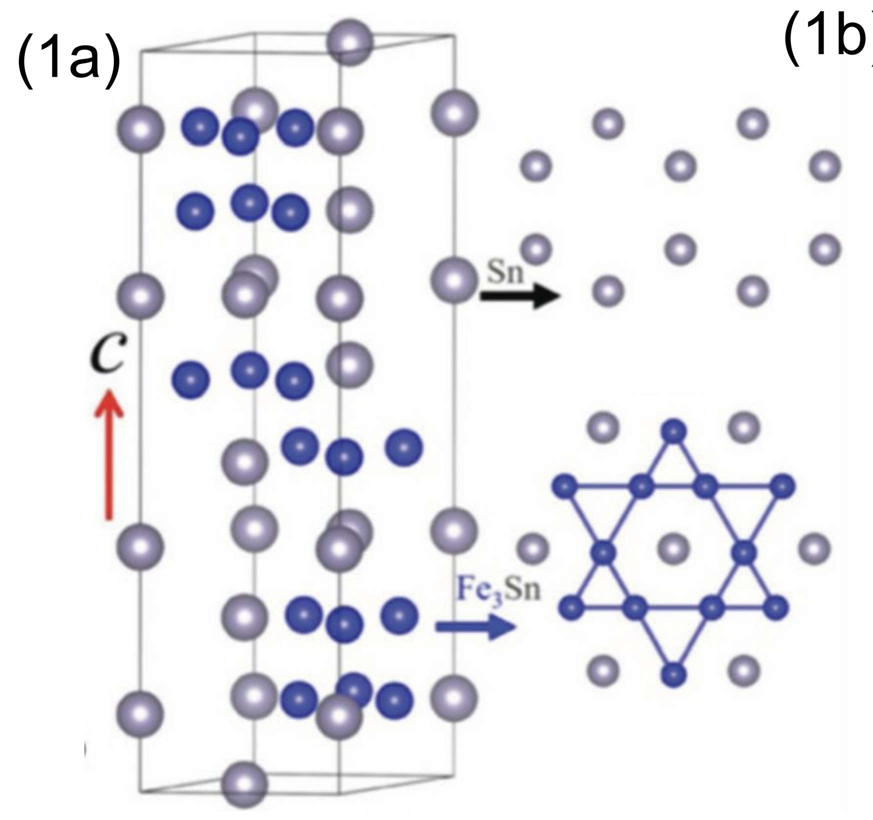
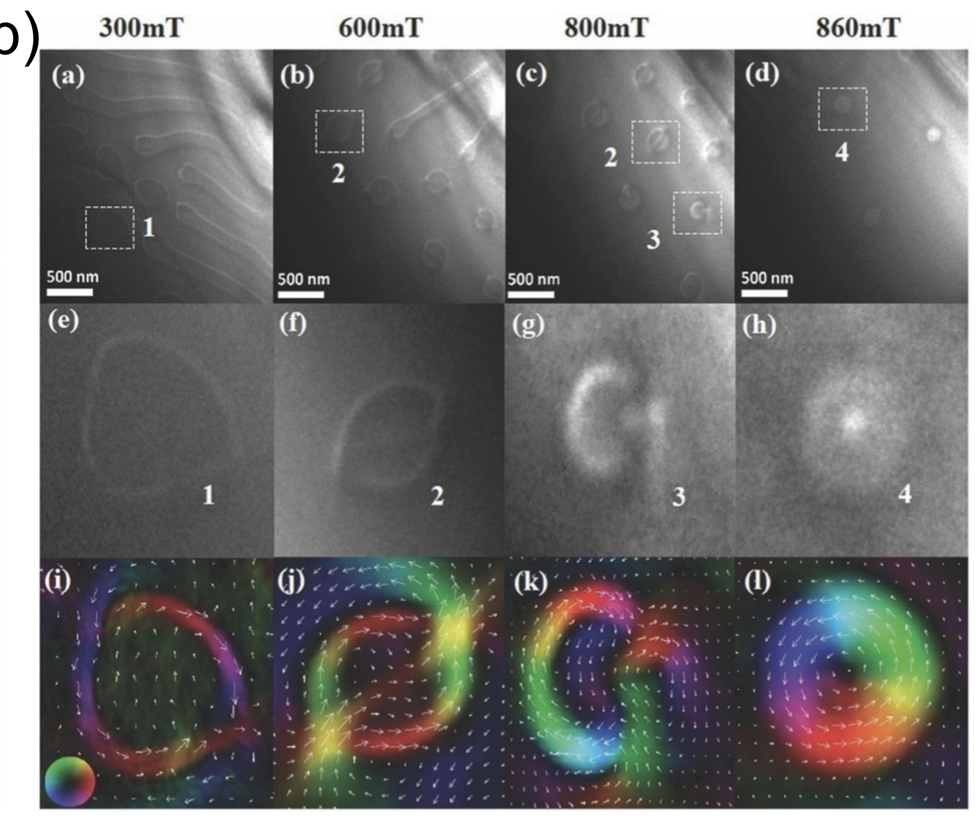
Synthesis and Characterization of Dirac Semimetal Fe_3Sn_2

