Investigation of the Structure and Properties of $NbFeTe_2$ – A Layered Precursor to 2D Materials

Jaime A. Garcia-Oliver, Govind Sasi Kumar, Michael Shatruk

Department of Chemistry & Biochemistry, Florida State University, Tallahassee, Florida 32306

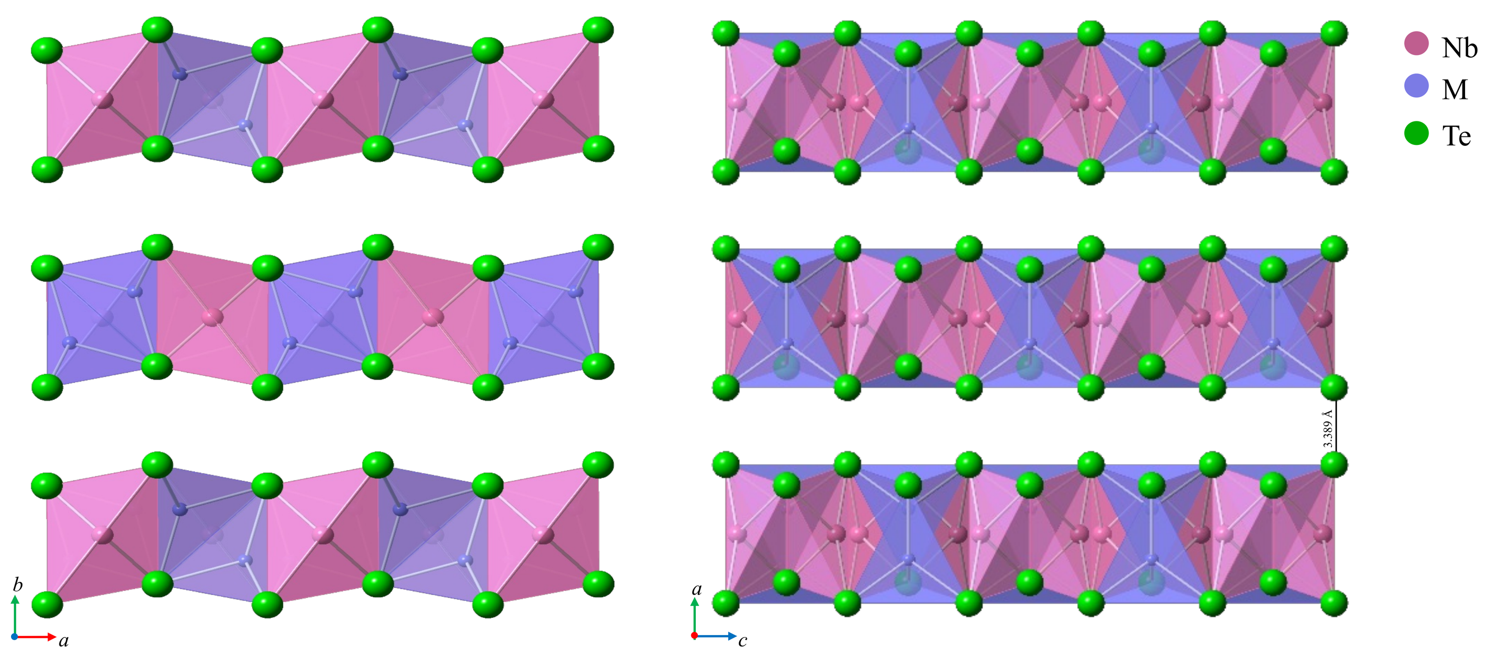
Abstract

Magnetic 2D materials have strong potential for applications in next-generation spintronics and integrated circuits. Layered chalcogenides of niobium and tantalum have been well studied due to their exotic applications in superconductivity, anisotropic electrical conductivity, charge density waves, etc. In the present work, we focus on the ternary tellurides of niobium and tantalum with 3d transition metals. We investigate different aspects of these compounds, including their structure, magnetism, intercalation chemistry, and the influence of dimensionality on their electronic and magnetic properties. In this contribution, I demonstrate the synthesis of NbCoTe2, NbFeTe2, and $NbCo_{0.6}Fe_{0.4}Te2$, their crystal structures, and physical properties, as well as the influence of substitutions of other transition metals on the magnetic behavior of these materials.

