Investigating a removable capping layer for Fe3GeTe2 films

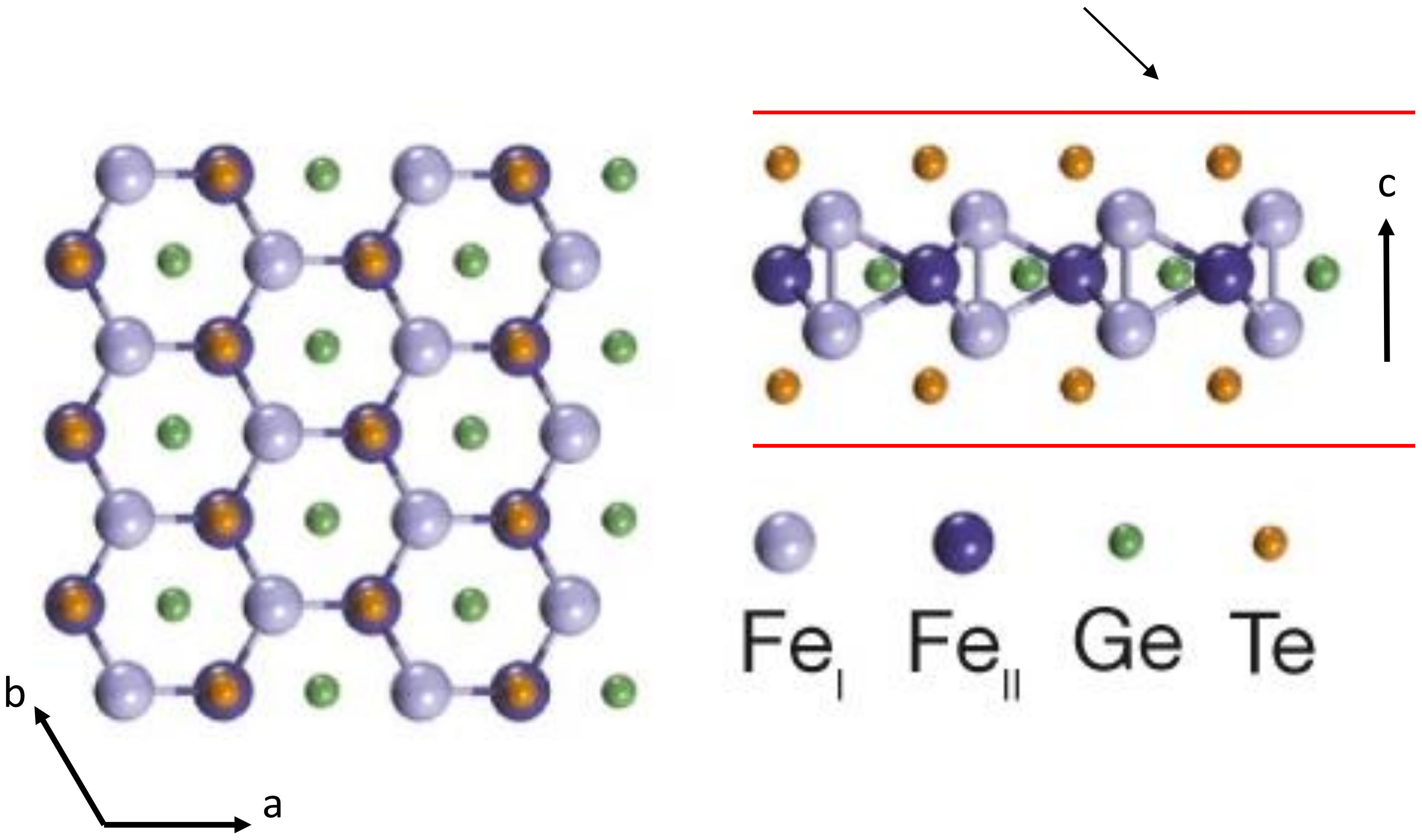
Dante Prins 2021

Stewart Blusson Quantum Matter Institute

What is Fe3GeTe2?

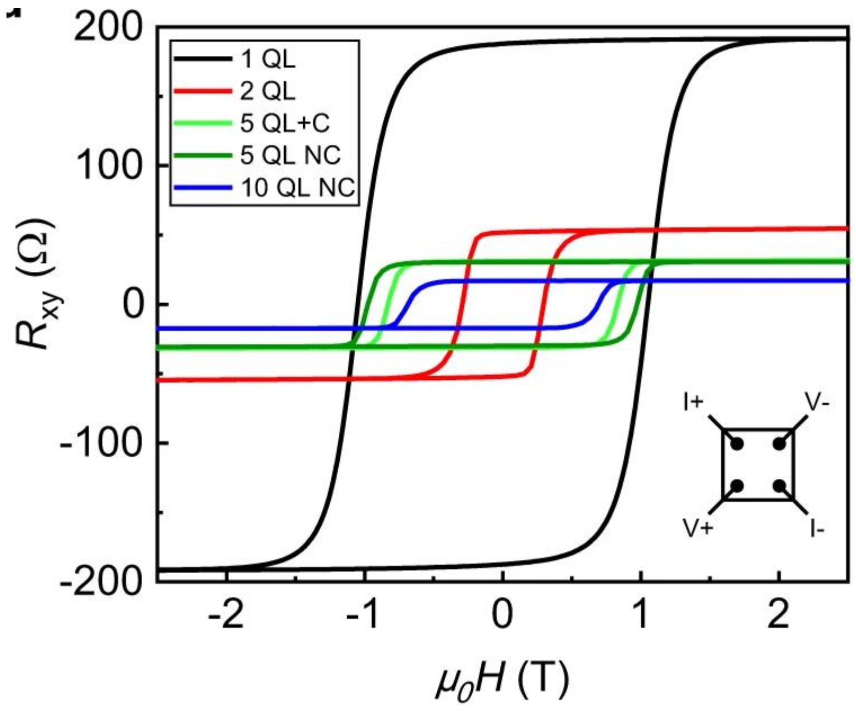
Atom structure of Fe3GeTe2.

Van Der Waals gap between layers

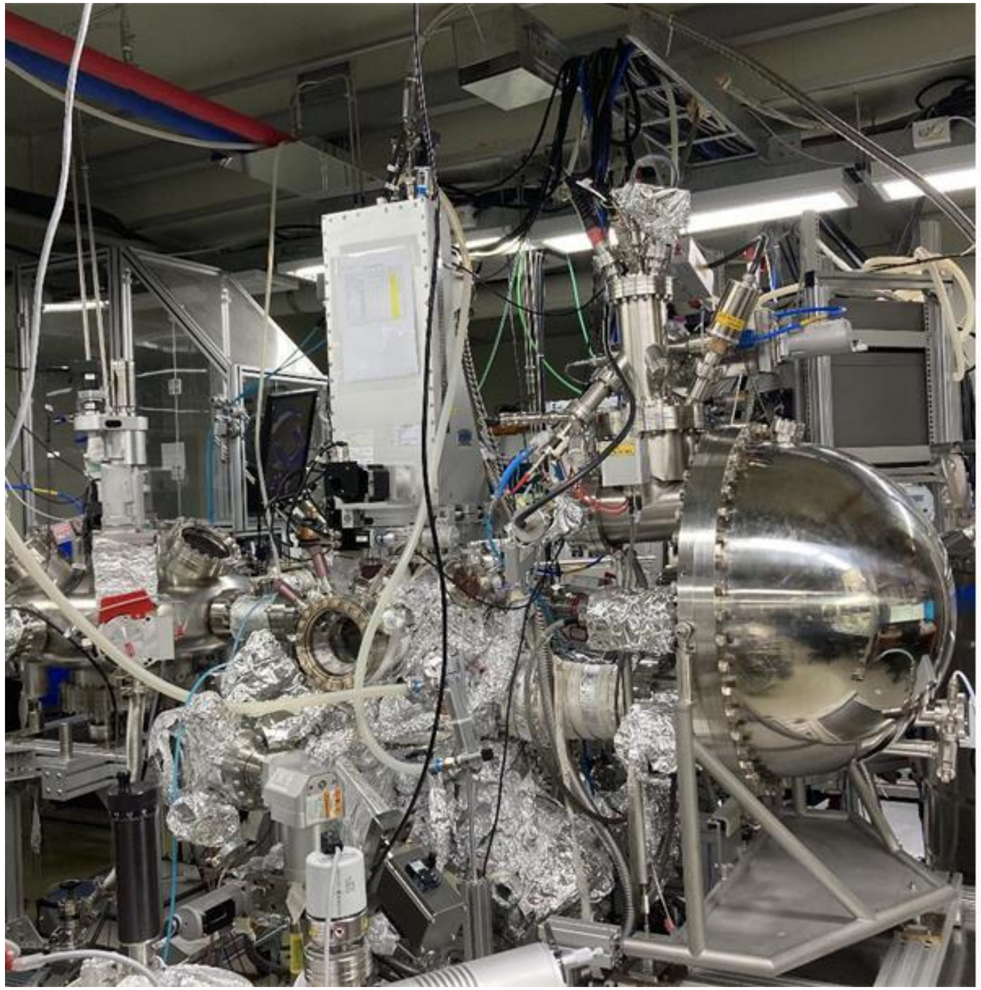


eng, Y., Yu, Y., Song, Y. et al. Gate-tunable room-temperature ferromagnetism in two-dimensional Fe3GeTe2.

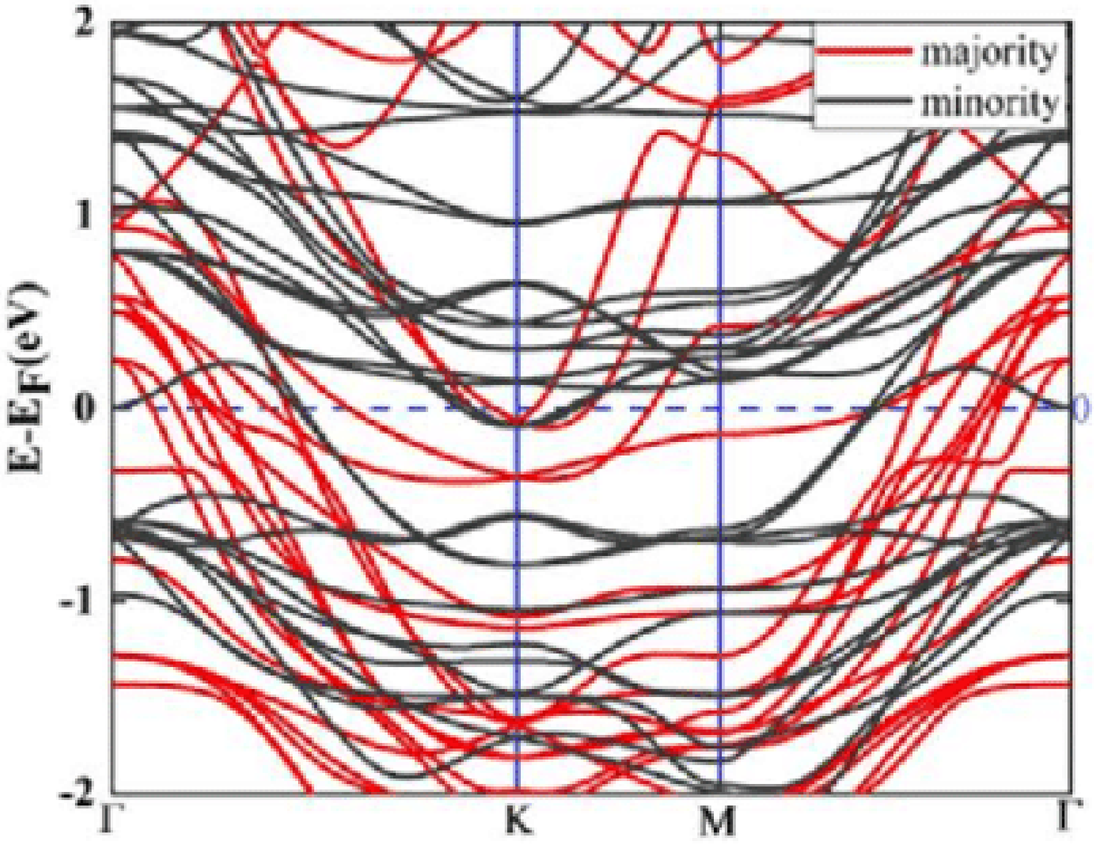
Transverse resistance hysteresis showing Anomalous Hall Effect behavior in different thickness samples.



Roemer, R., Liu, C. & Zou, K. Robust ferromagnetism in wafer-scale monolayer and multilayer Fe3GeTe2.



Spin-resolved Angle-resolved Photoemission Spectroscopy at the Electronic Structures Group in Korea.



Li, Xinlu et al. Spin-dependent transport in van der Waals magnetic tunnel junctions with Fe3GeTe2 electrodes.

