Three types of structures obtained from the $Mn_{\alpha}Bi_{\beta}Sb_{\gamma}Te_{\delta}$ materials family.

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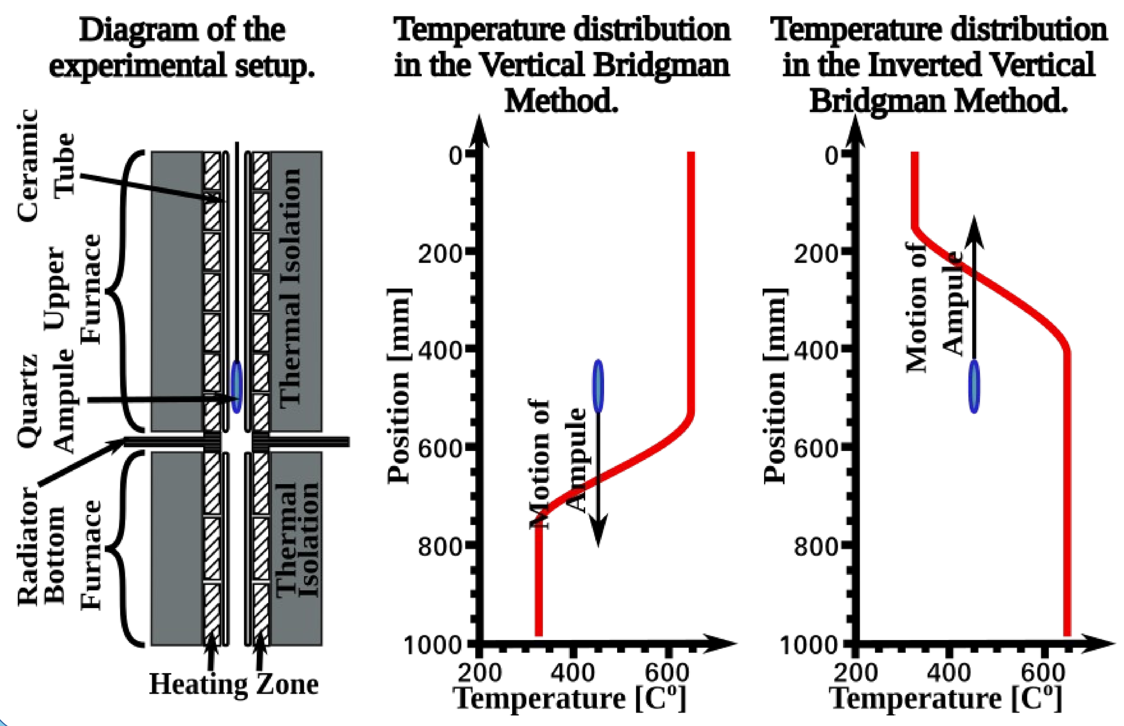
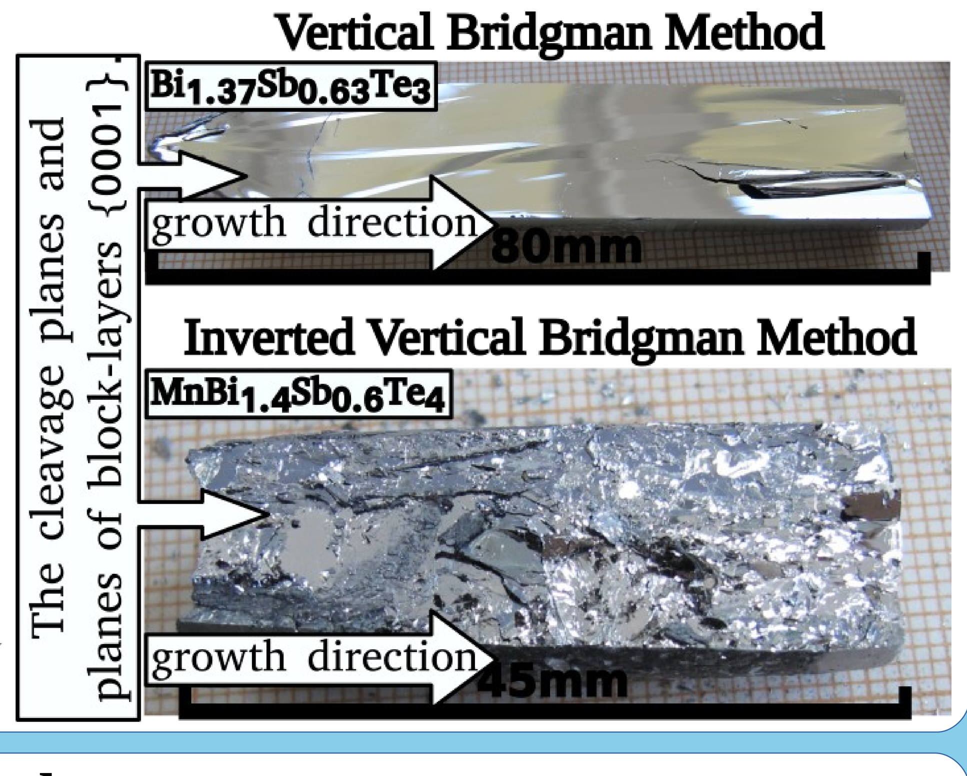
Introduction