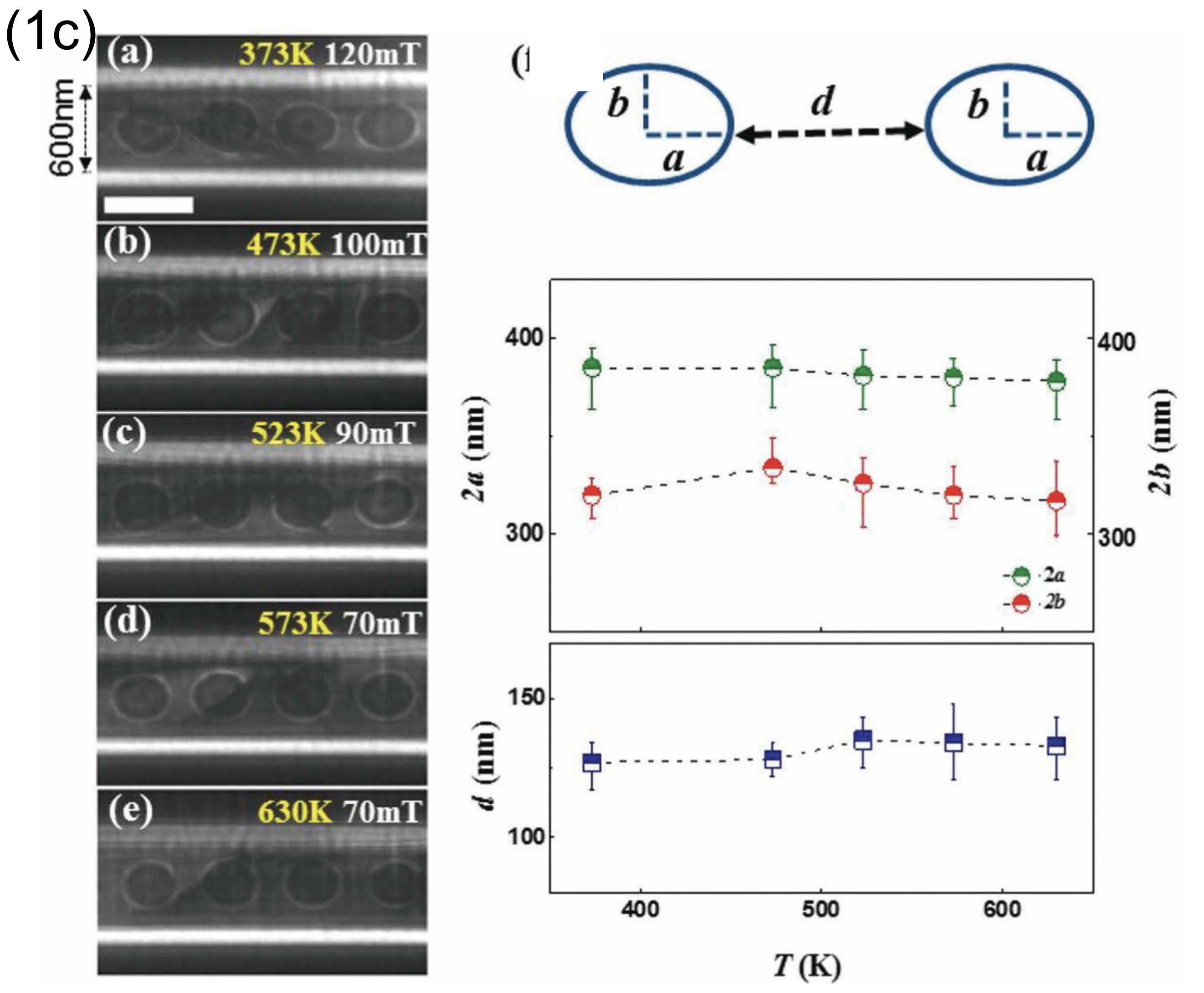
Yash Anand, Emerson Hemley and Johnpierre Paglione
University of Maryland
Quantum Materials Center

