Investigation of Magnetic Properties of Fe-Intercalated VTe_2

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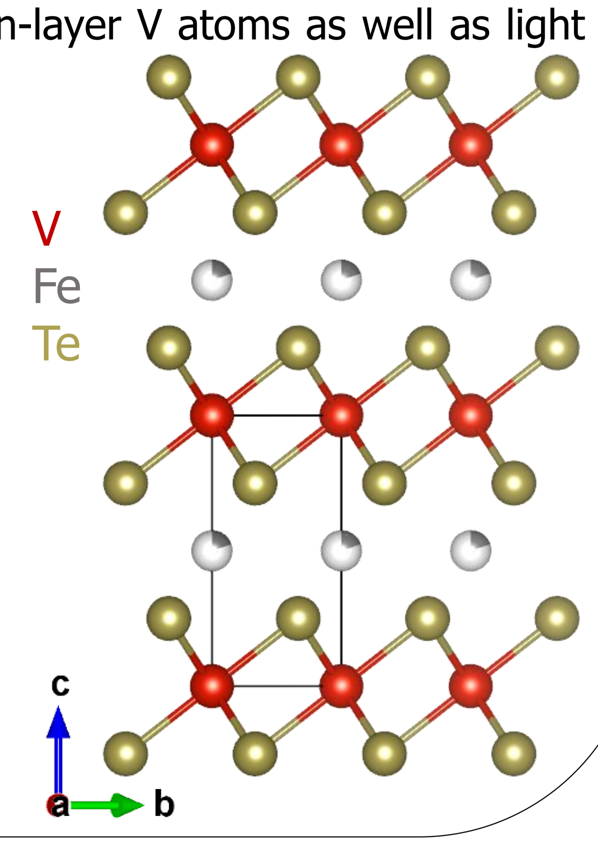
Abstract

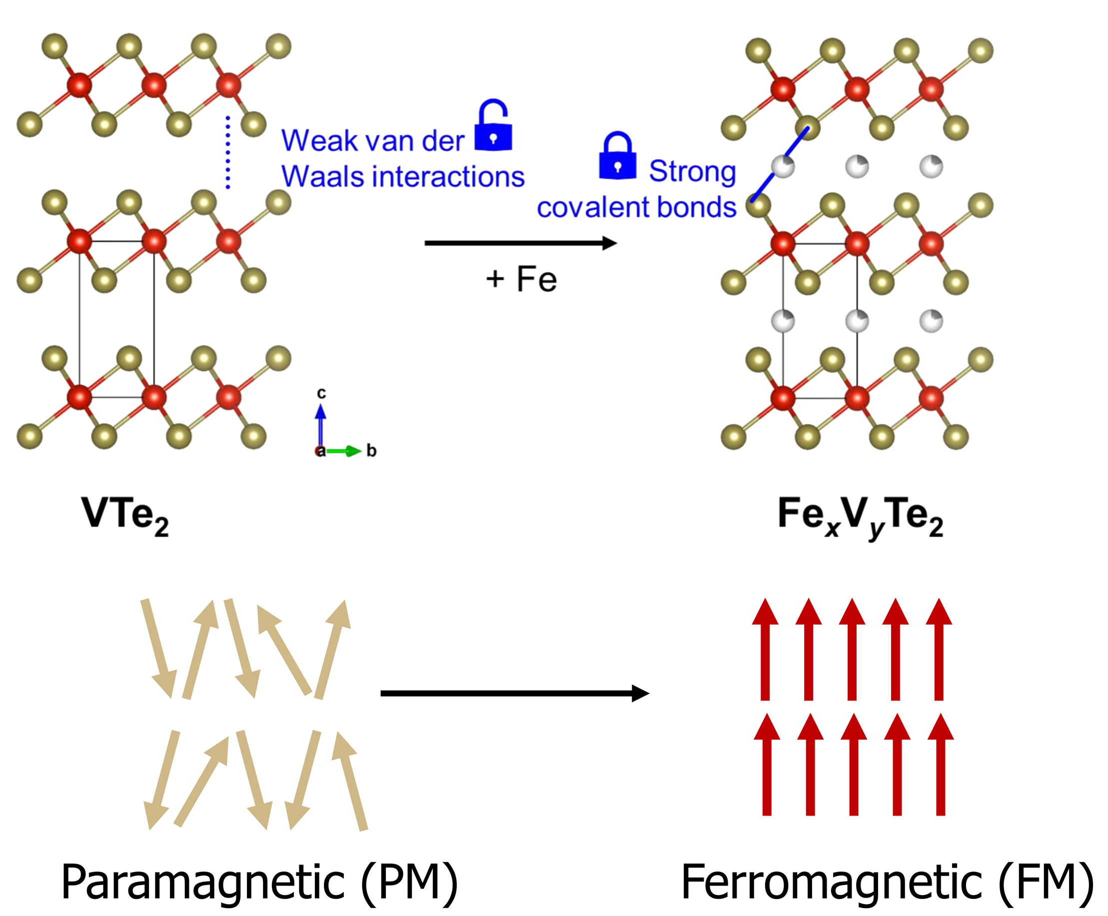
Layered two-dimensional materials, such as transition metal dichalcogenides (TMDs), express magnetic and electronic properties that could make them useful in a variety of electronic devices, such as MRIs or photodetectors. However, metallic TMD's have limitations to real world applications, namely structural instability under ambient conditions. The Shatruk lab has previously demonstrated that light transition metal intercalation can stabilize VTe_2 and promote ferromagnetic (FM) ordering. Intercalation studies using Cr reveal complex structures with some Cr substitution of in-layer V atoms as well as light intercalation within the van der Waals gaps.