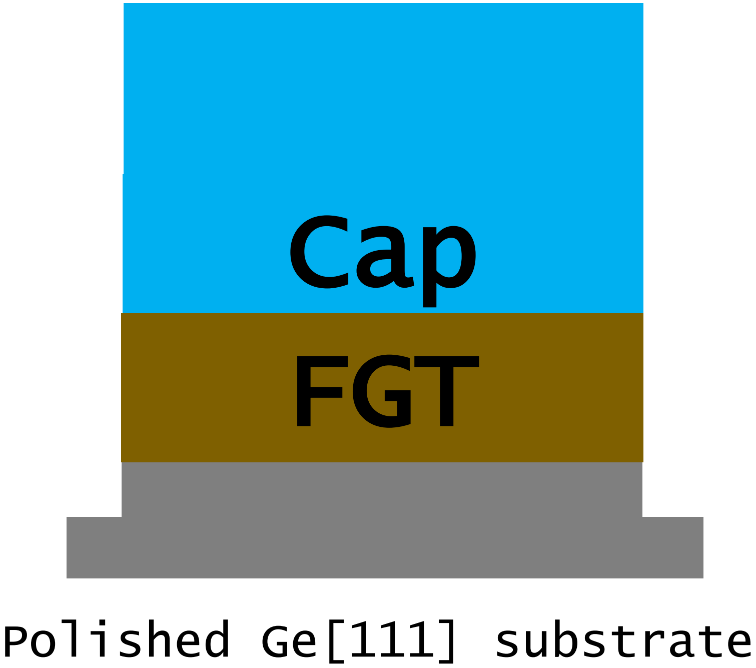
Protective cap specifications

Growable and removable at under 360^{o}C.

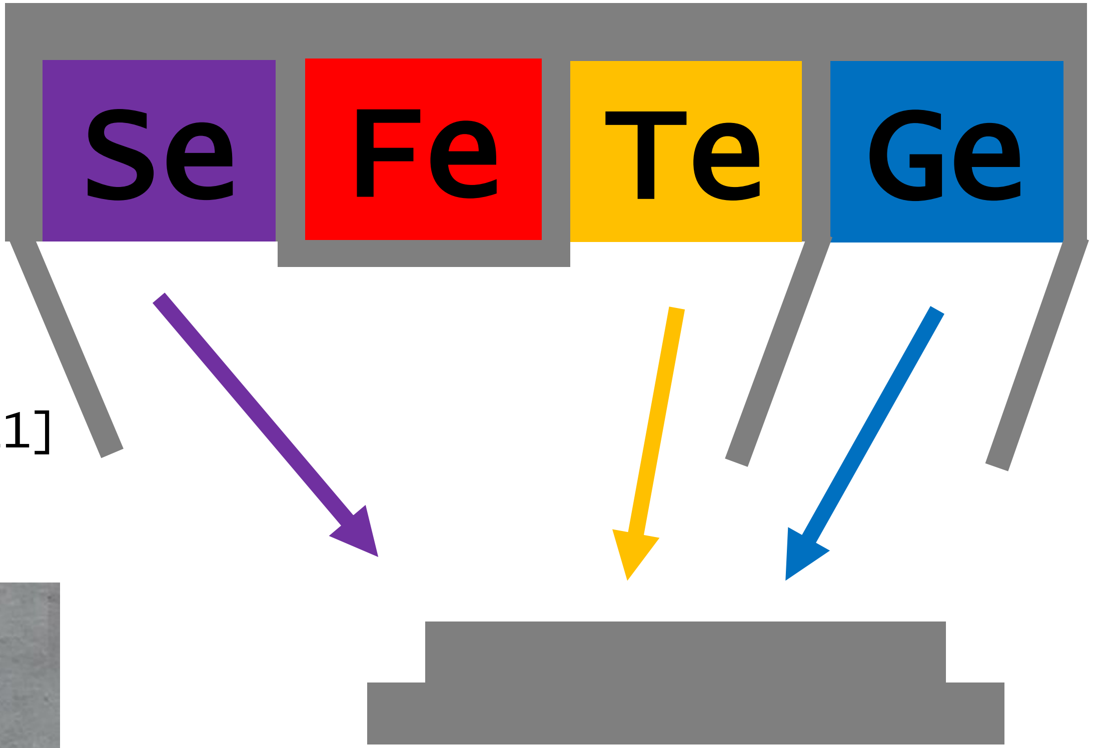
O_2

Protects sample from oxidation in air.

FGT Surface remains flat and unchanged after cap removal.

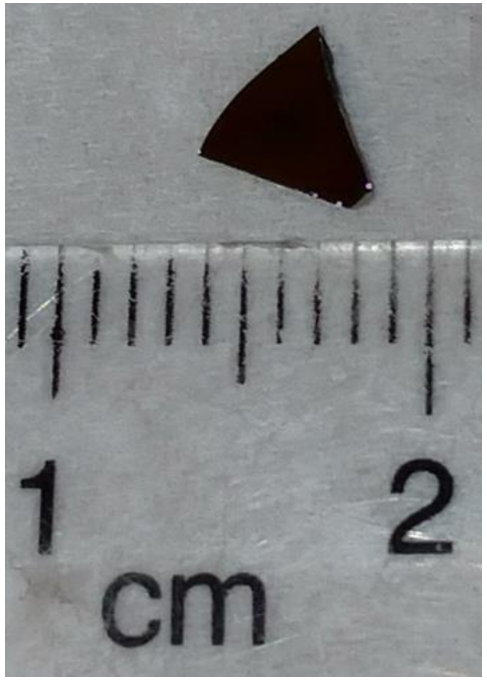


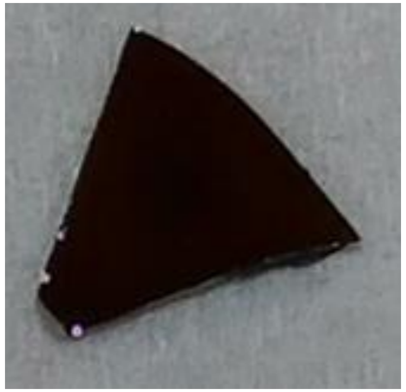
Molecular Beam Epitaxy film growth

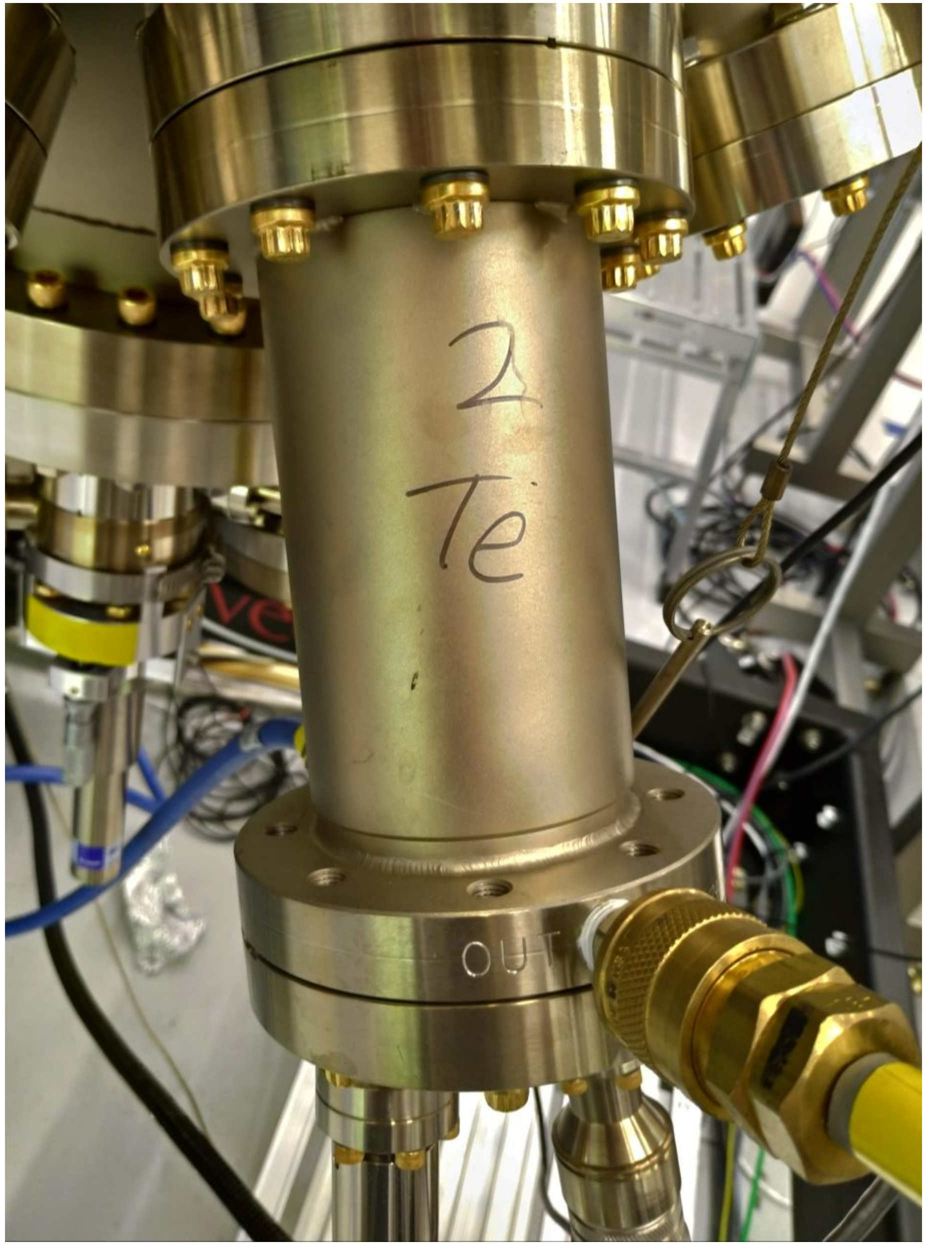


MBE substrate

Polished Ge[111]
Substrate,
length 5mm.







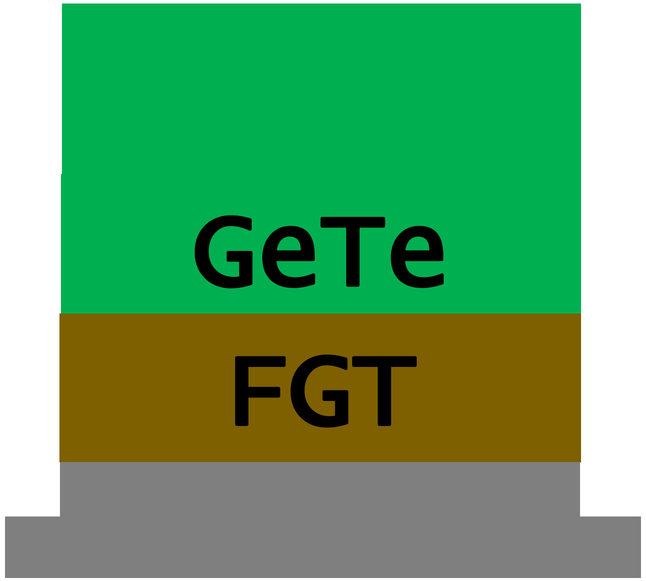
A Tellurium cell with power and cooling cables seen below.

Candidate materials

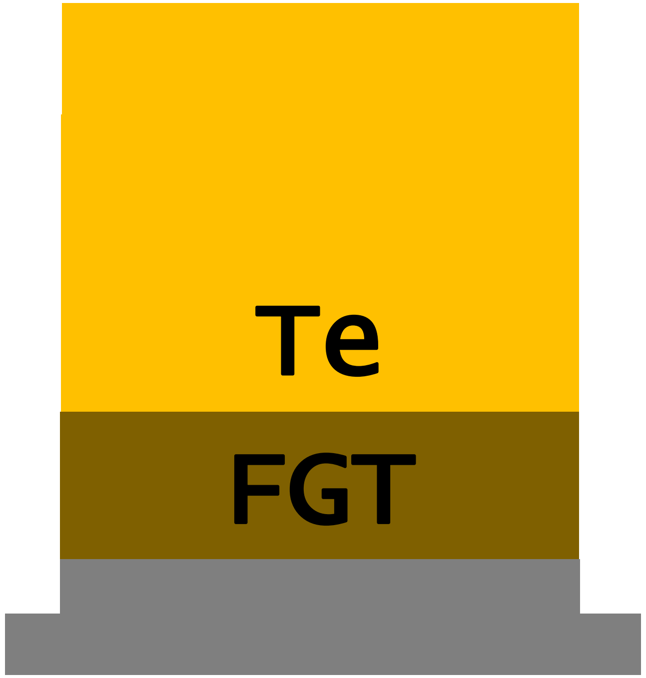
Temperature at which each atom has vapor pressure of 10^{-8} torr.