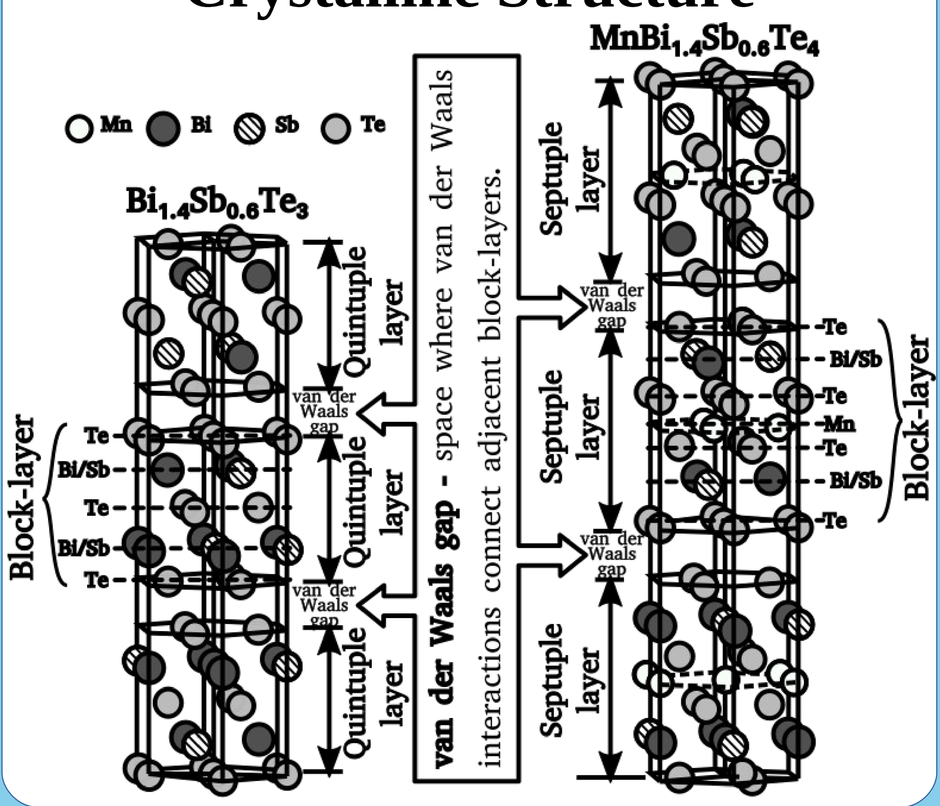
The chalcogenide semiconductors are materials with a specific crystal structure, built of sheets of multi-atomic layers connected to each other by van der Waals forces. $Mn_{\alpha}Bi_{\beta}Sb_{\gamma}Te_{\delta}$ belongs to this type of family, which structure and properties can be modified by appropriate selection of growth parameters. In this work we used the Inverted Vertical Bridgman growth method to obtain $Mn_{\alpha}Bi_{\beta}Sb_{\gamma}Te_{\delta}$. As a result of our experiments, we have obtained three types of crystal structures: (I) a phase consisting of septuple layers where each layers containing a centerpiece Mn mono-atomic layer, (II) strong doping by Mn quintuple layers and (III) the multi-phase crystal structure where manganese-rich septuple layers can be separated by a quite regular number of quintuple layers.