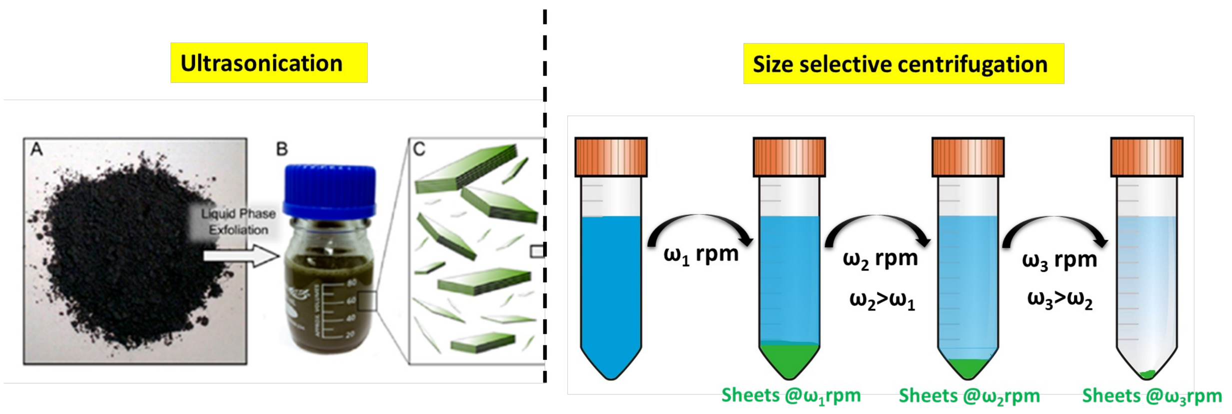
Introduction

2D materials possess a sheet-like structure that is only a few atoms thick. Such a structure causes unusual optical, electronic, and magnetic properties,[1,2] due to the strong in-plane confinement of electrons. The ultrathin layers also offer enhanced flexibility and optical transparency which would be beneficial for device fabrication purposes. Currently, 2D materials are widely investigated for applications in catalysis,[3] spintronics, energy conversion, etc.[4,5]
Although numerous 2D materials have been predicted theoretically, for many of them experimental validation and property characterization are still lacking. Most of the predictions do not account for experimental conditions such as synthetic feasibility and air and moisture sensitivity. Our research aims to investigate new layered materials that can be exfoliated to ultrathin sheets.

$NbMTe_2$ (M = Fe, Co)



Cost-effective, large-scale synthesis of 2D materials is crucial for their future applications. Liquid-phase exfoliation (LPE) is an important technique that has been advanced recently to synthesize large quantities of 2D nanosheets.[6] This method uses ultra-sonication to break bulk materials into ultrathin layers. The selection of solvent, the duration and temperature of sonication, and other parameters need to be optimized to achieve efficient liquid-phase exfoliation.[7]