Importance of Fe_3Sn_2: Provides evidence of topological band structures and properties such as:
(1) Weyl Points which can be moved in reciprocal space by rotating the magnetization direction
(2) Quasi Two-Dimensional Dirac cones (~70 meV below E_F) with a mass gap of 30 meV
(3) magnetization-driven giant nemaic energy shift
(4) flattened bands near E_F
(5) Large AHE and observed magnetic skyrmions bubbles

Lattice Structure: Layered Rhombohedral crystal structure (R3m space group) with a=5.338 Å and c = 19.789 Å. Sn honeycomb layers sandwiching 2 Fe_3Sn kagome layer with Fe on kagome lattice and Sn at the center of the hexagons formed.







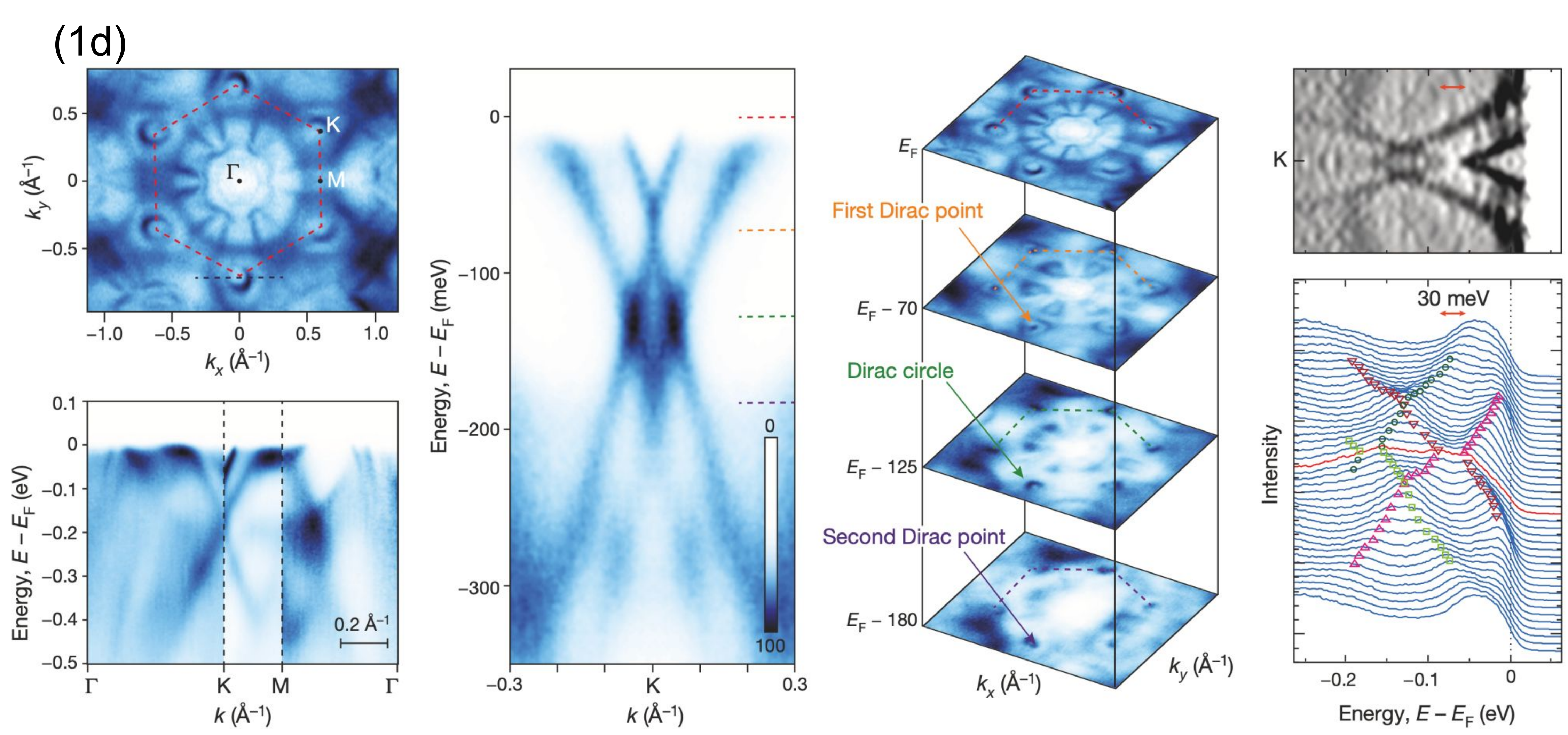


FIGURE 1: (a) Crystal structure of Fe_3Sn_2.[2] (b) LTEM images at 300 K under different magnetic fields, showing magnetic bubbles.[2] (c) LTEM image of temperature stable skyrmionic bubbles on Fe_3Sn_2 nanostrip.[2] (d) Massive dirac fermion at the zone corner of Fe_3Sn_2.[1]

