Terahertz electronics (TE) can be applied to high-speed data interconnects, bioimaging, and communication systems. However, TE is not used in consumer electronics due to technical challenges in generating and detecting THz signals. Antiferromagnets can generate and respond to THz signals and, in principle, can be used in microelectronic THz devices. In this project, magnetic (Mn,Bi)₂Te₃ thin films on single crystal Al₂O₃ substrates were grown using molecular beam epitaxy to synthesize antiferromagnetic MnBi₂Te₃, a topological antiferromagnet potentially useful in TE devices. The results indicate that further optimization of the growth conditions can lead to the successful synthesis of this material.

Objective
Grow MnBi₂Te₃ (MBT) thin films using molecular beam epitaxy (MBE) to make a device that can detect and generate THz signals.

Background
Terahertz electronics (TE) Advantages:
• Higher Frequency
• Reduced Interference
TE can be used in
• High-speed data interconnects
• Bioimaging
The device needs:
• Intrinsic magnetic topological insulator (MBT)
• Applying a voltage to the system creates an electric field in the material that drives the motion of electrons
• The spin-orbit coupling present in the Pt couples the motion of the electrons to their spin, which creates a spin current [2].
• The spin current is then injected into a magnetic topological insulator (MTI) in contact with the Pt
• The spin current interacts with the magnetization of the MTI, resulting in the emission of THz radiation
• THz radiation induces a transverse spin current in the Pt film via the inverse spin Hall effect (ISHE)
• The ISHE arises from the spin-orbit coupling of the electrons in the Pt film, and it can convert the spin current into a charge current that can be detected

Abstract
Terahertz electronics (TE) can be applied to high-speed data interconnects, bioimaging, and communication systems. However, TE is not used in consumer electronics due to technical challenges in generating and detecting THz signals. Antiferromagnets can generate and respond to THz signals and, in principle, can be used in microelectronic THz devices. In this project, magnetic (Mn,Bi)₂Te₃ thin films on single crystal Al₂O₃ substrates were grown using molecular beam epitaxy to synthesize antiferromagnetic MnBi₂Te₃, a topological antiferromagnet potentially useful in TE devices. The results indicate that further optimization of the growth conditions can lead to the successful synthesis of this material.

Methods
To grow a thin film we:
• Anneal the Al₂O₃ substrate
• Look at the reflection of high-energy electron diffraction (RHEED)
• Deposited material on the substrate using MBE
• Look at the RHEED for qualitative structural characterization
• Analyzed the structure quantitatively using X-ray diffraction
MBT is a Van der Waals layered material member. It is a derivative of the topological insulator Bi₂Te₃ by inserting an Mn-Te layer into the middle of its Te-Bi-Te-Bi-Te quintuple layer [1].

Results: MBT 230210
• The substrate was annealed for 24 hours at 400 °C
• Deposited 3 QL of MnBi at 200 °C
• Deposited 12 SL of MnBi at 275 °C
• Quenched to 275 °C
• Separated to MnTe and BiTe

Conclusions
• We established that the growth of MBT is sensitive to temperature
• 230120 and 230201 were ferromagnetic, but 230210 had a similar structure to BiMn₃Te₄, shown in the figure to the right, which is antiferromagnetic.
• Next steps are to finalize the steps to grow MBT at specific temperatures and then deposit Pt on top to start testing the device.

References

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