Crystals growth methods

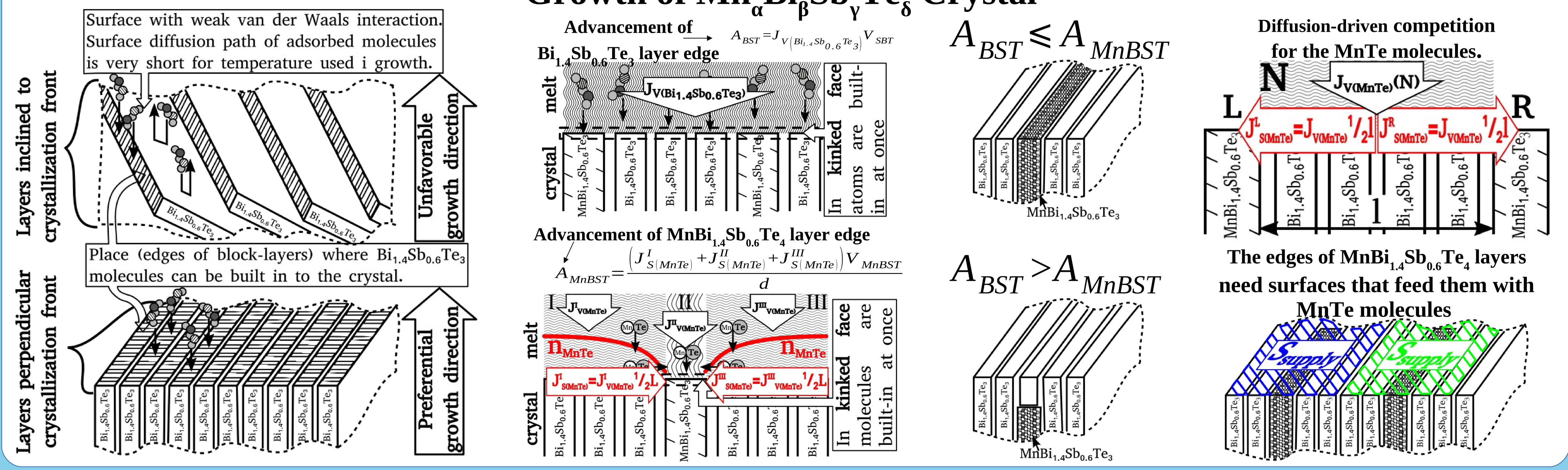




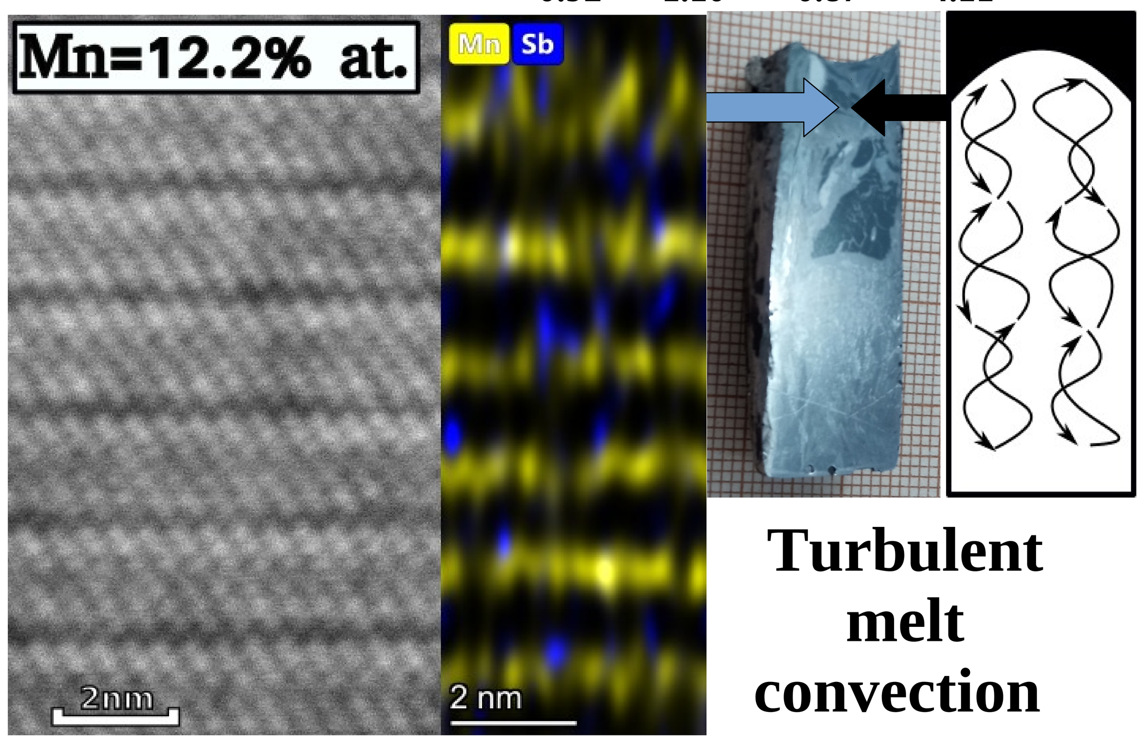
Crystalline Structure