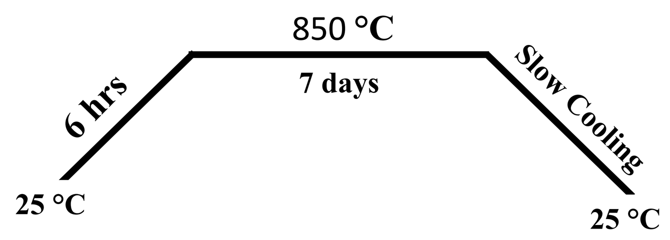


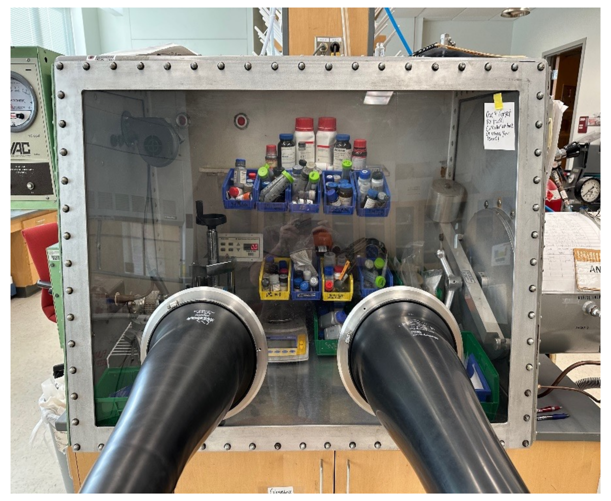
Synthesis & Crystal Growth

Synthesis

Element	Nb	Fe	Cu	Te
Molar Ratio	2	1	1	5

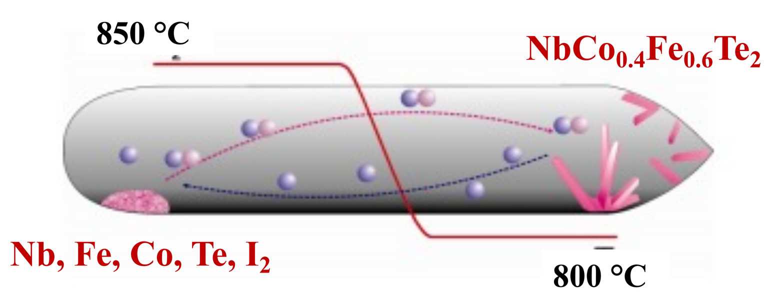
Heating Profile



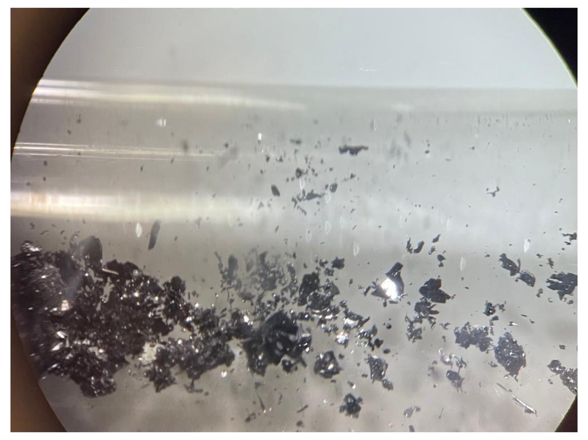


Crystal Growth

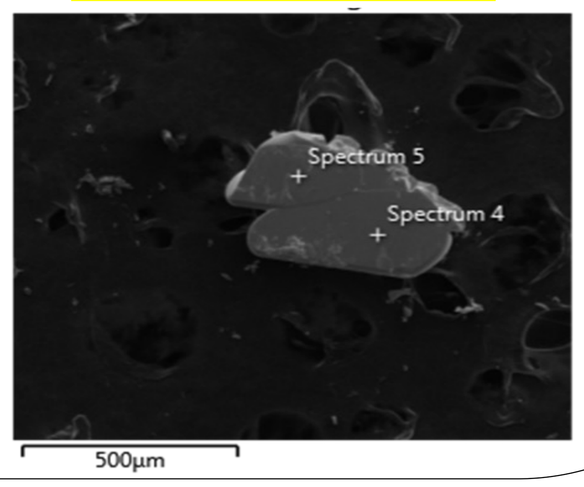
Chemical vapor transport (CVT) with iodine as a transport agent is used to grow crystals of $NbMTe_2$



