V_3Si thin film deposition at Daresbury Laboratory.

WP9 meeting

Christopher Benjamin

Overview

- As expected from an A15 superconducting material, V_3Si has a relatively high critical temperature, T_c , of ~17.2 K. Similar expectation to Nb_3Sn.

- Previous work has various methods of thin film production of V_3Si:
    - Diffusion of Si into Bulk V [1]
    - Co-sputtering and single target sputtering using magnetron sources[2]
    - HiPIMS [3]

- We have started with Pulsed DC magnetron sputtering of single alloy target.

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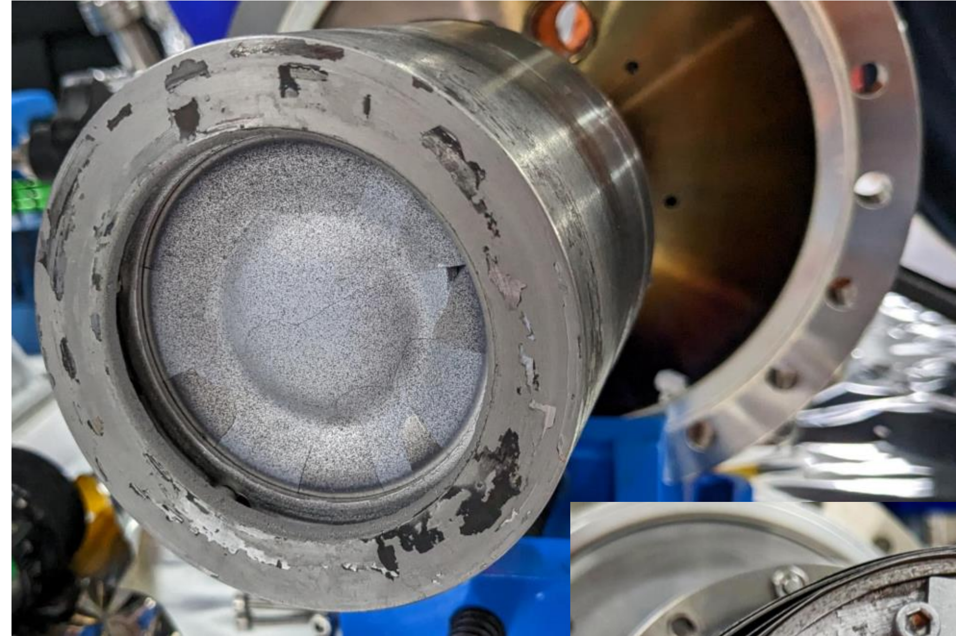
[1] S. M. Deambrosis. Proc. SRF '07. WE203.
[2] K. Howard, arXiv: 2031.00756, 2023
[3] F. L. Estrin, *9th Int. Workshop on Thin Films and New Ideas for Pushing the Limits of RF Superconductivity,* Poster 2021

Deposition system

- System is equipped with a single planar magnetron source (V_3Si alloy target).
- Sample holder capable of heating to 800 C.
- Kr as the process gas.
- Base pressure $5x10^{-9}$ mbar



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Deposition 1 –

- Pulsed DC magnetron sputtering.

- Three samples:
  - 10 x 10mm Cu piece
  - 50 mm diameter Cu disk
  - Sapphire wafer

Surface analysis:
SEM/EDX
SIMS
XPS

DC magnetic field penetration measurements
[Liam Smith]

T_c (Four point probe)
[Liam Smith]

Deposition parameters:
Substrate Temp: 790 C
Deposition length: 1:20:00
Pulse length: 1.1 µs
Frequency: 350 kHz
Power: 300 W