Growth of $Mn_{\alpha}Bi_{\beta}Sb_{\gamma}Te_{\delta}$ Crystal

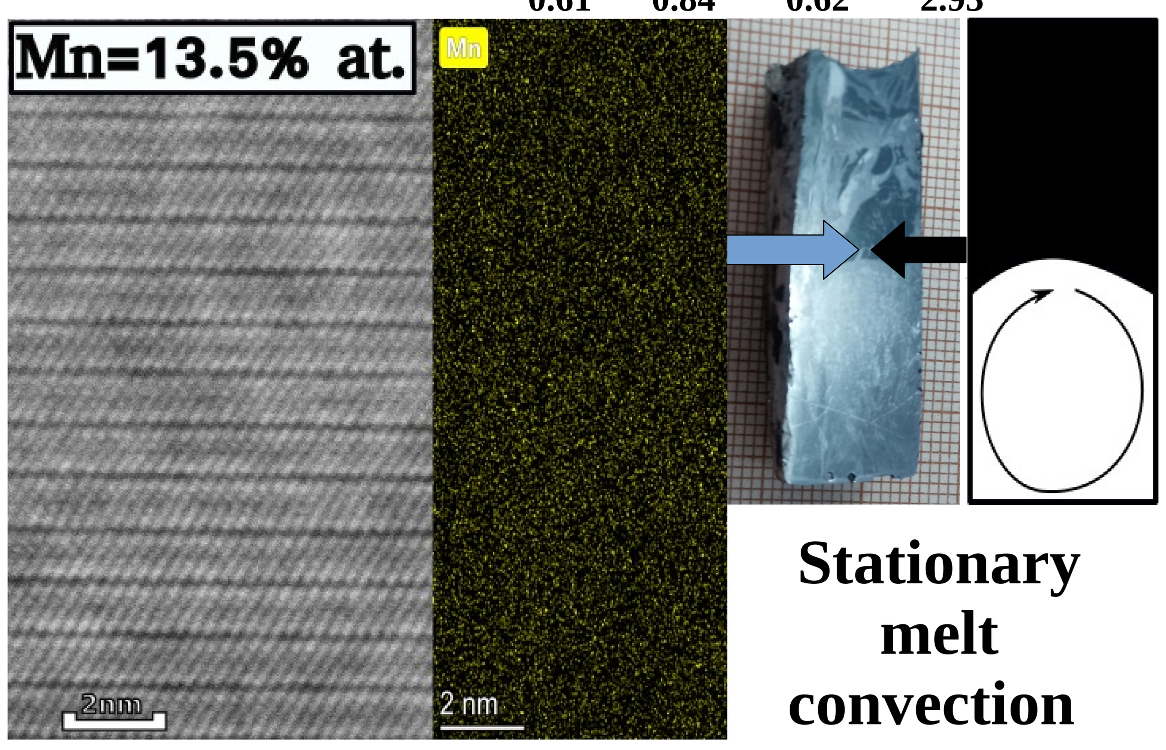


Structure of $Mn_{0.92}Bi_{1.10}Sb_{0.87}Te_{4.11}$