Optical Microscopy

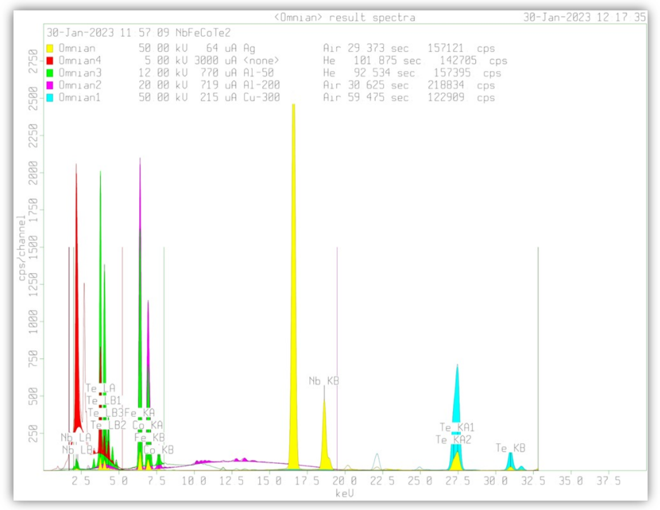


Electron Microscopy



X-Ray Analysis

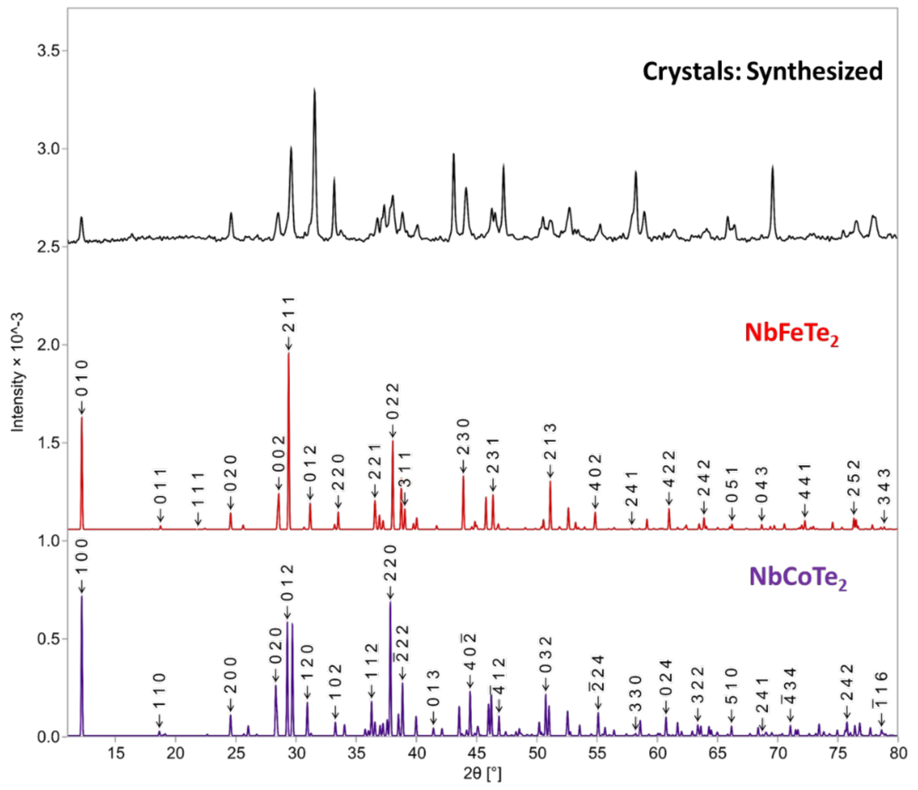
X-Ray Fluorescence Spectroscopy (XRF)



Element	Atomic Content
Niobium	0.8
Iron	0.6
Cobalt	0.4
Tellurium	2

The elemental composition suggests minor deficiency of Nb in the obtained material

Powder X-Ray Diffraction (PXRD)