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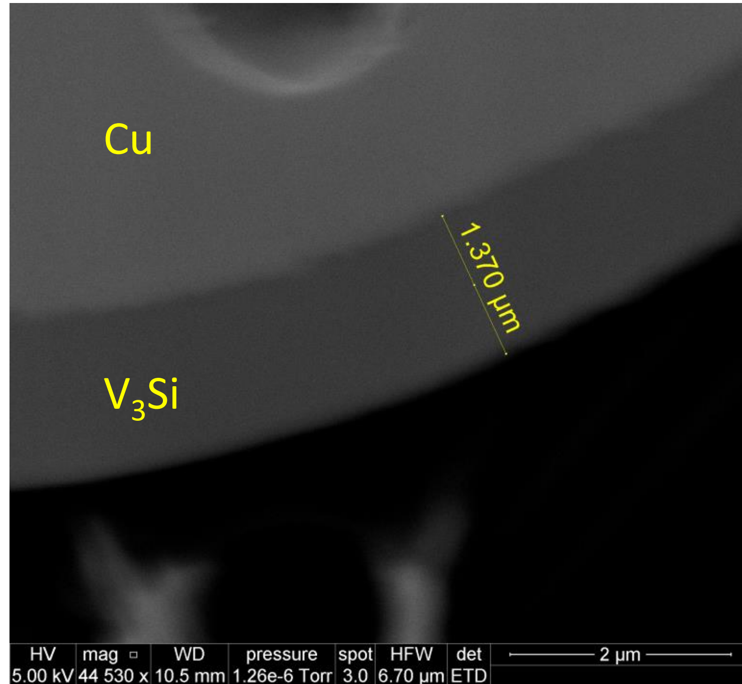
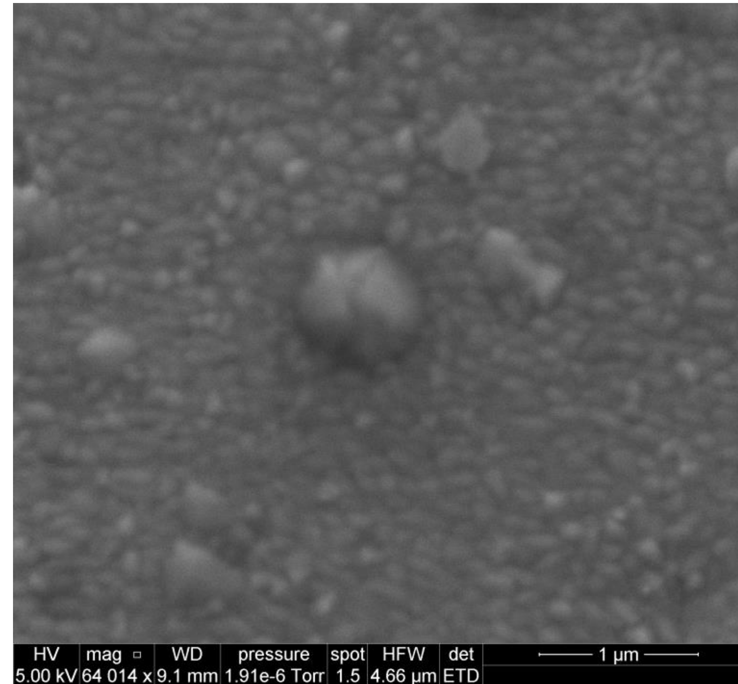
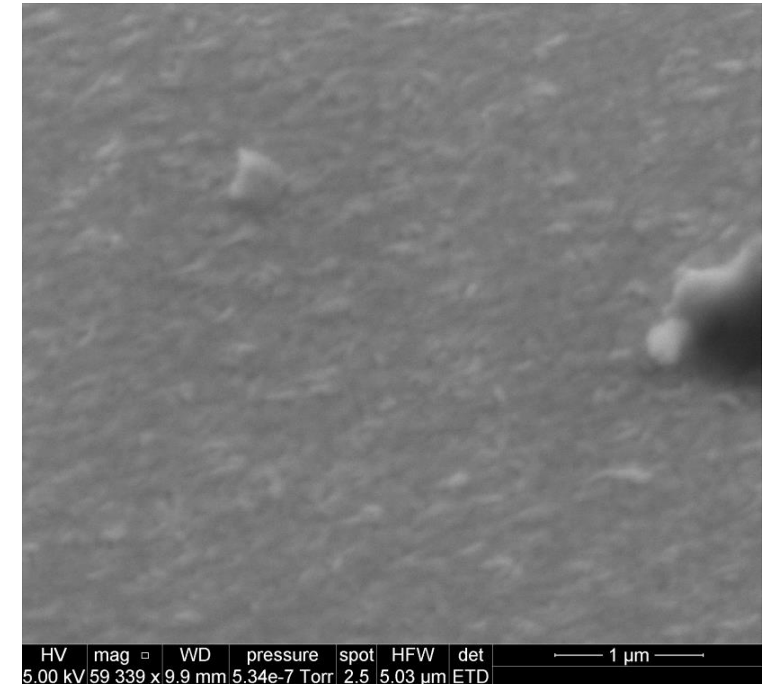
Surface Characterisation: SEM/EDX D1