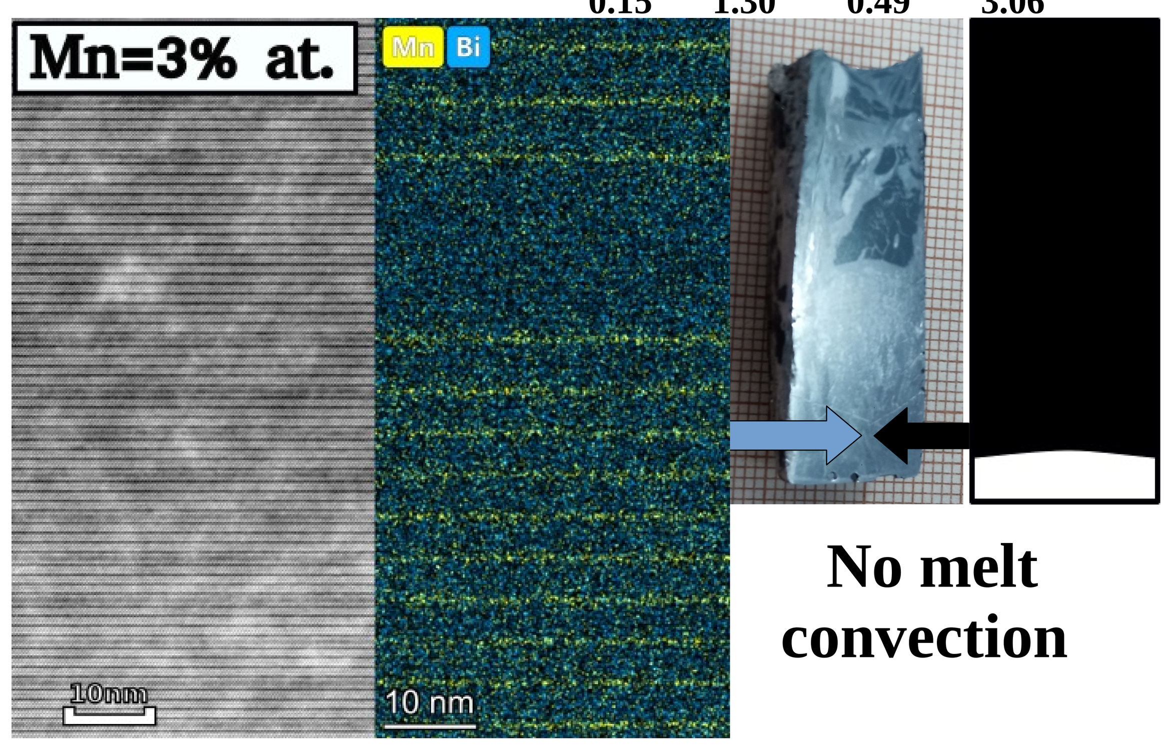
The turbulent melt convection provides a large flux of MnTe molecules from the melt which enables growth of septuple layers.