Se	Fe	Te	Ge
63°C	858°C	155°C	812°C

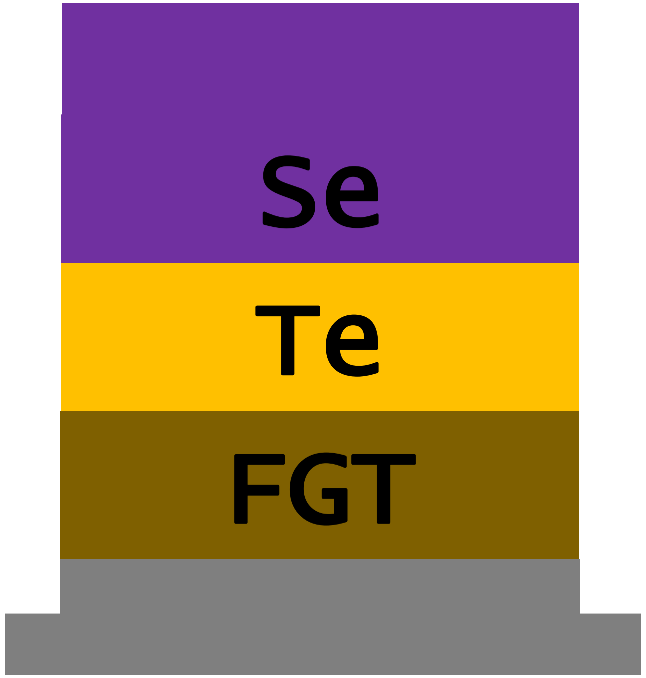
Thick germanium telluride cap



Thick tellurium cap

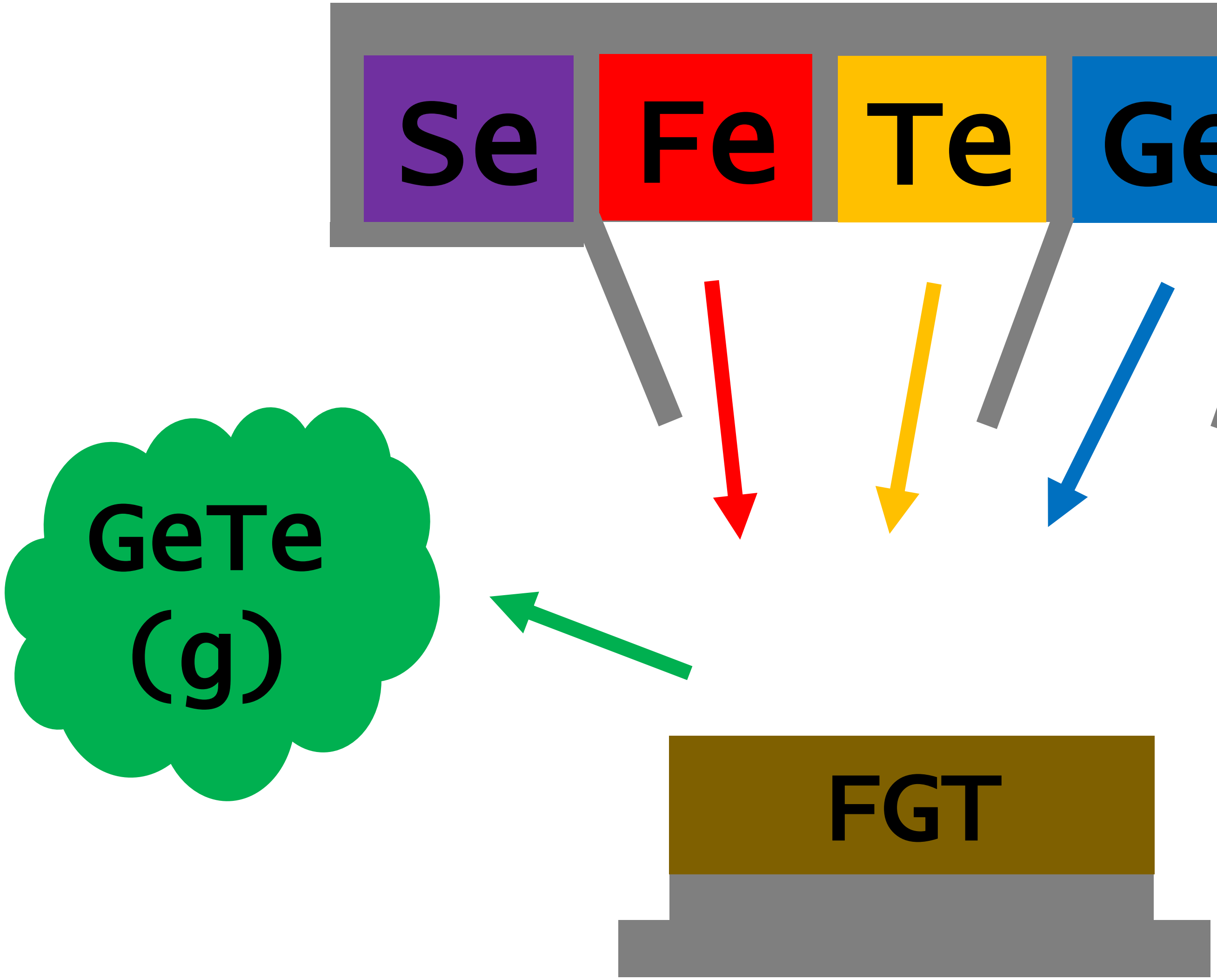


Tellurium buffer layer(s) with thick selenium cap

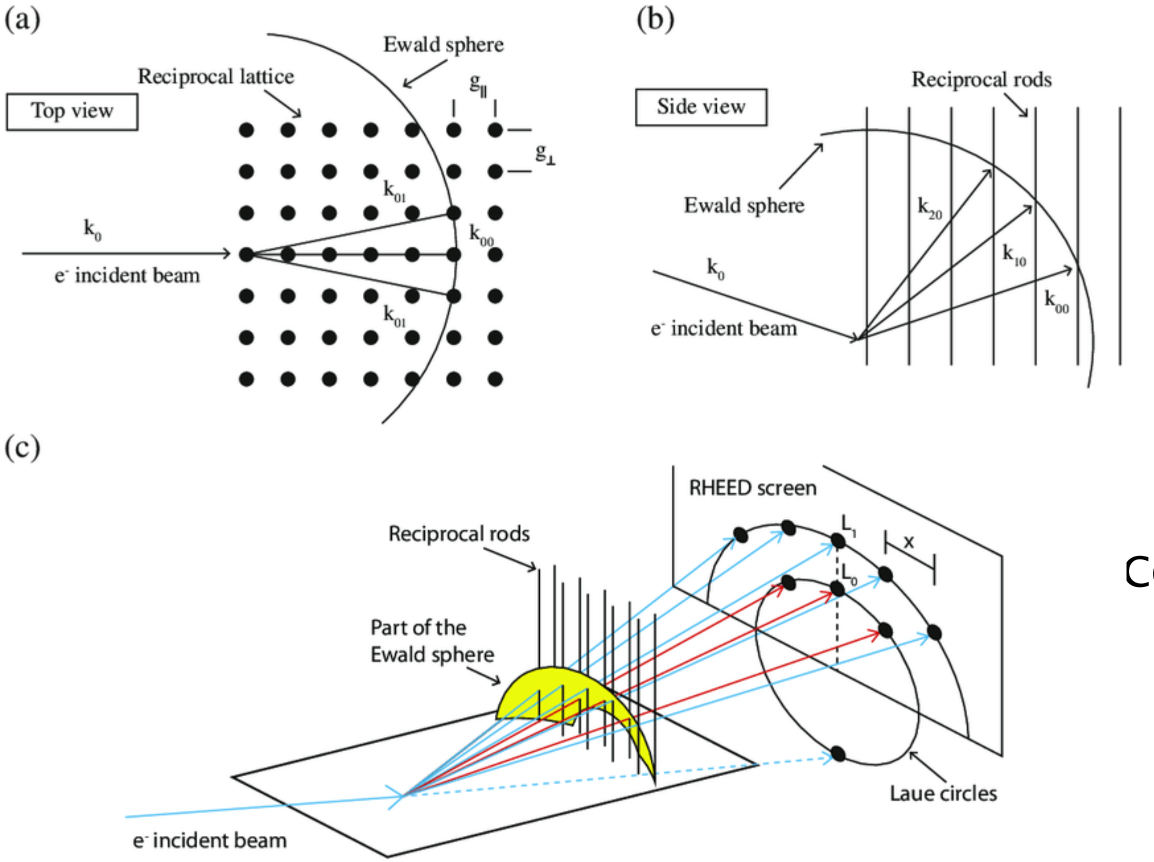


Germanium telluride

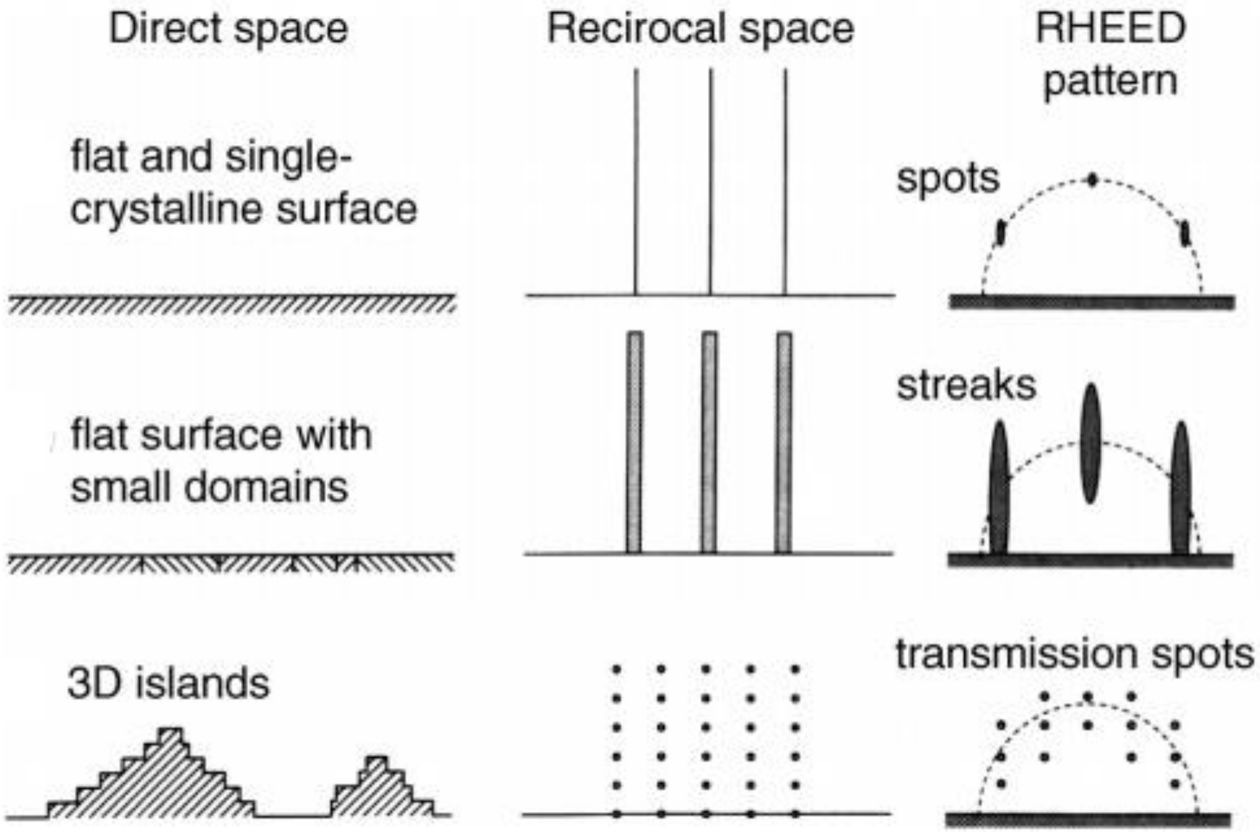
GeTe is known to vaporize at 360^{0}C during FGT growth.