V_3Si cross section on Cu



V_3Si on Cu morphology



V_3Si on sapphire

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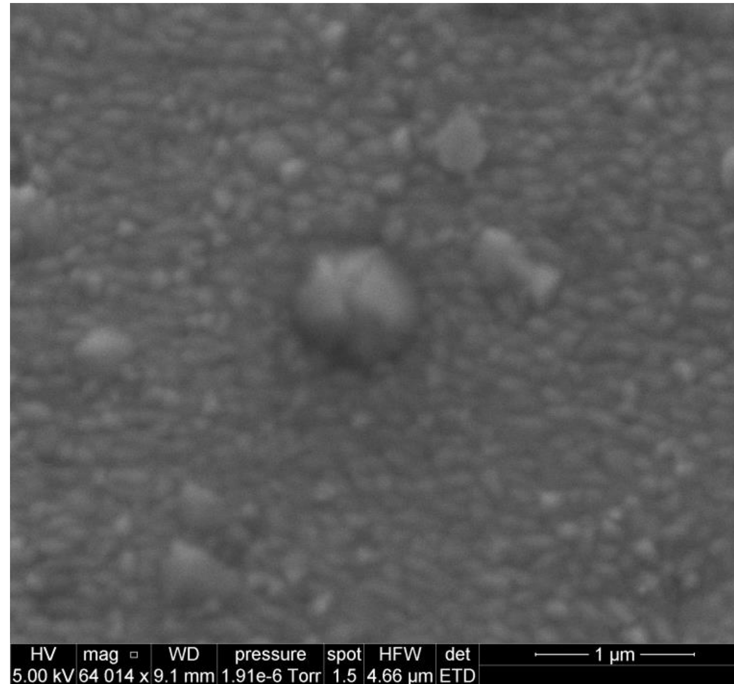
Surface Characterisation: SEM/EDX D1

Energy dispersive x-ray spectroscopy:

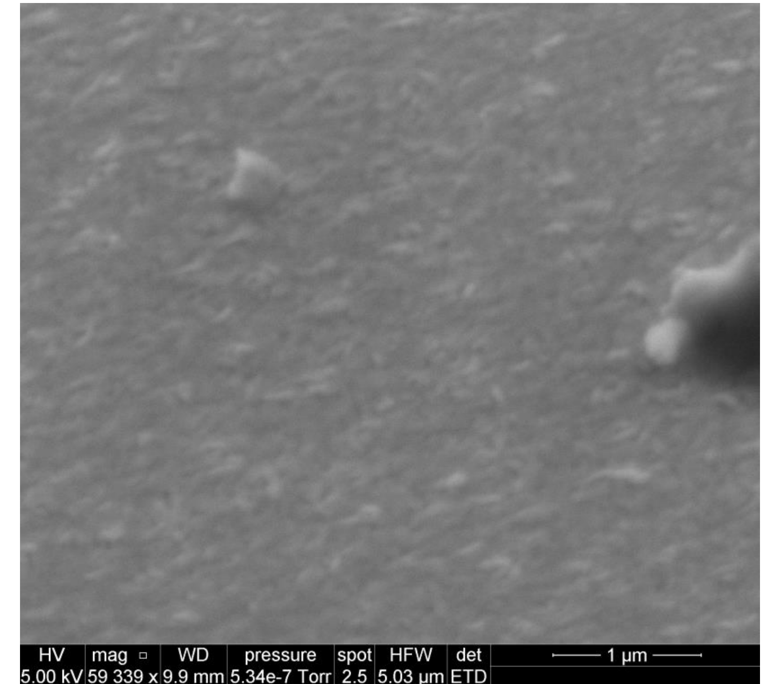
Composition:

- V 72 %
- Si 28 %

- Slightly silicon rich.