In this research, we investigate the intercalation of Fe into the VTe_2 to produce new, air-stable crystalline compositions of $Fe_{0.3}V_{0.6}Te_2$, $Fe_{0.4}V_{0.7}Te_2$, $Fe_{0.5}V_{0.5}Te_2$, and $Fe_{0.5}V_{1.2}Te_2$. Here we present the elemental and structural characterization of the compounds. Our results have revealed that Fe, like Cr, undergoes a complex combination of substitution and intercalation which ultimately stabilizes VTe_2, yielding a more thermodynamically stable material which is less air-sensitive and may exhibit ferromagnetic ordering.

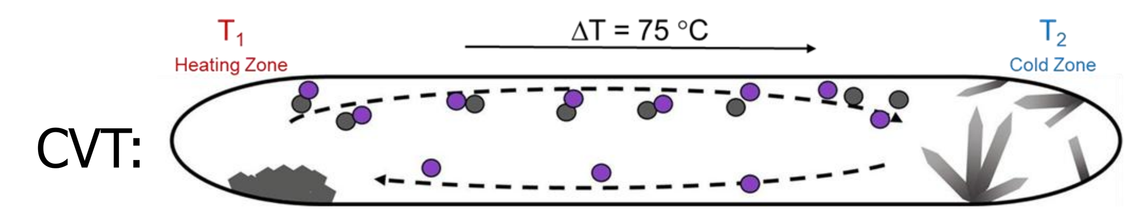


Introduction

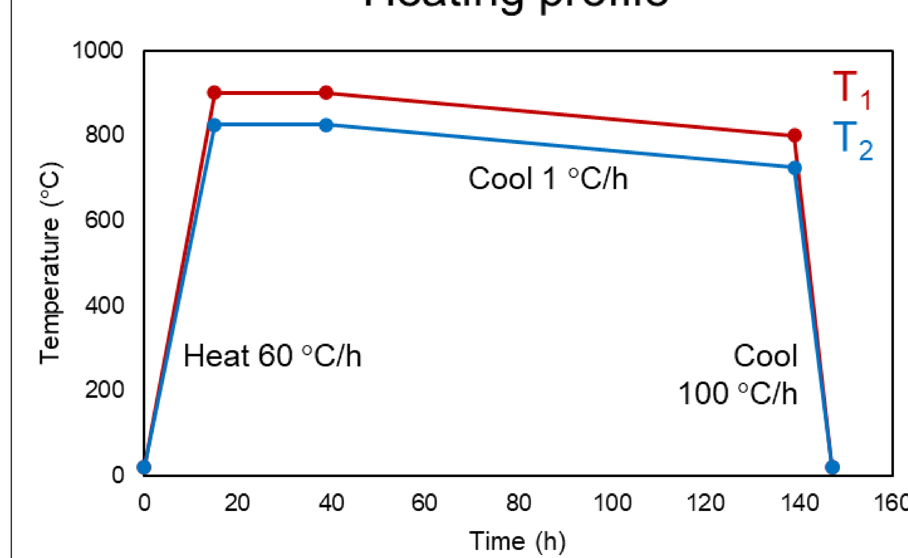
Transition metal dichalcogenides (TMDs) are inorganic materials made of two-dimensional (2D) MX_2 layers. Each layer contains a transition metal atom between two chalcogenide atoms, which are S, Se, or Te and are held together by weak van der Waals forces. Intercalating transition metals into the van der Waals gaps of TMD's such as VTe_2 has been shown to alter bonding interactions within the lattice such that structural stability and magnetic order are promoted. These properties allow for the use of these materials in development of next-generation electronic devices.