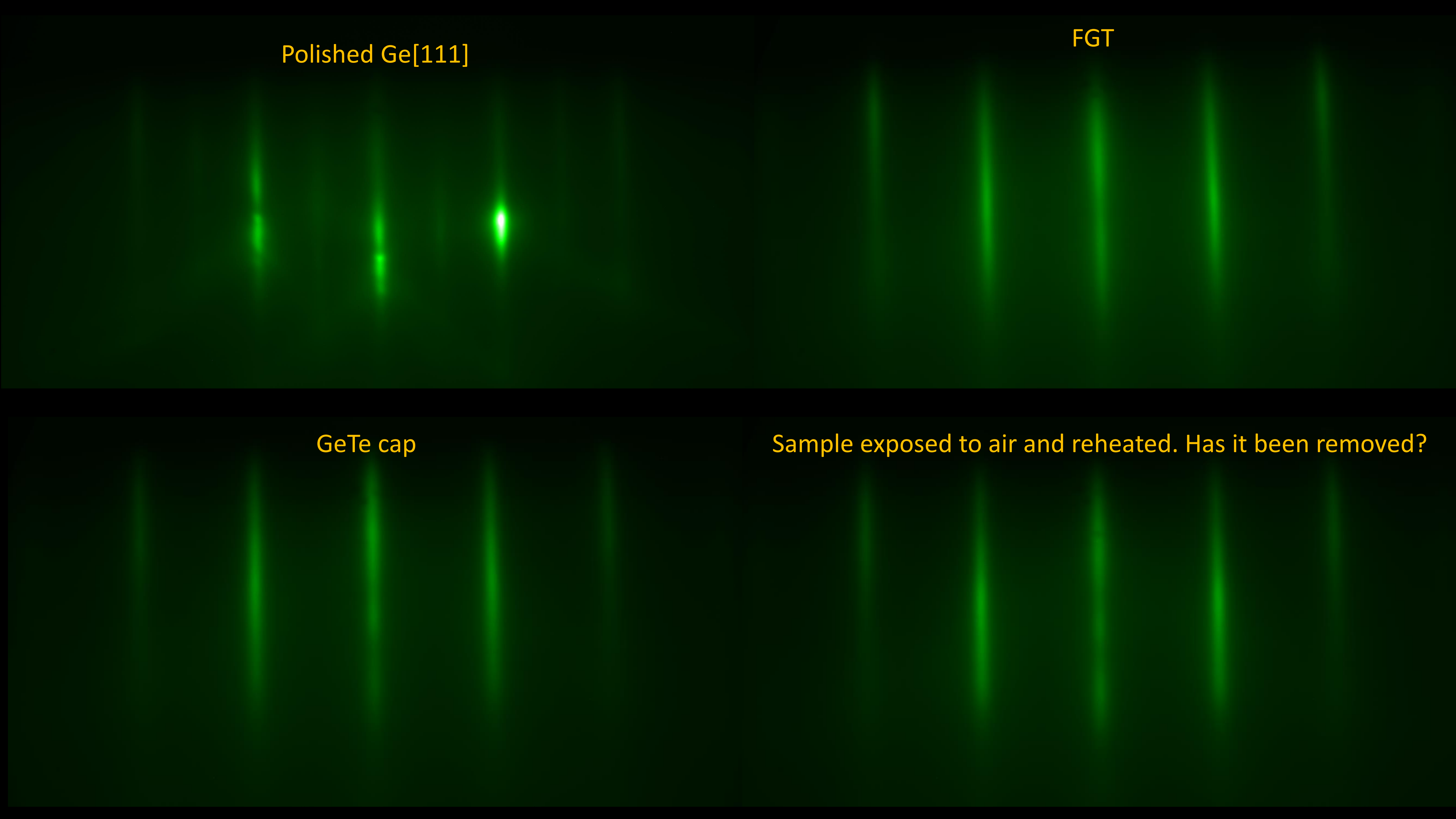
Reflective High-Energy Electron Diffraction



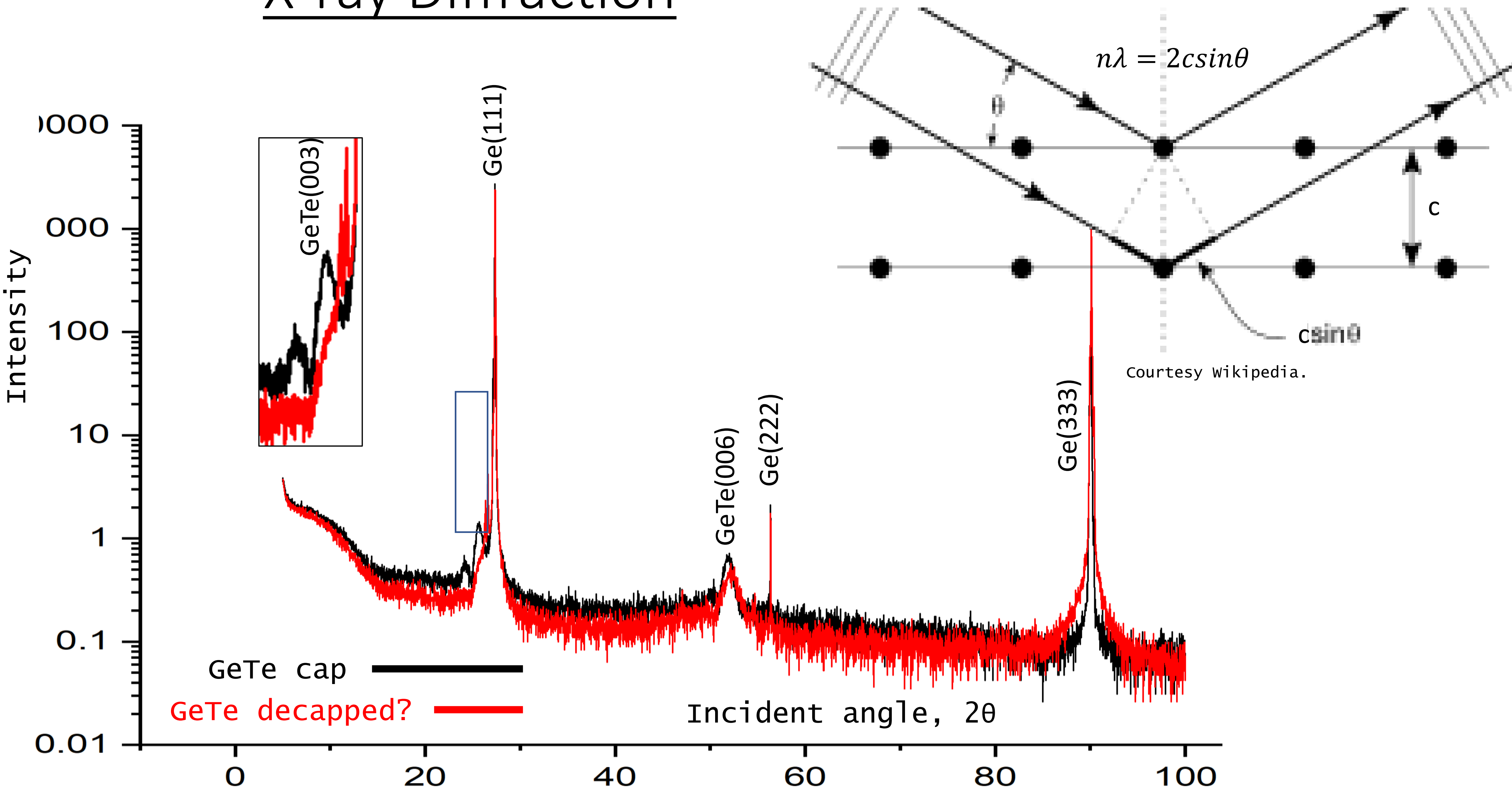
Landgraf, Boris. (2014). Structural, magnetic and electrical investigation of Iron-based III/V-semiconductor hybrid structures.



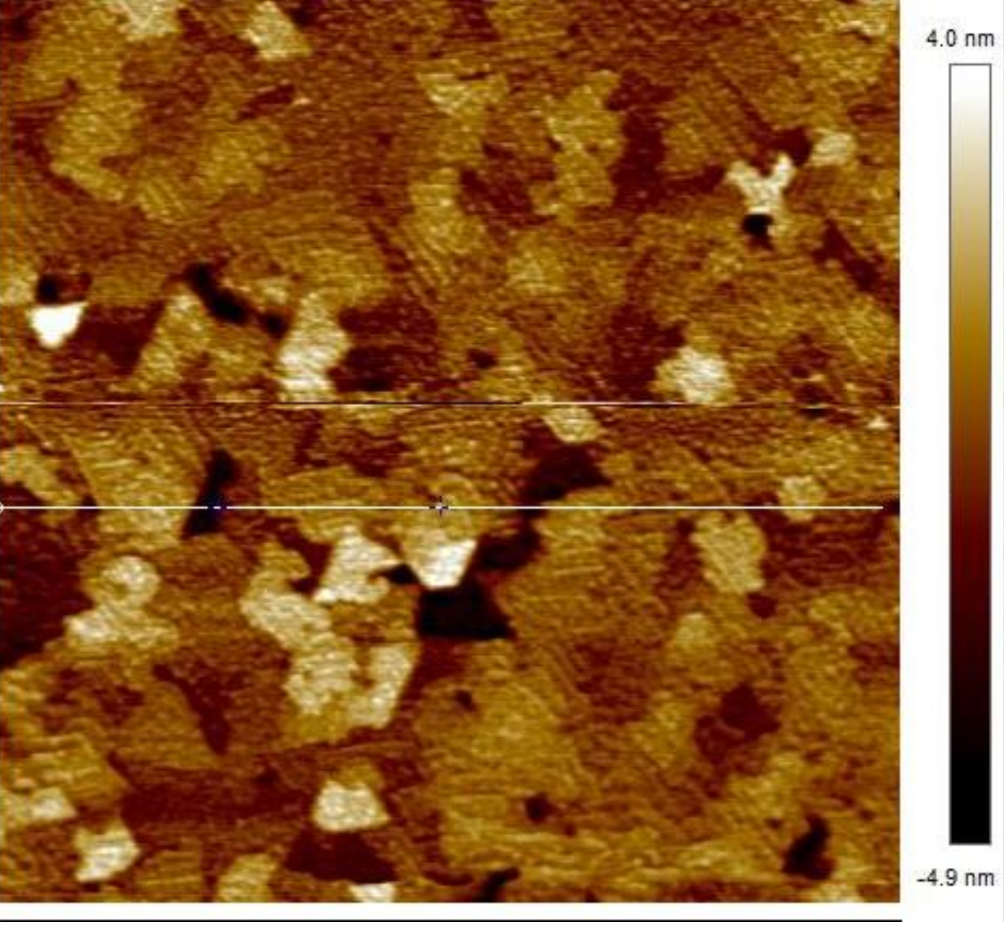
Common RHEED patterns, courtesy of Yoshimi Horio.


Polished Ge[111]
FGT
GeTe cap
Sample exposed to air and reheated. Has it been removed?