Structure of $Mn_{0.61}Bi_{0.84}Sb_{0.62}Te_{2.93}$



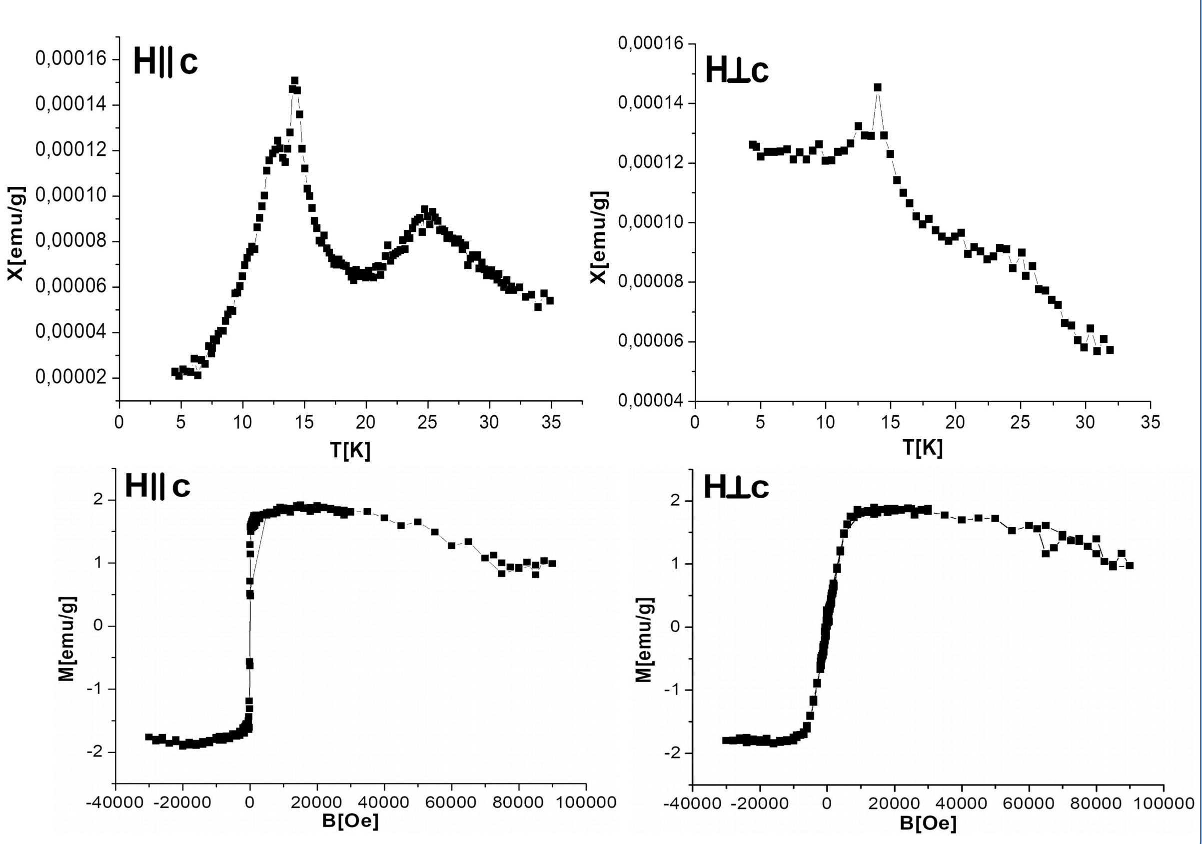
The stationary melt convection does not provide a sufficient flux of molecules for growth septuple layers. High concentration of manganese causes strong doping of the quintuple layers.