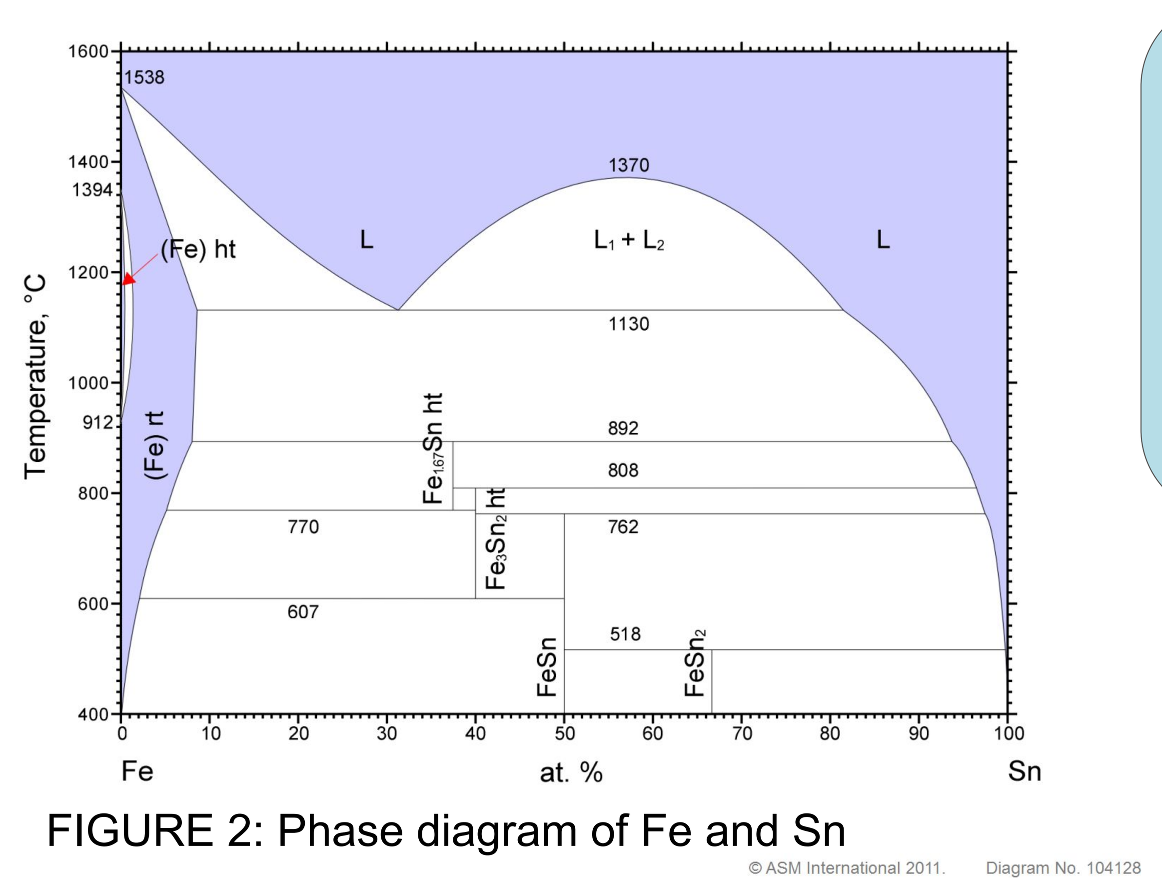
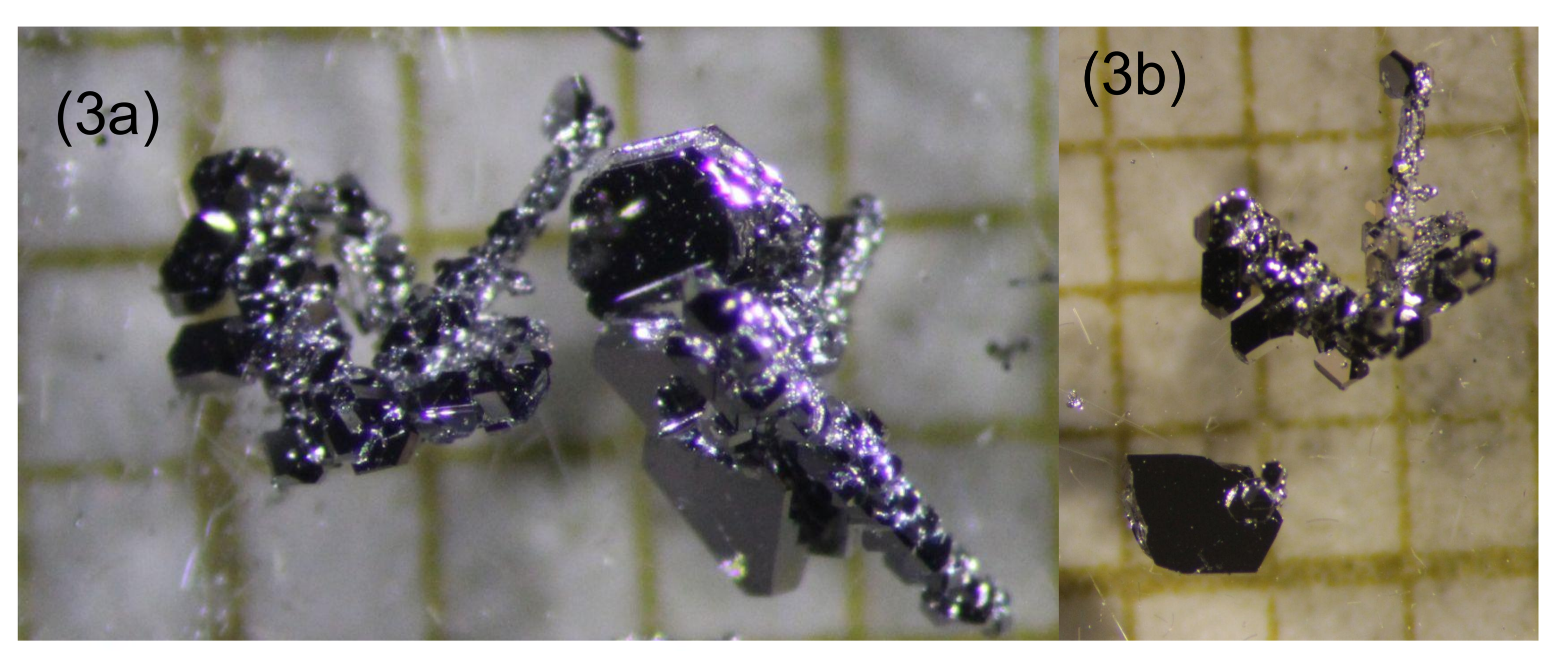


FIGURE 2: Phase diagram of Fe and Sn

Fe-Sn Phase Diagram:
Very narrow range for the crystal formation:
96.5%-97% Sn between 770 ºC and 806 ºC