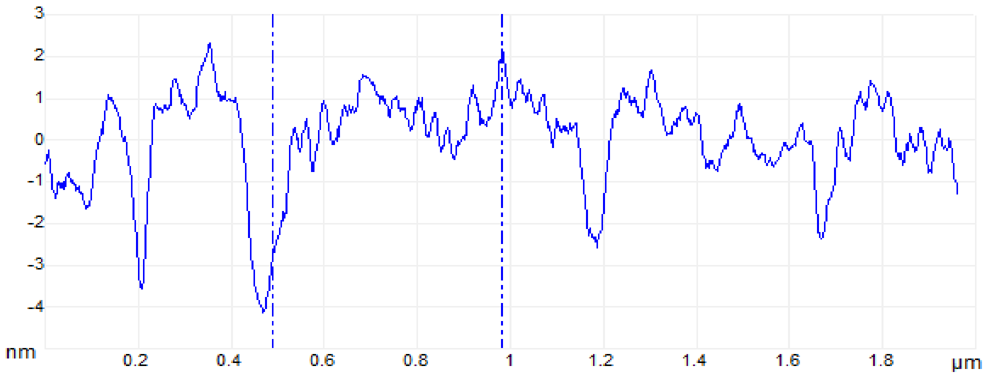
X-ray Diffraction

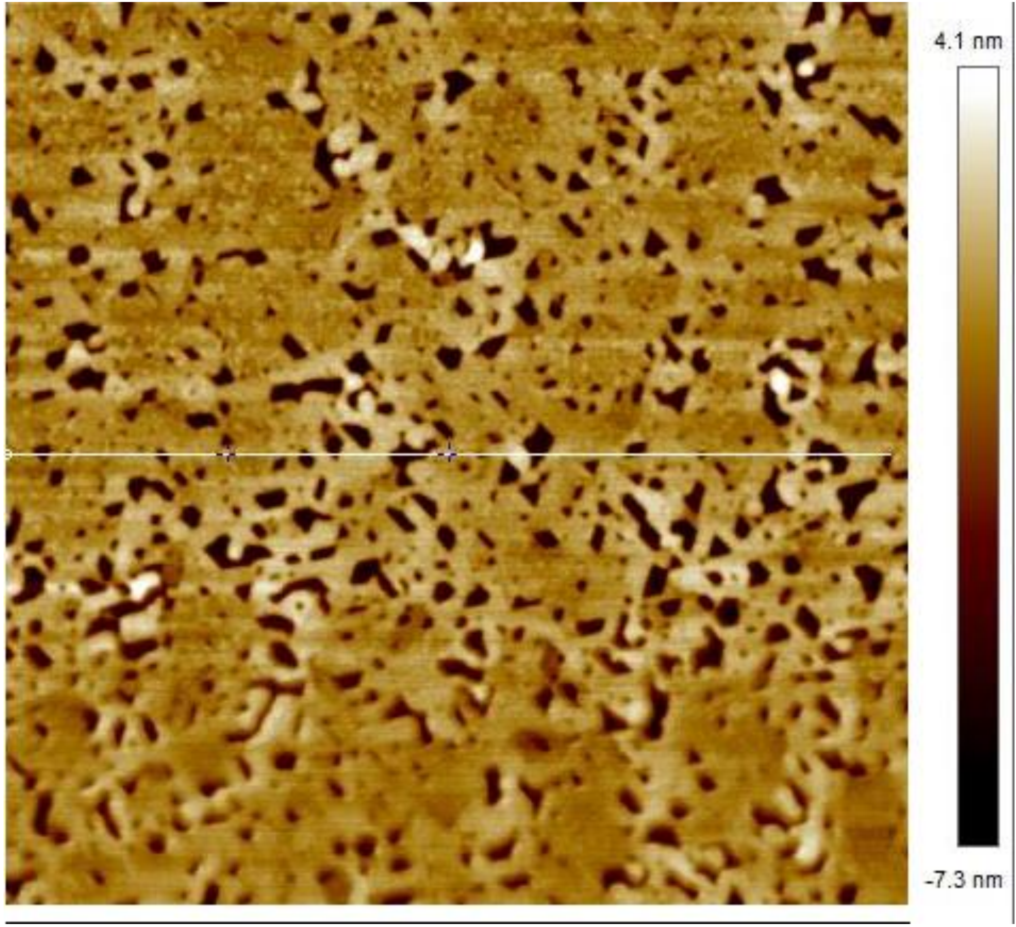


Atomic Force Microscopy

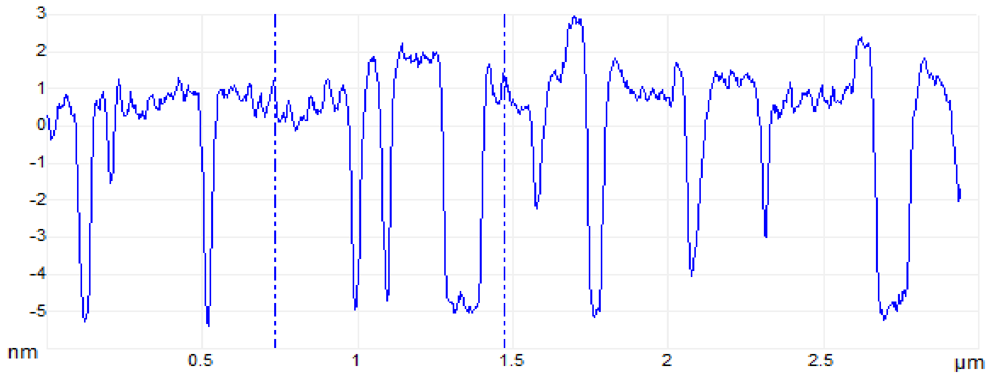


GeTe cap

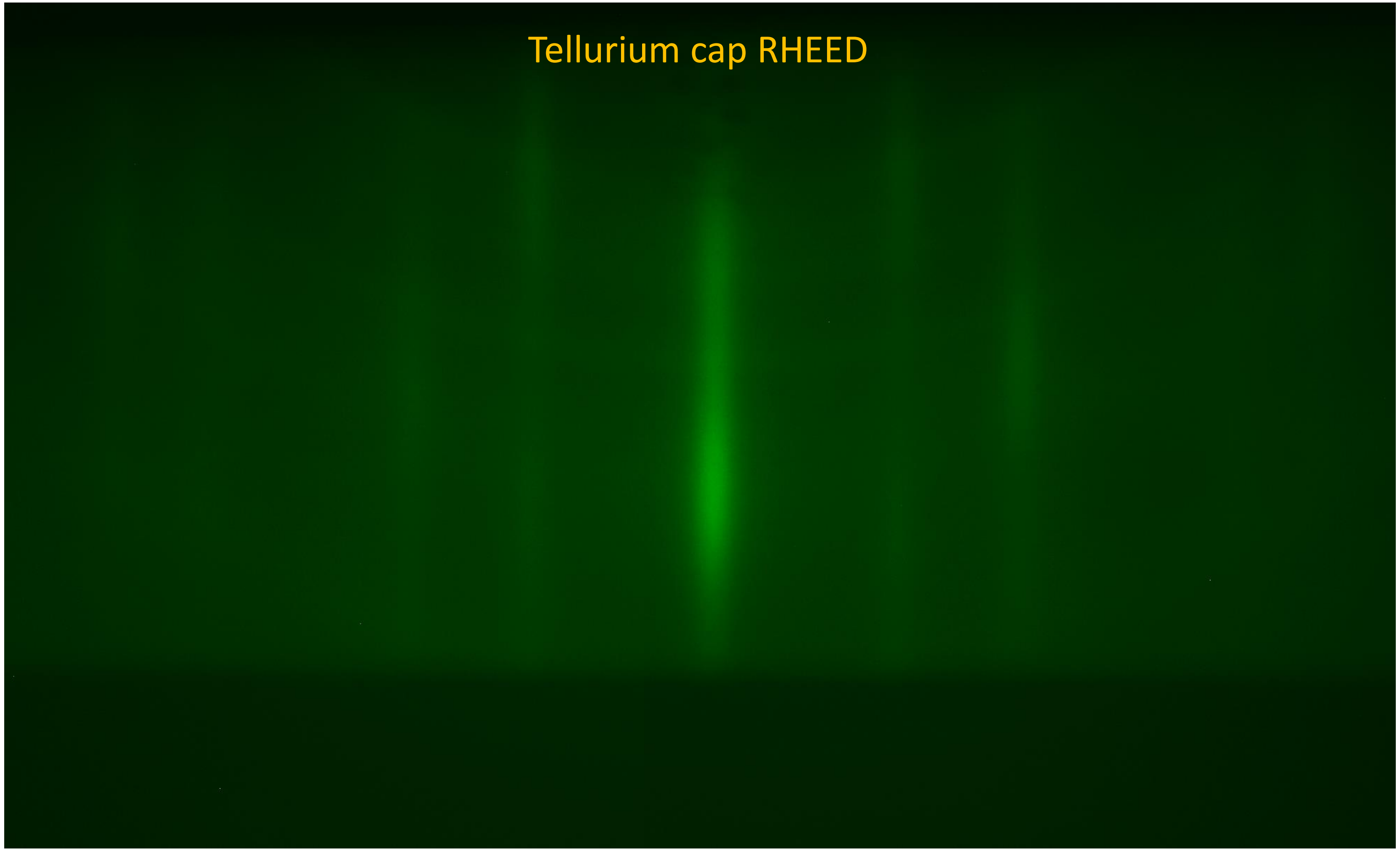


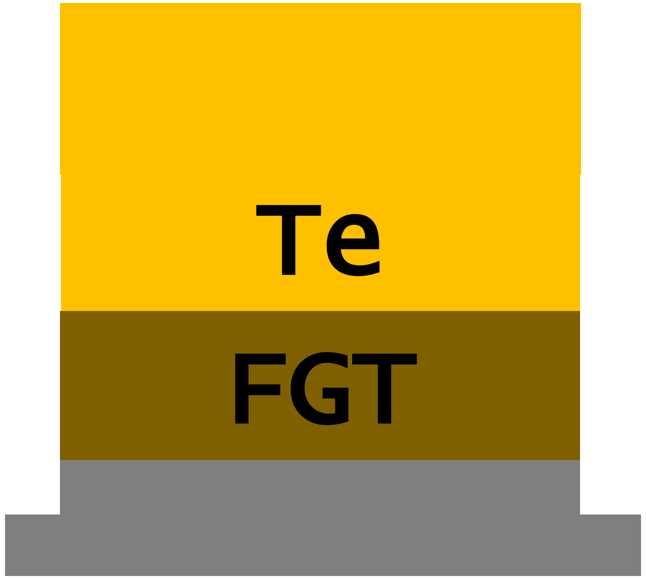


GeTe decapped?