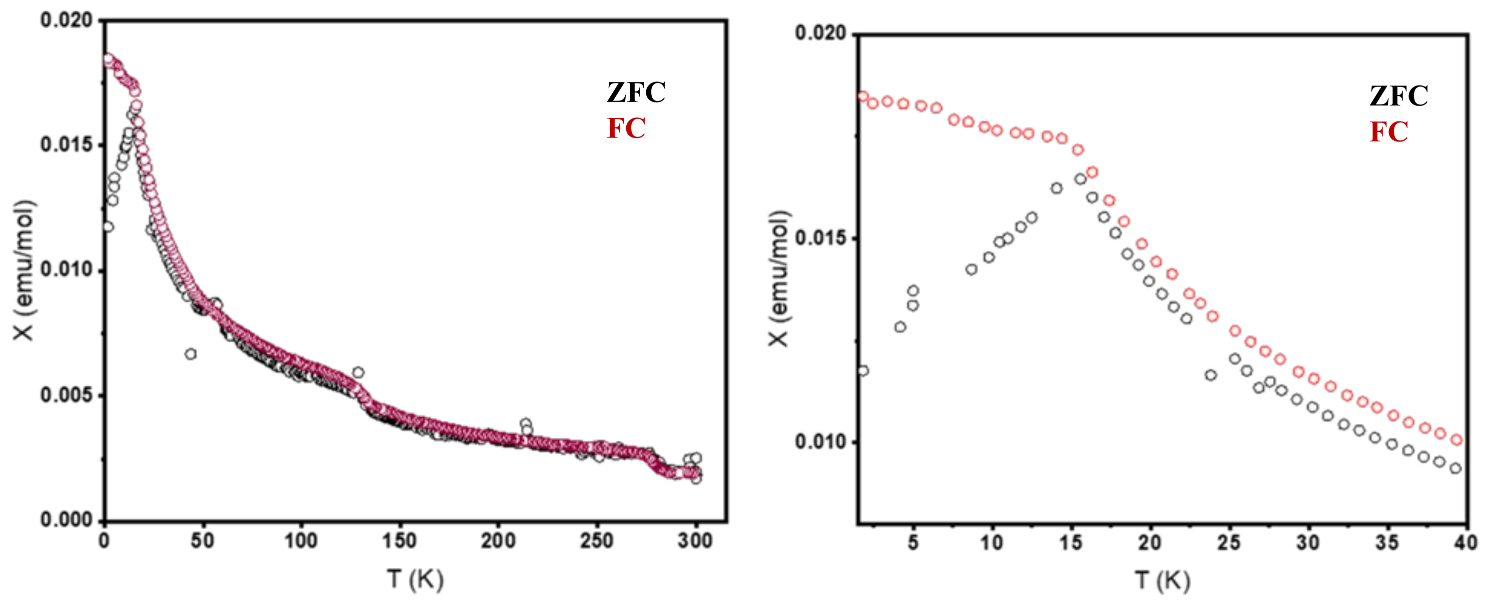


The experimental PXRD pattern match well those calculated from the crystal structures of $NbFeTe_2$ and $NbCoTe_2$

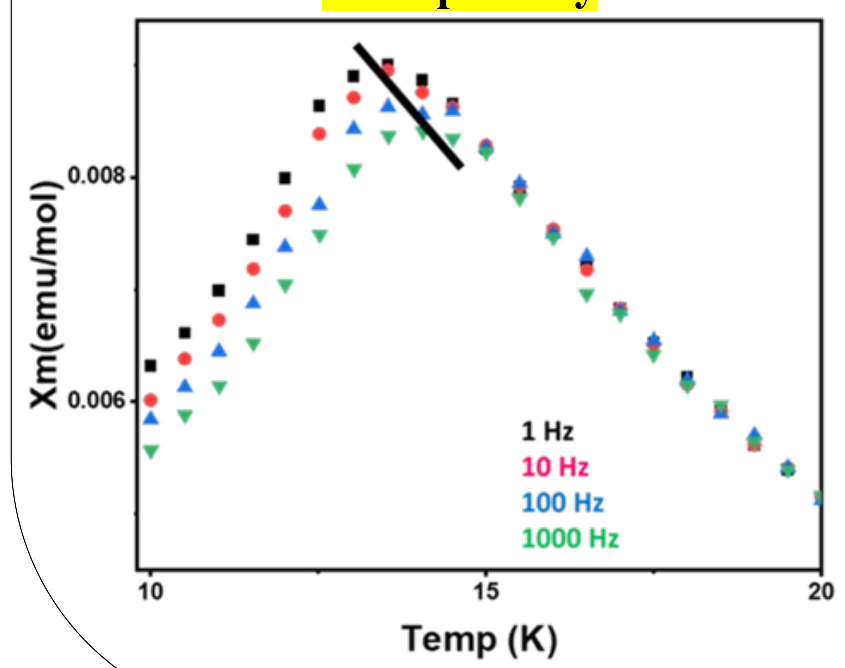
Magnetic Properties

The magnetic properties were studied with a SQUID magnetometer. The DC magnetic susceptibility was measured in zero-field-cooled (ZFC) and field-cooled (FC) regimes, to probe for magnetic ordering.

DC Magnetic Susceptibility (ZFC & FC)



AC Magnetic Susceptibility



Both DC and AC magnetic susceptibility studies reveal *a spin glass transition at 14 K.* In the spin glass state, magnetic moments freeze in random orientations, resulting in a highly metastable, irreversible state. Above 14 K, the material behaves as a paramagnet, with disordered and fluctuating magnetic moments.

Acknowledgments & References

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