular beam epitaxy (MBE), $MnSb_2Te_4$, a 3D magnetic topological material, self-assembles into multilayered van der Waals structures of Sb_2Te_3 quintuple layers (QLs) and $MnSb_2Te_4$ septuple layers (SLs) in which the QL to SL layer ratios depend on the Mn to Sb flux ratio used during growth, and other MBE growth parameters. Our group has shown that the full composition range of $(Sb_2Te_3)_{1-x}(MnSb_2Te_4)_x$, where the composition x varies between 0 and 1, can be grown by controlling the MBE growth parameters.[1] Furthermore, we also showed that the magnetic and electrical properties of the materials depend strongly on these compositions, yielding ferromagnetic materials with Curie temperatures (T_C) as high as 80K for 70-80% SL.[2] T_C values as high as 100K have recently been observed by reducing the growth rate of the materials.[3]

We will present our observations of the dependence of the structural, electrical, and magnetic properties of the $(Sb_2Te_3)_{1-x}(MnSb_2Te_4)_x$ materials on the MBE growth conditions to develop a plausible mechanism for their growth by MBE. Our results suggest that Mn incorporation in the Sb_2Te_3 topological insulator materials to form the $MnSb_2Te_4$ SL crystal structure requires the accumulation of excess Mn on the growing MBE surface. Once a threshold Mn level is reached the SL crystal can form. Prior to that, the Mn incorporates as an impurity of the QL Sb_2Te_3 structure. Excess Mn can also incorporate into the SLs. Our results show that Mn can substitute for Sb and/or Te in both the Sb_2Te_3 and the $MnSb_2Te_4$ units, modifying the magnetic and electrical properties of the resulting material in specific ways. Understanding of the detailed growth habits of these materials by MBE will enable the directed "on-demand" growth of magnetic TI structures with optimized properties.

[1]I. Levy et al, Crystal Growth & Design **22**, 3007−3015 (2022)
[2]I. Levi et al, www.researchsquare.com/article/rs-2381594/v1 (Under Review)
[3]C. Forrester et al, 2023 APS March Meeting, Las Vegas, NV March 6-10, 2023