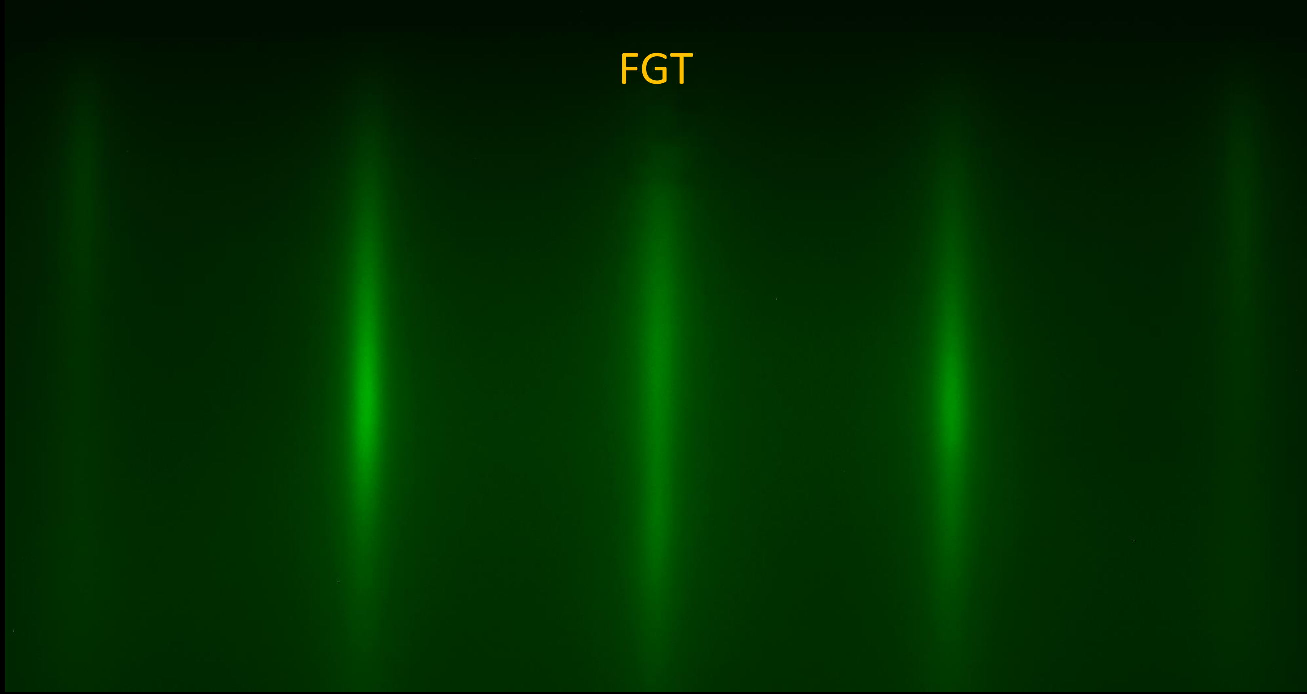


Thick Tellurium cap



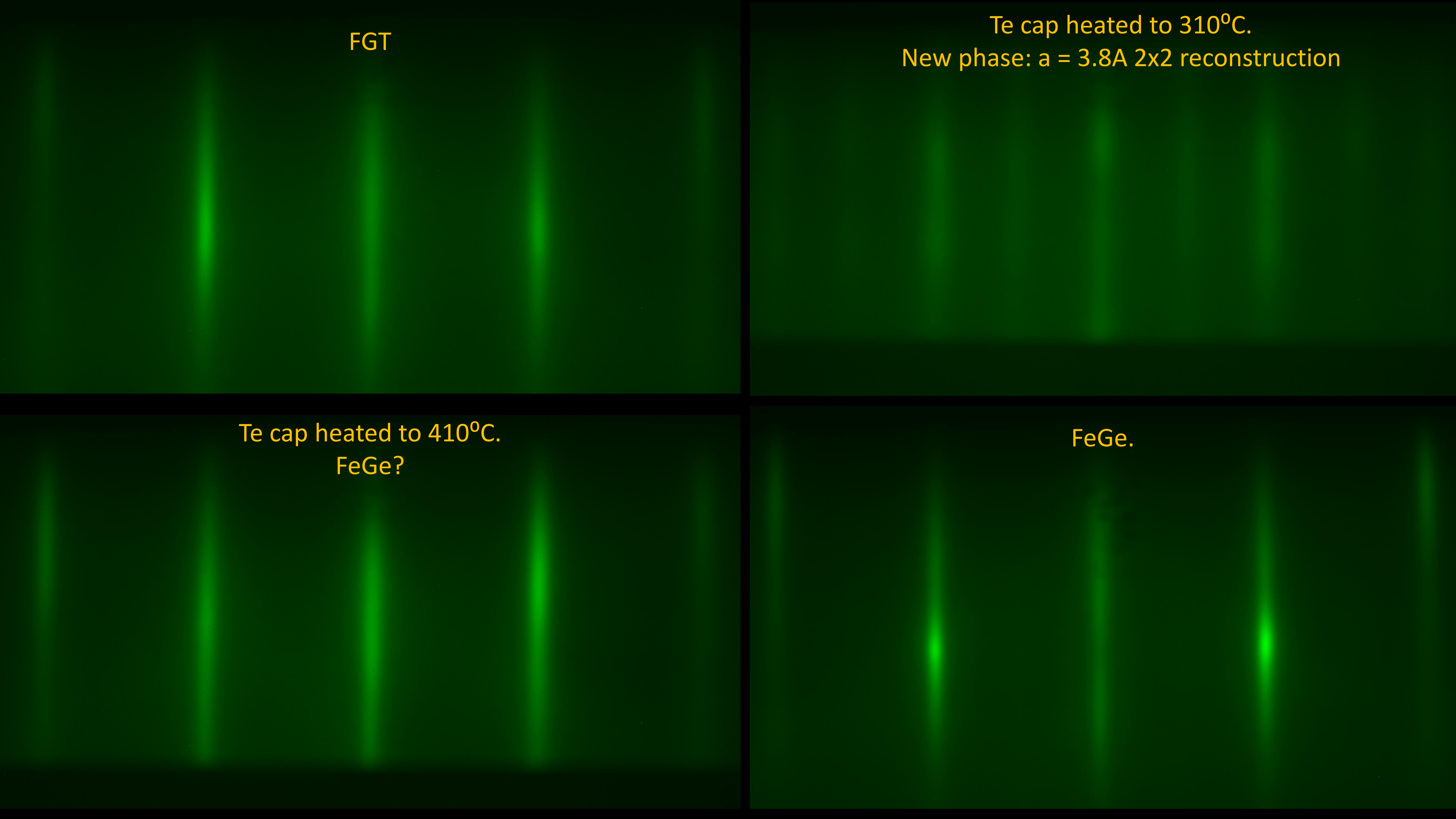



Iron germanide


FGT

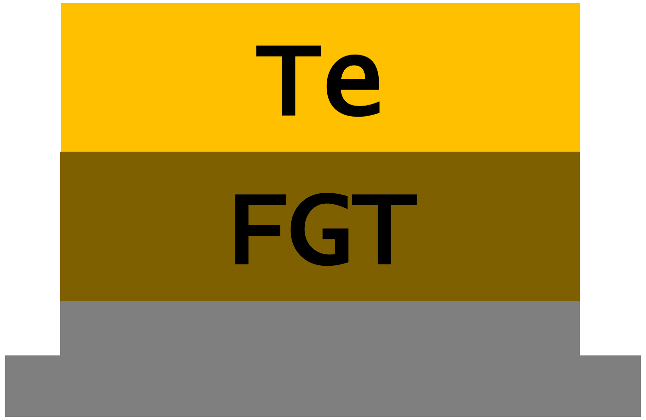

Te cap heated to 310^{o}C.
New phase: a = 3.8A 2x2 reconstruction

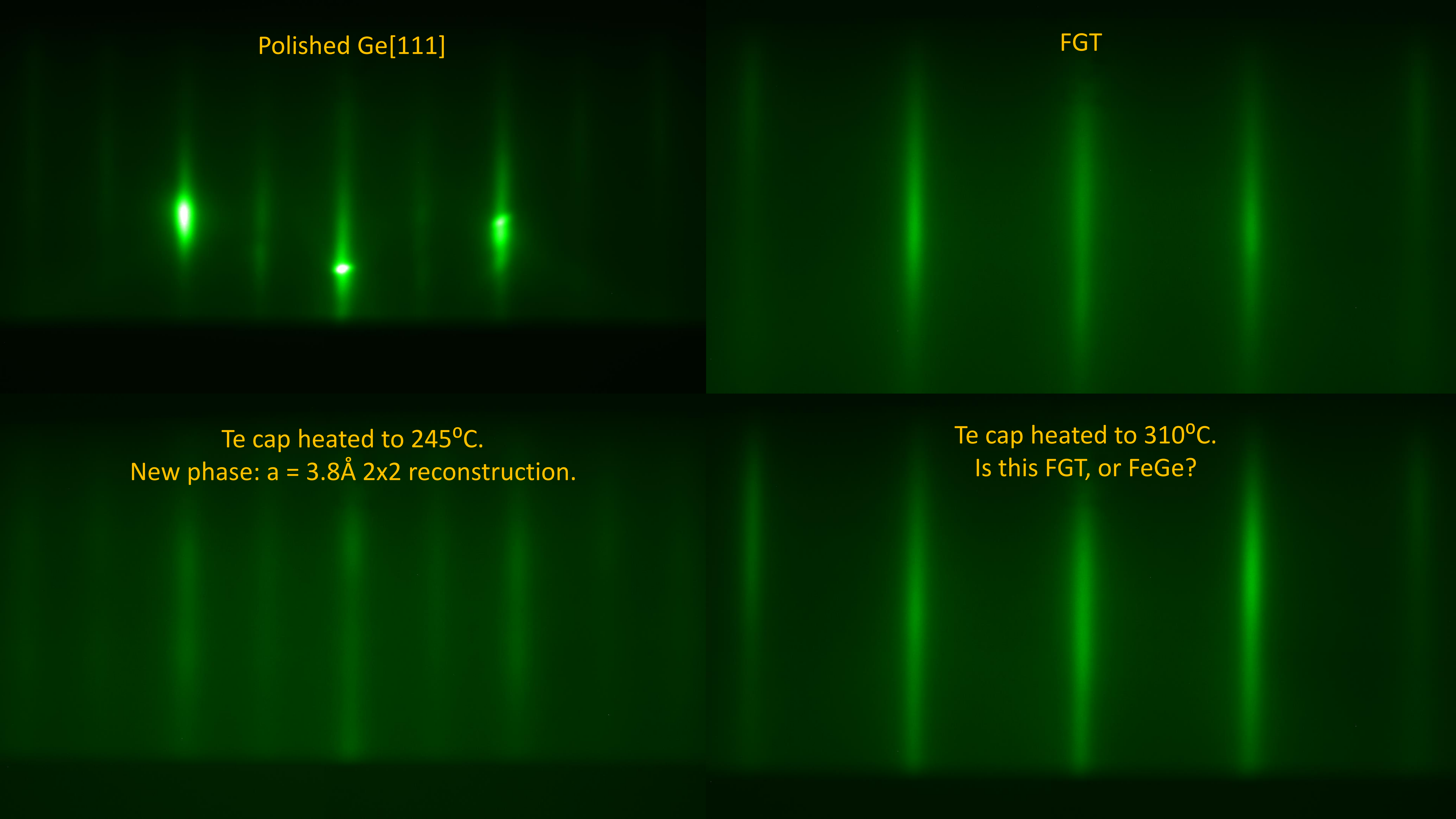

Te cap heated to 410^{o}C.
FeGe?


FGT
Te cap heated to 310°C.
New phase: a = 3.8A 2x2 reconstruction
Te cap heated to 410°C.
FeGe?
FeGe.

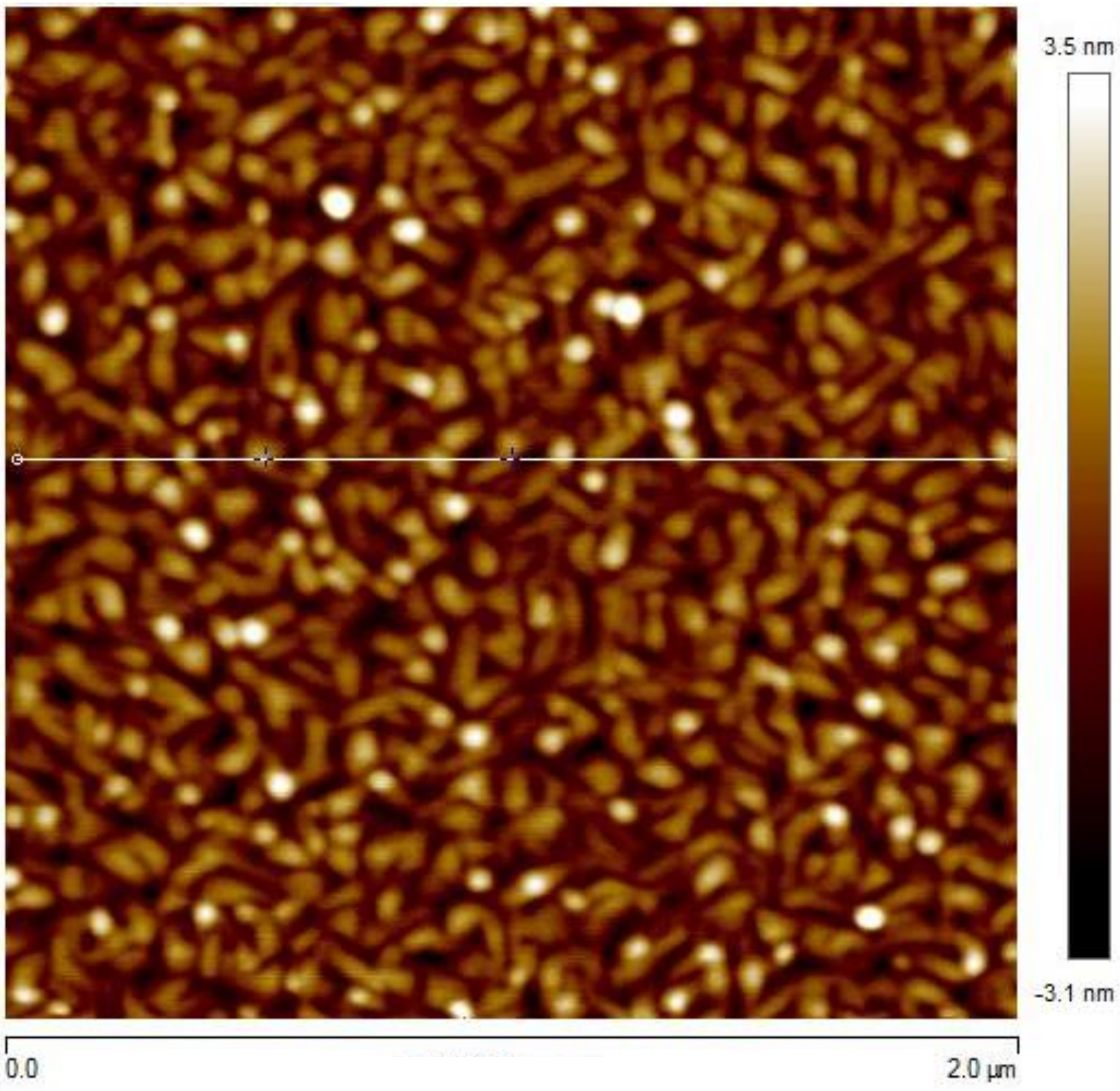
Thin Tellurium cap

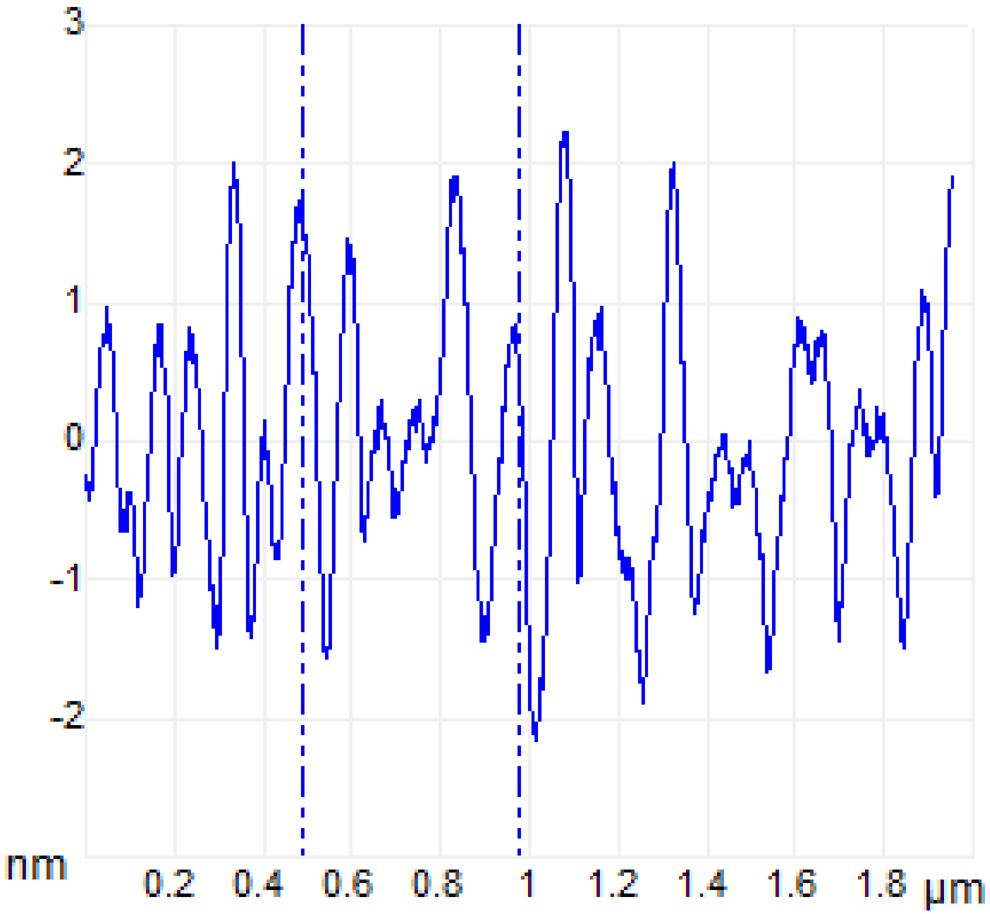
1-6 layers of Tellurium < 25Å.