V_3Si on Cu morphology



V_3Si on sapphire

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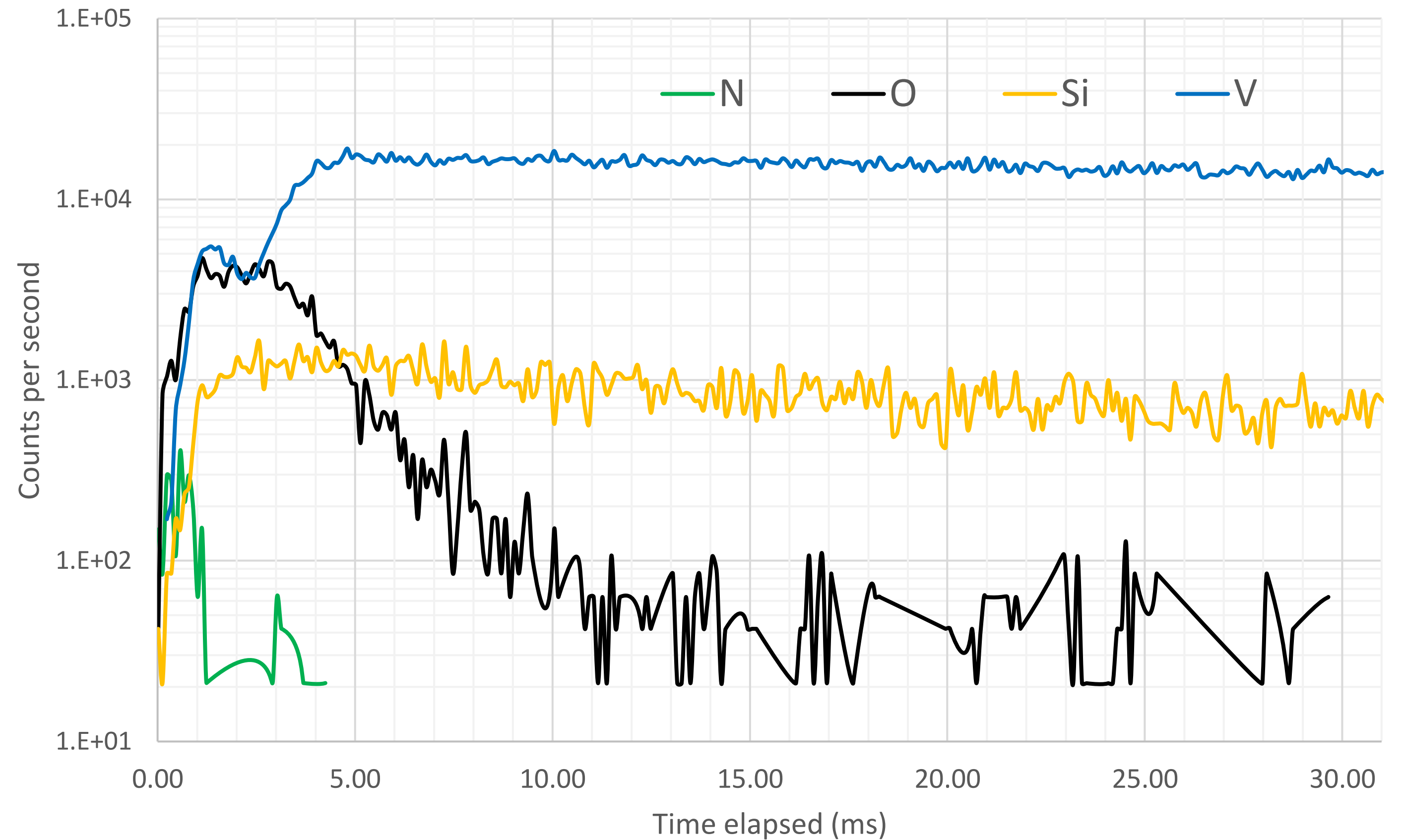
Surface Characterisation: SIMS D1