Structure of $Mn_{0.15}Bi_{1.30}Sb_{0.49}Te_{3.06}$

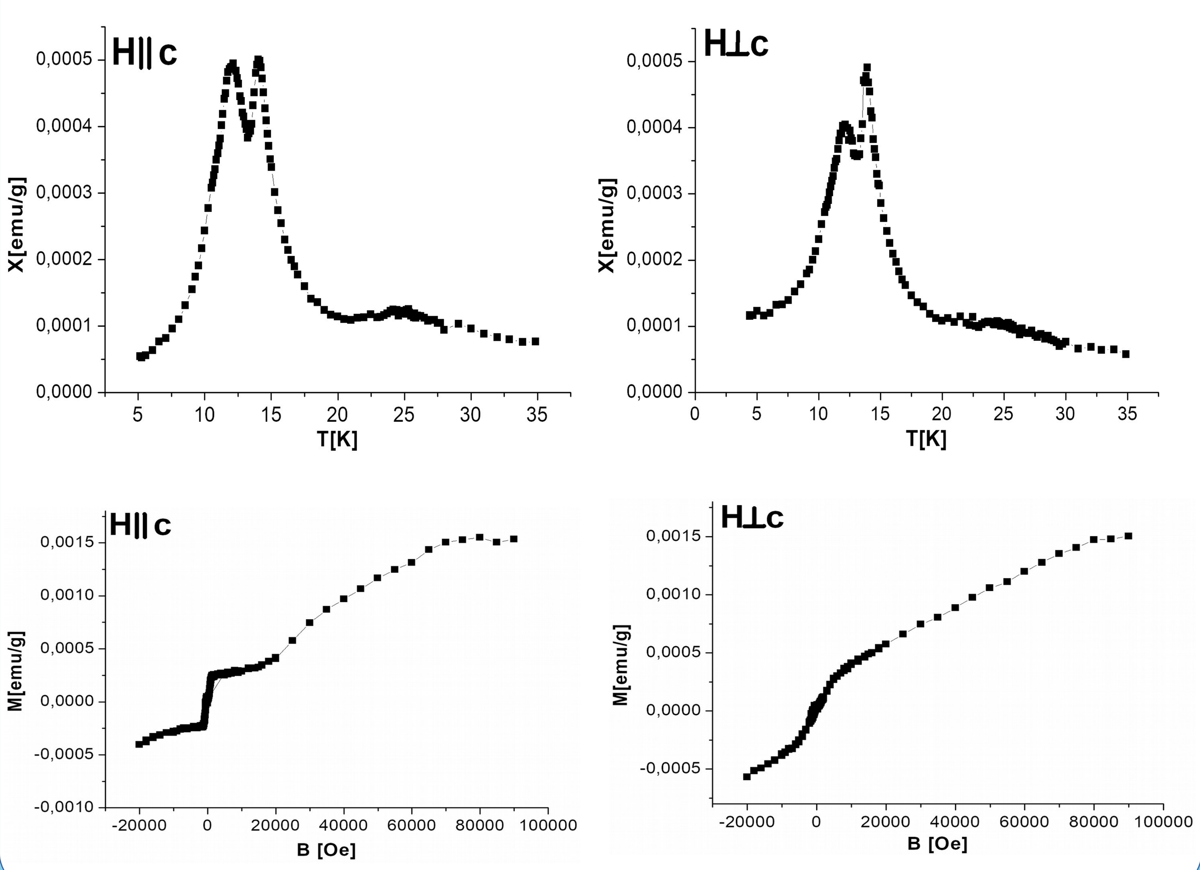


In the absence of convection in the melt and the low concentration of manganese the surface phenomena begin to dominate the growth of septuple layers and diffusion-driven competition is started.