Polished Ge[111]
FGT
Te cap heated to 245°C.
New phase: a = 3.8Å 2x2 reconstruction.
Te cap heated to 310°C.
Is this FGT, or FeGe?

Atomic Force Microscopy





Thin Tellurium cap adding selenium

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1-6 layers of Tellurium < 25Å
And then 20nm of Se.
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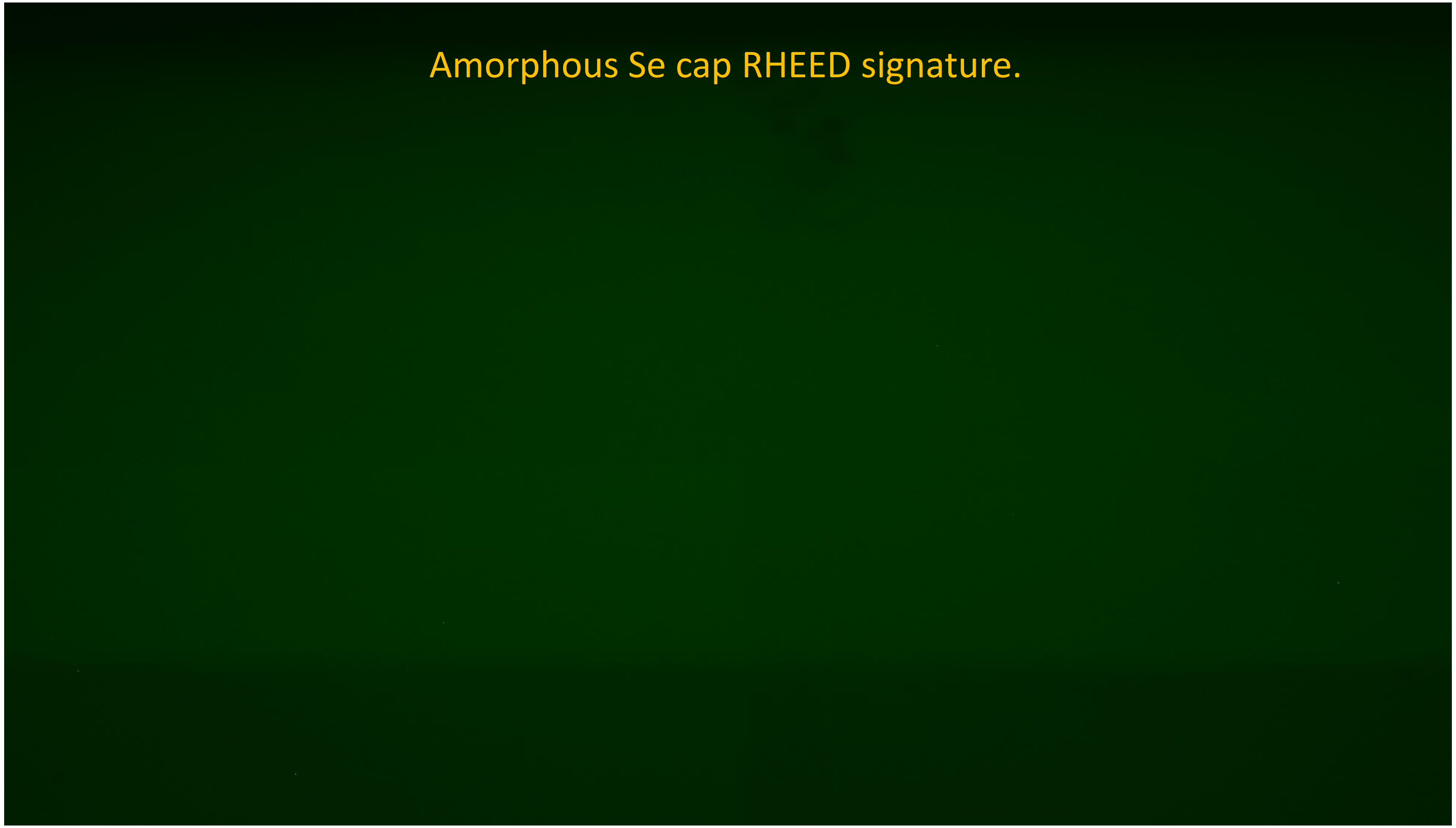
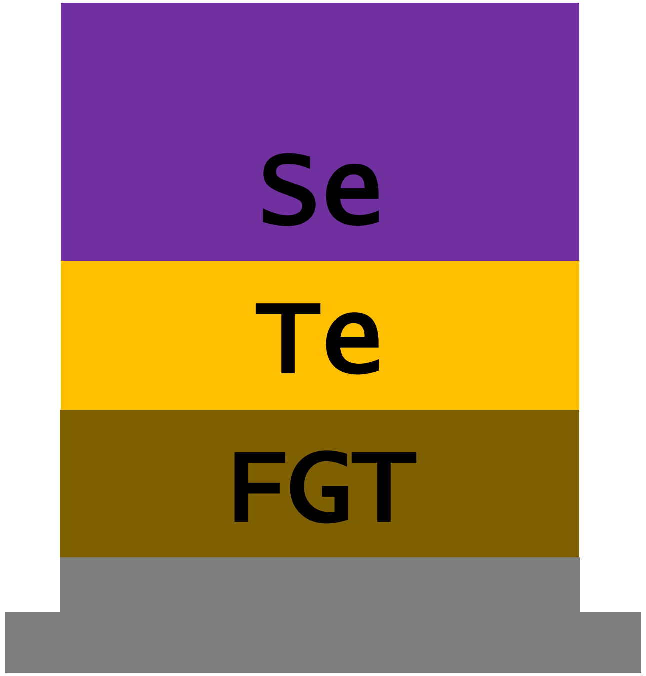
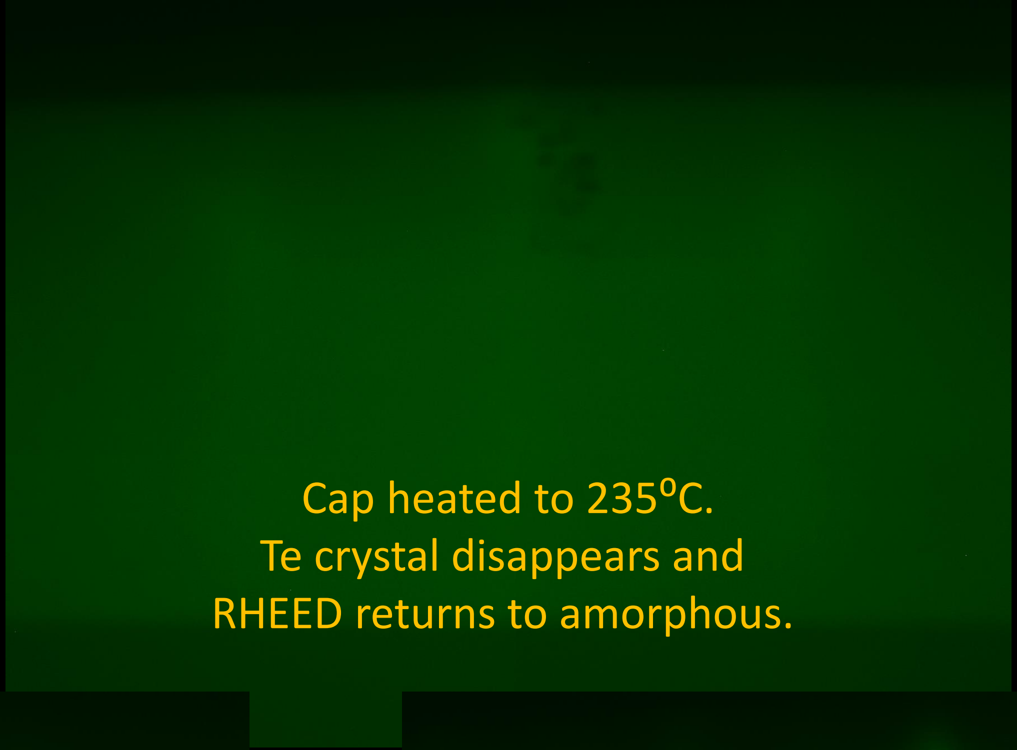
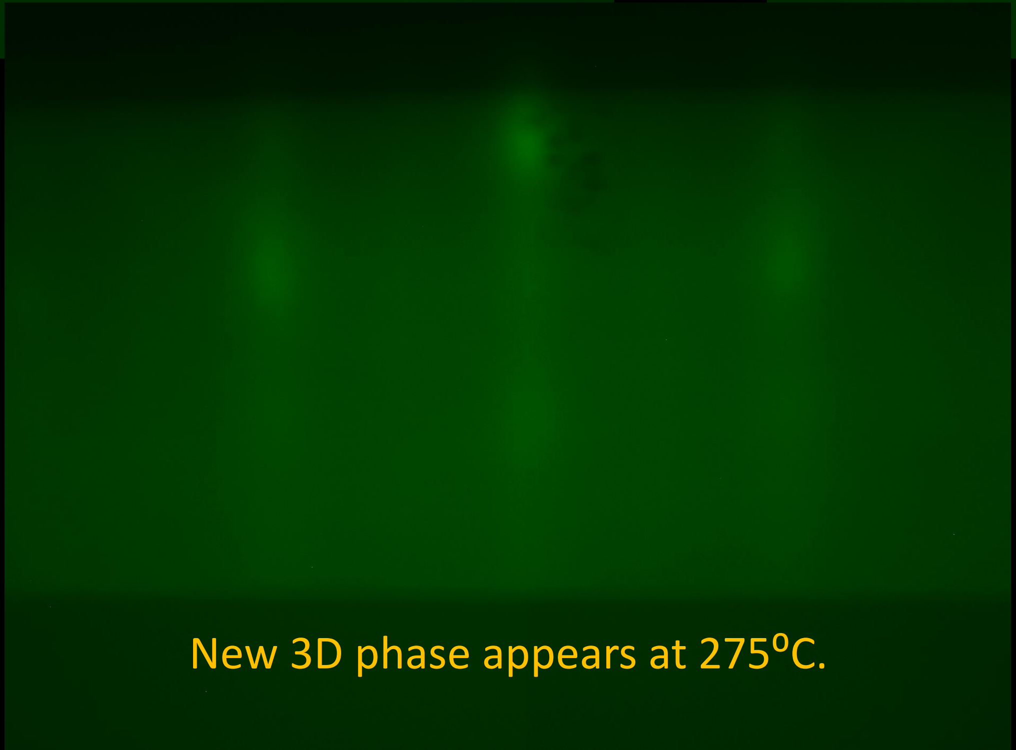