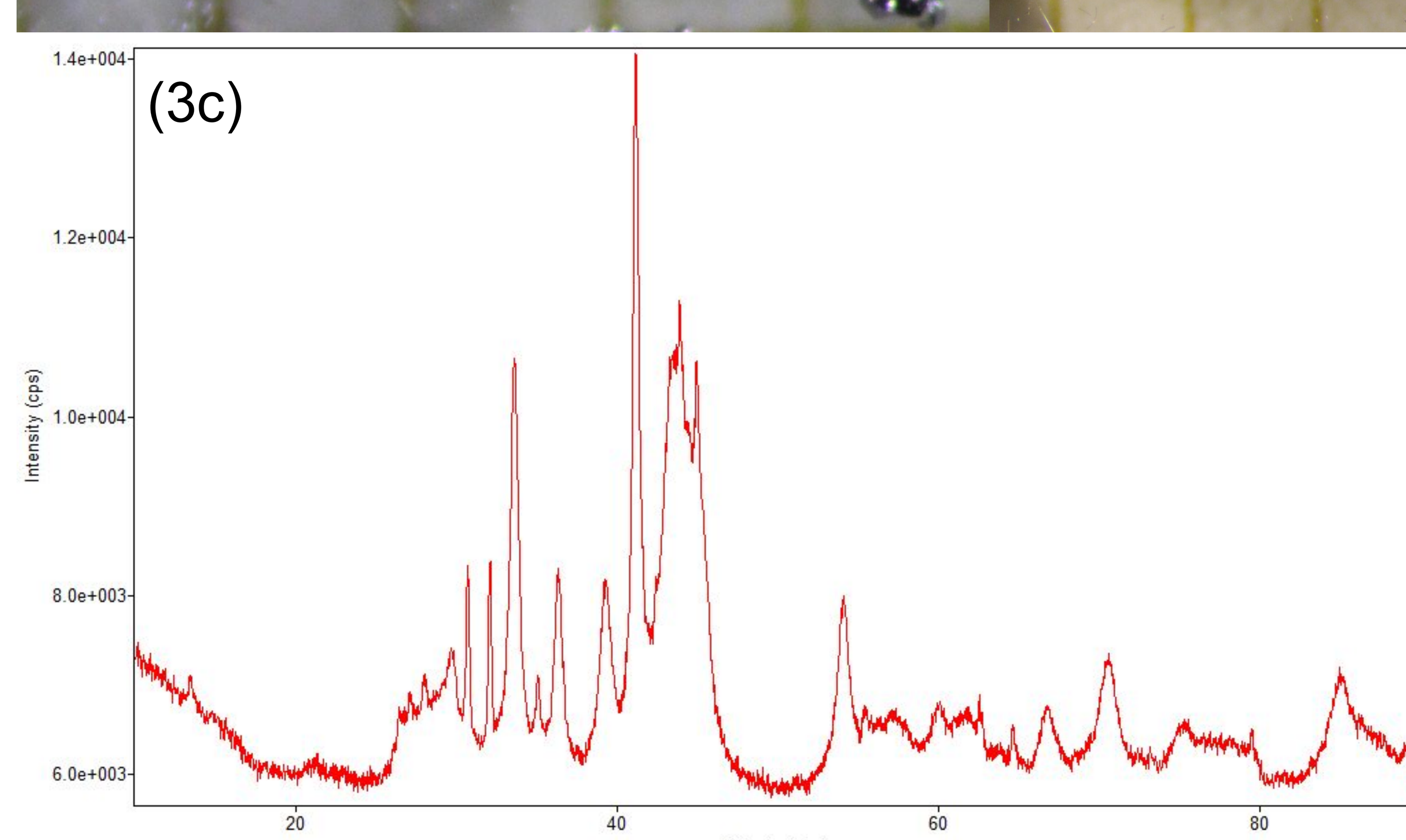


FIGURE 3: (a) Crystal from growth Ya017 which was crushed to produce the X-ray diffraction in (c). (b) More crystals from Ya017. (c) X-ray diffraction of the crystal grown form vertical Sn Flux method.

Vertical Sn Flux Method: No successful crystals yet, but we have found some crystals whose powder X-ray show Fe_3Sn_2 phases (Figure 3a and 3b). We have tampered with the ratio of Sn to Fe, and are currently working on spin out temperatures.

Horizontal Sn Flux Method: Only one growth done yet (Figure 4a), but we have put in the second growth. We spun out the growth for 2a, but no good crystals formed. Tampering with temperature parameter of each end to see if we can produce good crystals.

FIGURE 4: first horizontal growth.

Reference:
(1) Ye, L., Kang, M., Liu, J. et al. Massive Dirac fermions in a ferromagnetic kagome metal. Nature 555, 638–642 (2018). https://doi.org/10.1038/nature25987
(2) Zhang, D., Hou, Z., & Mi, W. (2022). Progress in magnetic alloys with kagome structure: Materials, fabrications and physical properties. *Journal of Materials Chemistry C*, *10*(20), 7748–7770. https://doi.org/10.1039/d2tc01190e