Synthesis & Elemental Analysis

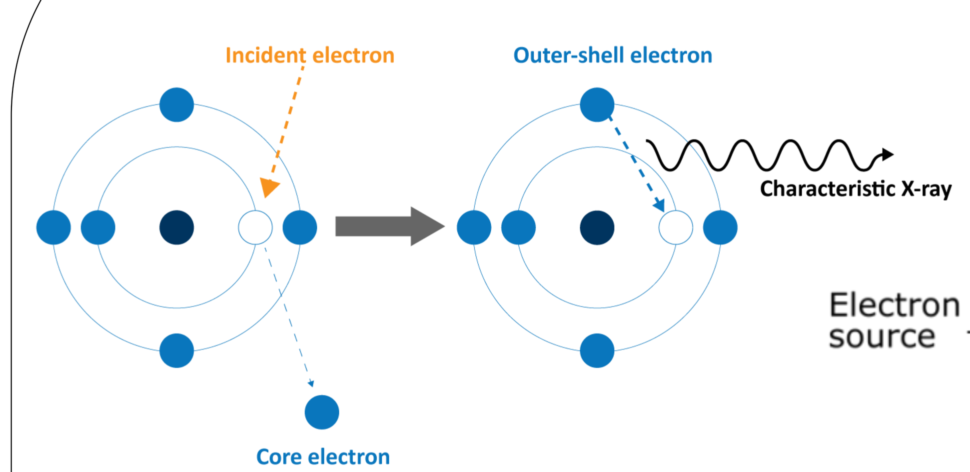


We synthesized crystals of $Fe_xV_yTe_2$ using the chemical vapor transport method (CVT). A stoichiometric 1:2 molar ratio of V:Te was combined with half the desired molar amount of Fe (to avoid excess) under Ar atmosphere and sealed under vacuum with 50mg of I_2 to act as the carrier agent.

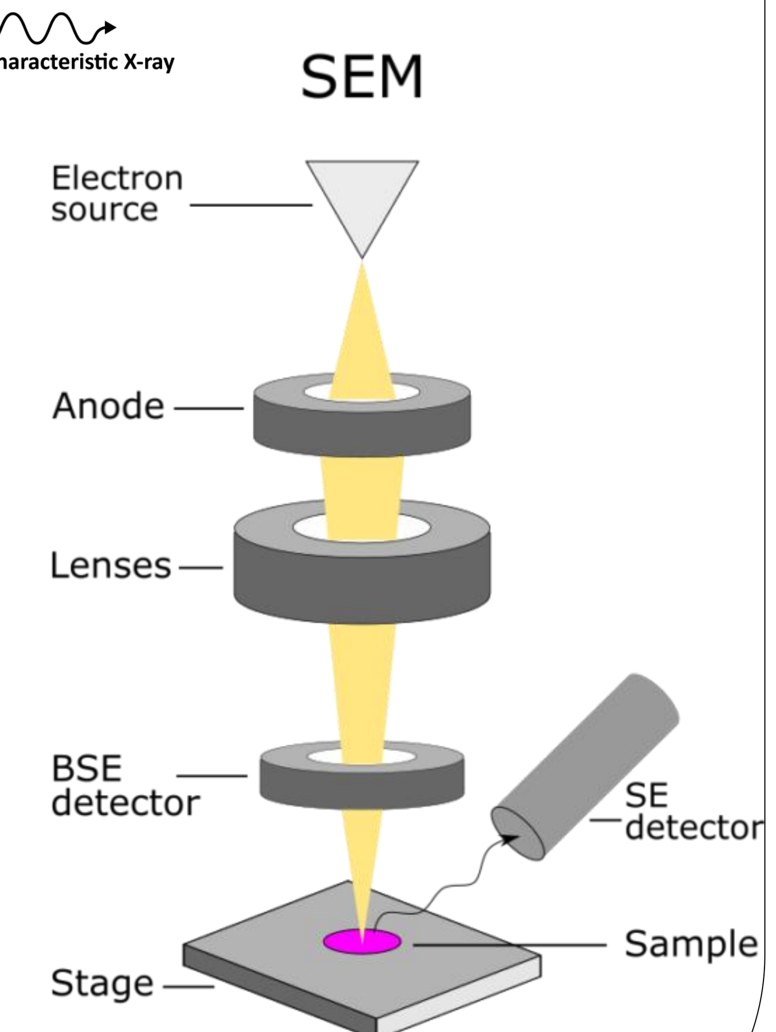


Samples were heated in a horizontal furnace under a temperature gradient of 75 °C to allow the powders to react and be carried to the cold end of the tube where the products were deposited. The furnace was cooled slowly to allow the crystals to grow. All four samples formed crystals at the cold end, but some residual powder was observed in the tube.