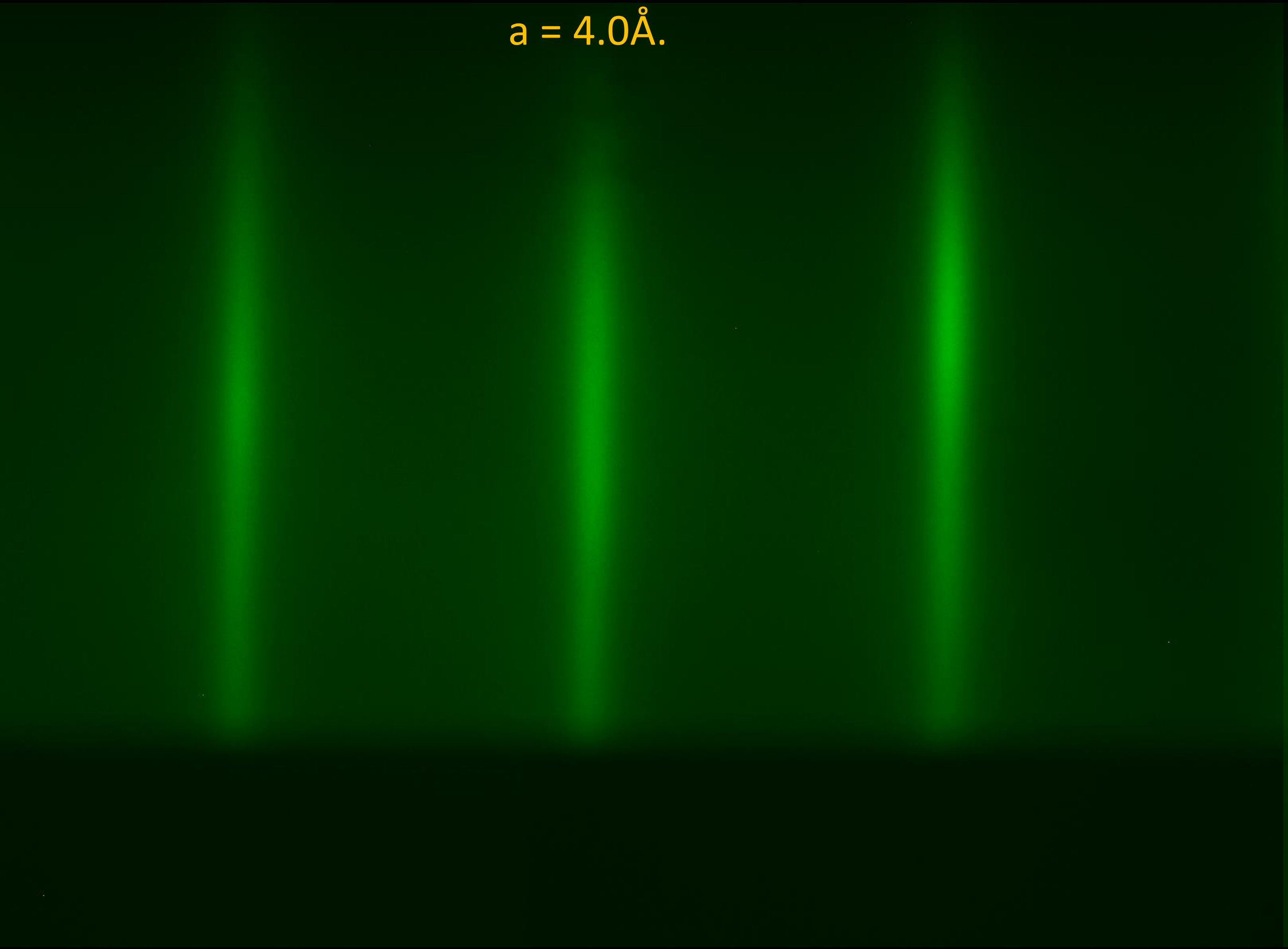

Cap heated to 200ºC.
Se leaves revealing Te crystal.


Cap heated to 235ºC.
Te crystal disappears and
RHEED returns to amorphous.

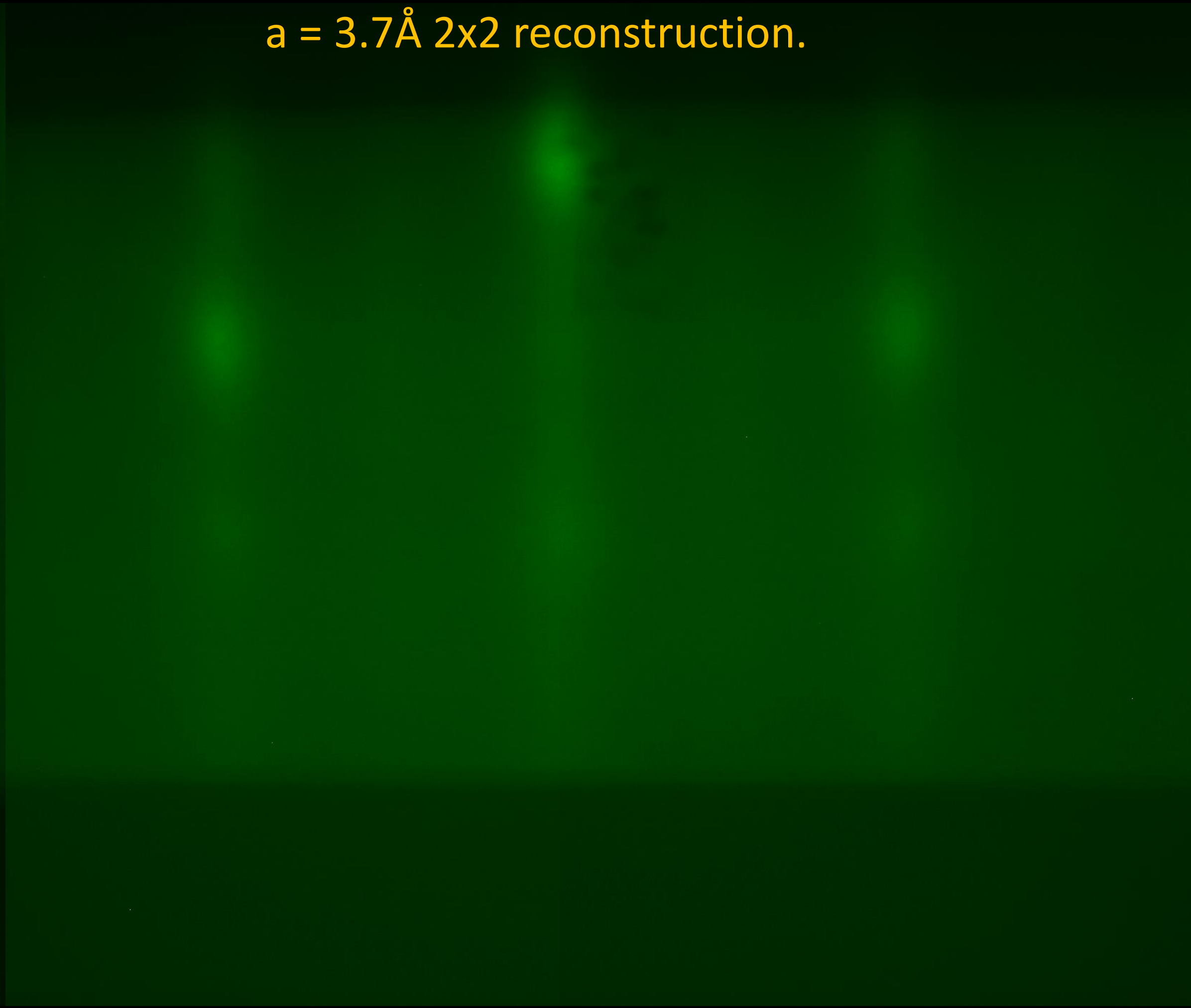

New 3D phase appears at 275ºC.


New phase has: a = 3.7Å, is 3D,
slight reconstruction.

Thin Te decapped
a = 4.0Å.

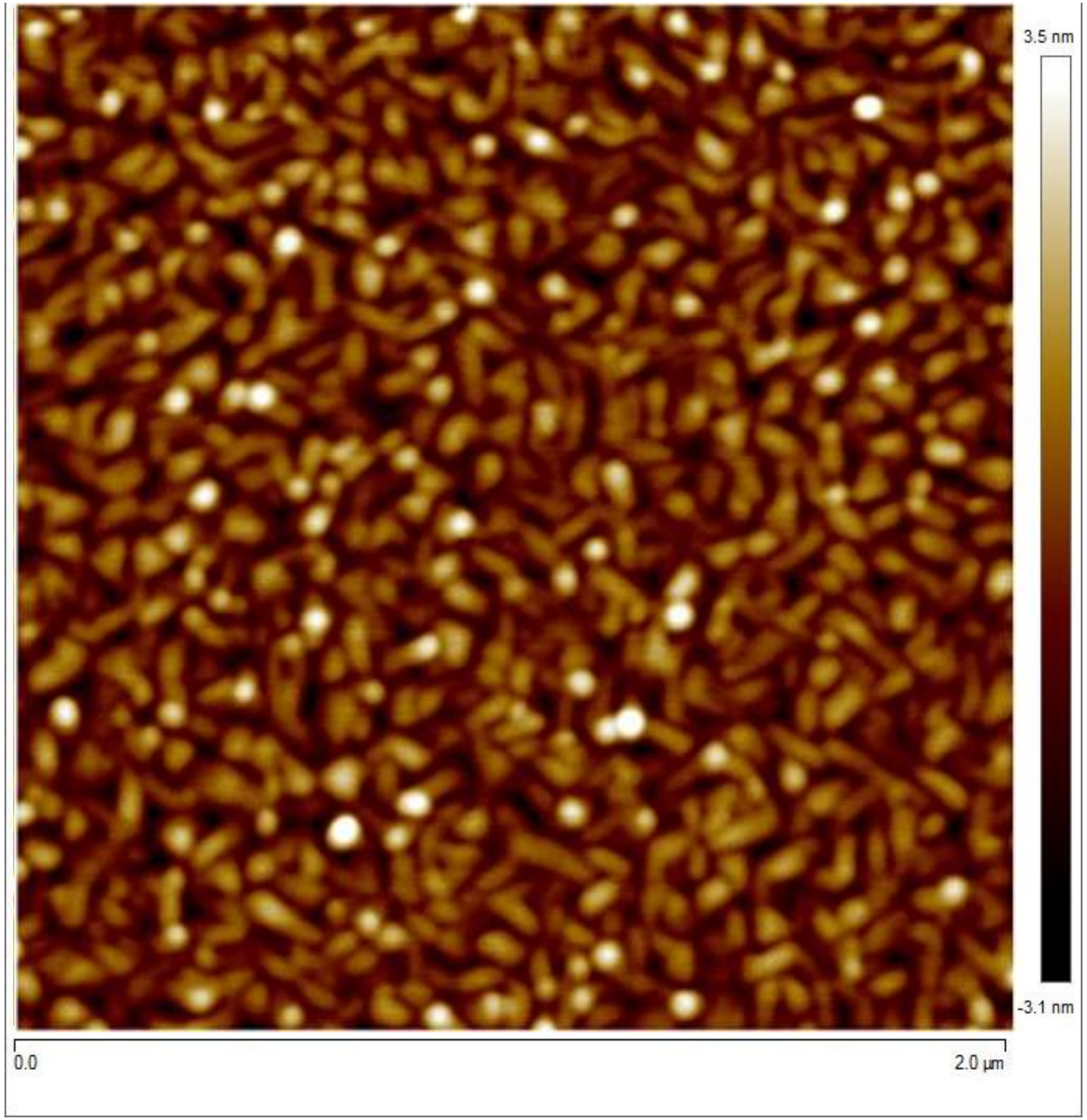


Thin Te with Se decapped
a = 3.7Å 2x2 reconstruction.



Selenium penetration

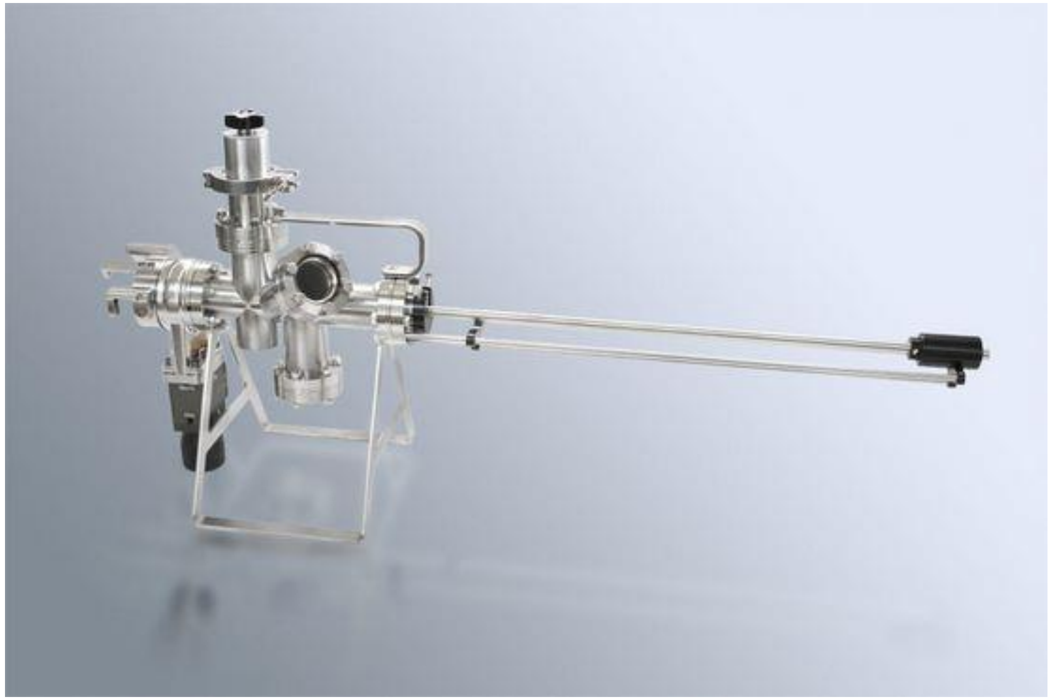
At low temperatures tellurium does not have energy to reorganize to a single crystal, resulting in random distributions.



AFM of a flat crystal capped with Tellurium at room temperature.

Next steps for the project

New elements for the chalcogen MBE chamber?



Long range Ultra-High Vacuum suitcase?