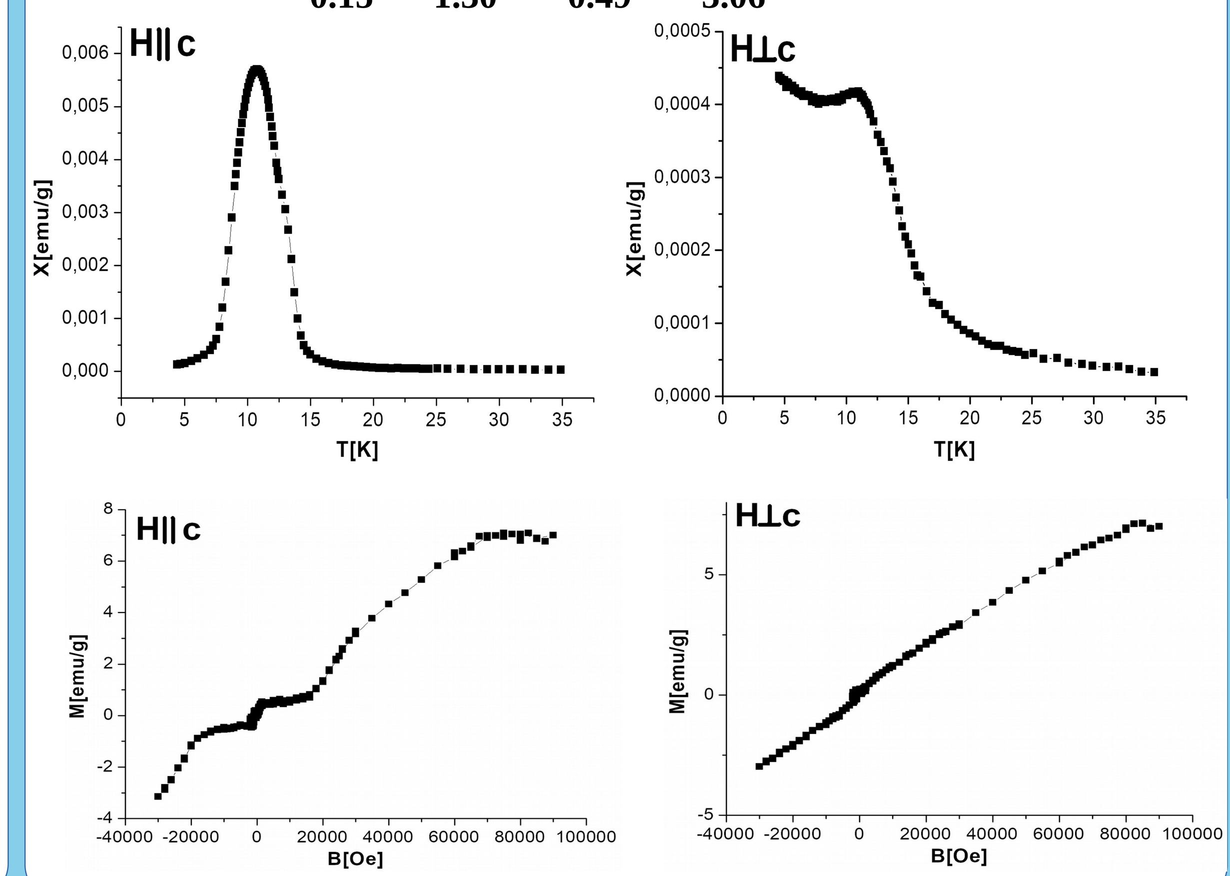
Magnetic properties of the $Mn_{0.92}Bi_{1.10}Sb_{0.87}Te_{4.11}$ structure



Magnetic properties of the $Mn_{0.61}Bi_{0.84}Sb_{0.62}Te_{2.93}$ structure



Magnetic properties of the $Mn_{0.15}Bi_{1.30}Sb_{0.49}Te_{3.06}$ structure



Conclusion

- The application of Inverted Vertical Bridgman Method causes the appearance of areas with different ordering in crystal.
- The pure septuple layers phase can be obtained by disruption of the diffusion-driven competition by intensive mixing of the liquid components of the crystal just above the crystallization front (turbulent melt conwection).
- In the stationary melt convection there flux of manganese telluride molecules from liquid phase is insufficient to grow the septuple layers which results in the growth of highly doped quintuple layers.
- The relationship between the distances between the septuple layers and the total concentration of Mn in the crystal originates from the mechanism of supply of MnTe molecules to the edge of the growing layer by surface diffusion. For the low concentration of Mn in the melt, the supply area for the growing septuple layer must be bigger (longer distances between layers) and for the higher concentration of Mn in the melt, the smaller supply area is sufficient for septuple layer growth (shorter distances).
- Three phase transitions are visible in magnetic susceptibility measurements for crystals with high manganese content. Transition in the temperature range from 21 to 32 K is probably related to antiferromagnetic order of neighbouring septuplet layers. The two phase transitions near 11 K can be related to the appearance of the ferromagnetic order of the septuplet layers and individual manganese ions in a crystal lattice. In crystals with three percent manganese we observe transitions only close to 11 K.

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