Elemental Analysis - Methods

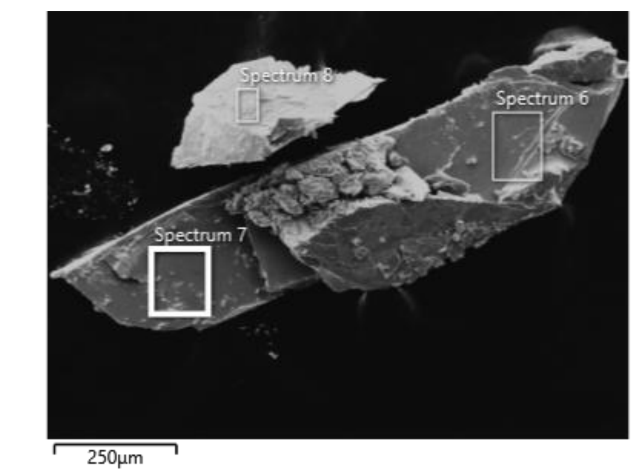


Energy Dispersive X-ray Spectroscopy (EDS) analyzes elemental composition by detecting characteristic X-rays emitted when a high-energy electron beam excites atoms in the sample. The emitted X-ray energies are unique to each element, allowing for identification and quantification, making EDS useful in materials science, metallurgy, and contamination analysis.



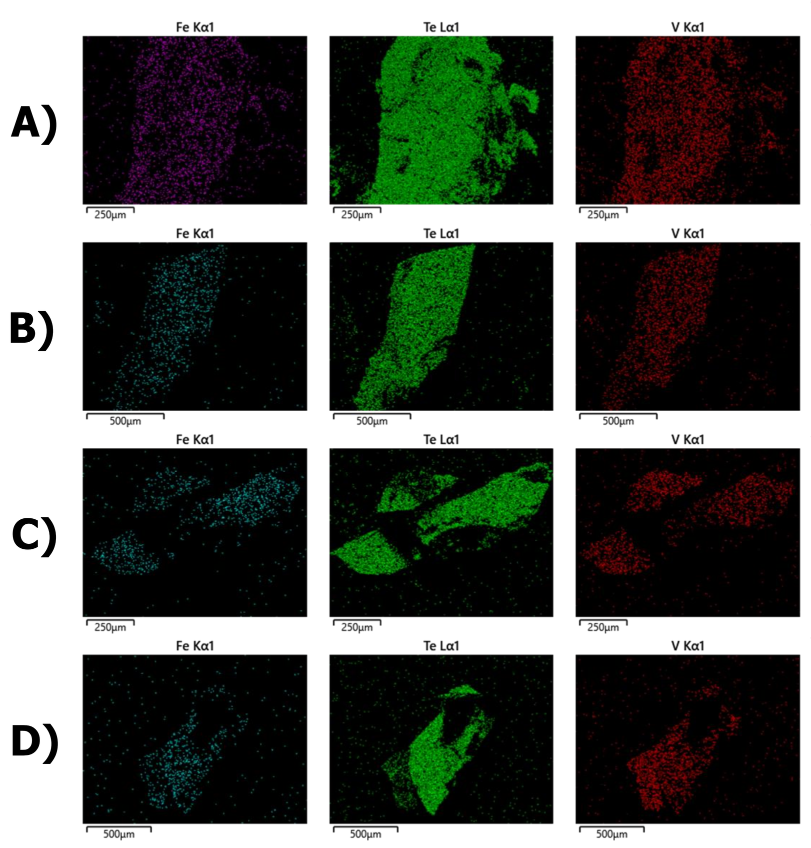
Elemental Analysis - Results

We determined the elemental composition of the samples using a scanning electron microscope (SEM-EDX) equipped with an elemental dispersive X-ray detector. These measurements reveal an interesting range of compositions.



If Fe intercalates between the van der Waals gaps of VTe_2, then the products should have the composition Fe_xVTe_2. However, the molar ratio of V is greater than 1.0 in samples A, B, and C. This suggests the Fe is substituting for V first, and only the excess Fe intercalates between layers.

Elemental mapping shows even distribution of Fe throughout the crystals.



	Atomic % Fe	Atomic % V	Atomic % Te	Composition
A)	10.3	20.7	69.0	$Fe_{0.3}V_{0.6}Te_2$
B)	12.9	22.6	64.5	$Fe_{0.4}V_{0.7}Te_2$
C)	16.6	16.7	66.7	$Fe_{0.5}V_{0.5}Te_2$
D)	13.5	32.4	54.1	$Fe_{0.5}V_{1.2}Te_2$

Our findings here show that inclusion of Fe into VTe_2 in various concentrations is favorable, such that the resulting crystals are air-stable. The next steps of this project include crystal structure determination by single-crystal X-ray diffraction, and magnetic property measurements.

Acknowledgments & References

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