Last dataset taken on this sample set was Secondary Ion Mass Spectroscopy

- We now have the capability to conduct SIMS measurements and will be introducing it as a final characterisation step. Depth profiling and checking for contamination through the bulk.
- A surface oxide layer present.
- A consistent V – Si layer throughout the Bulk



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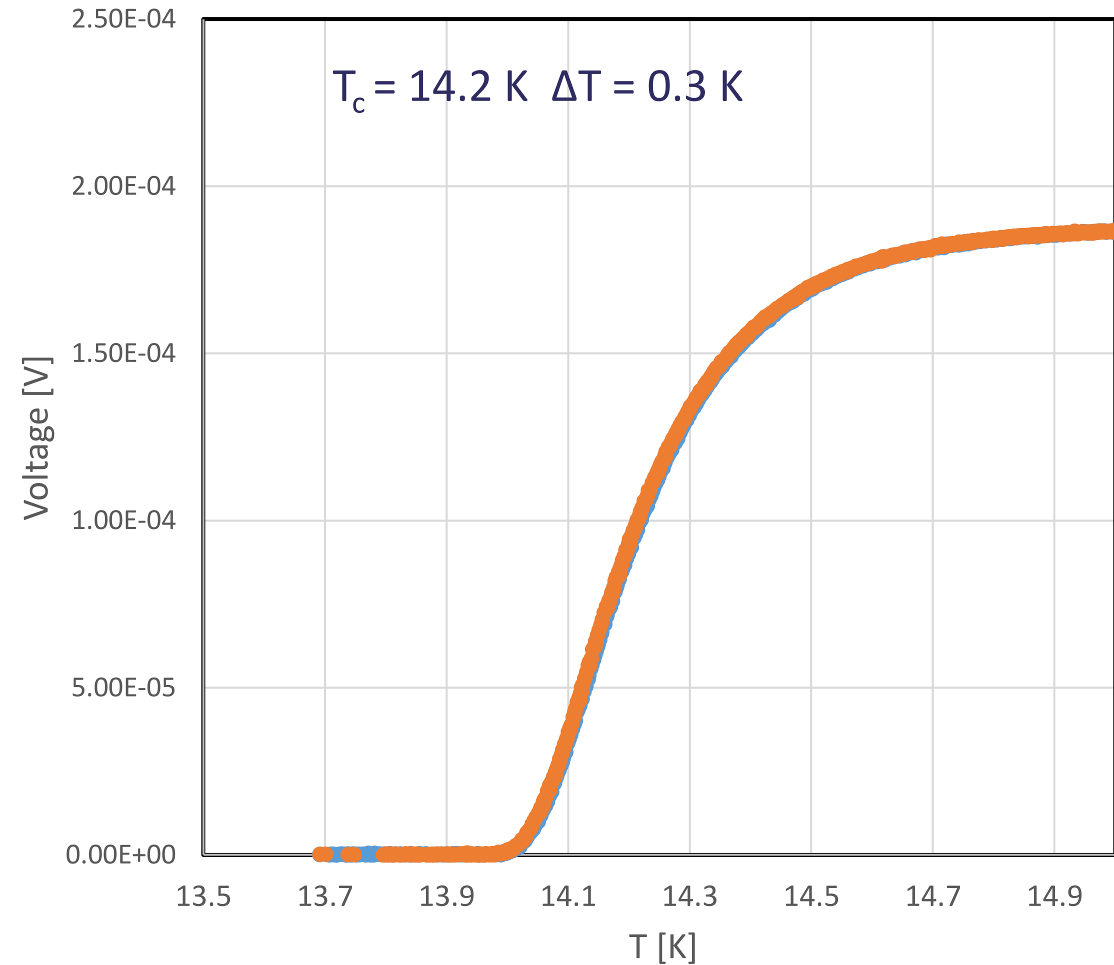
T_c Measurements D1

- A measured T_c of 14.2 K on the sapphire sample using four point probe.



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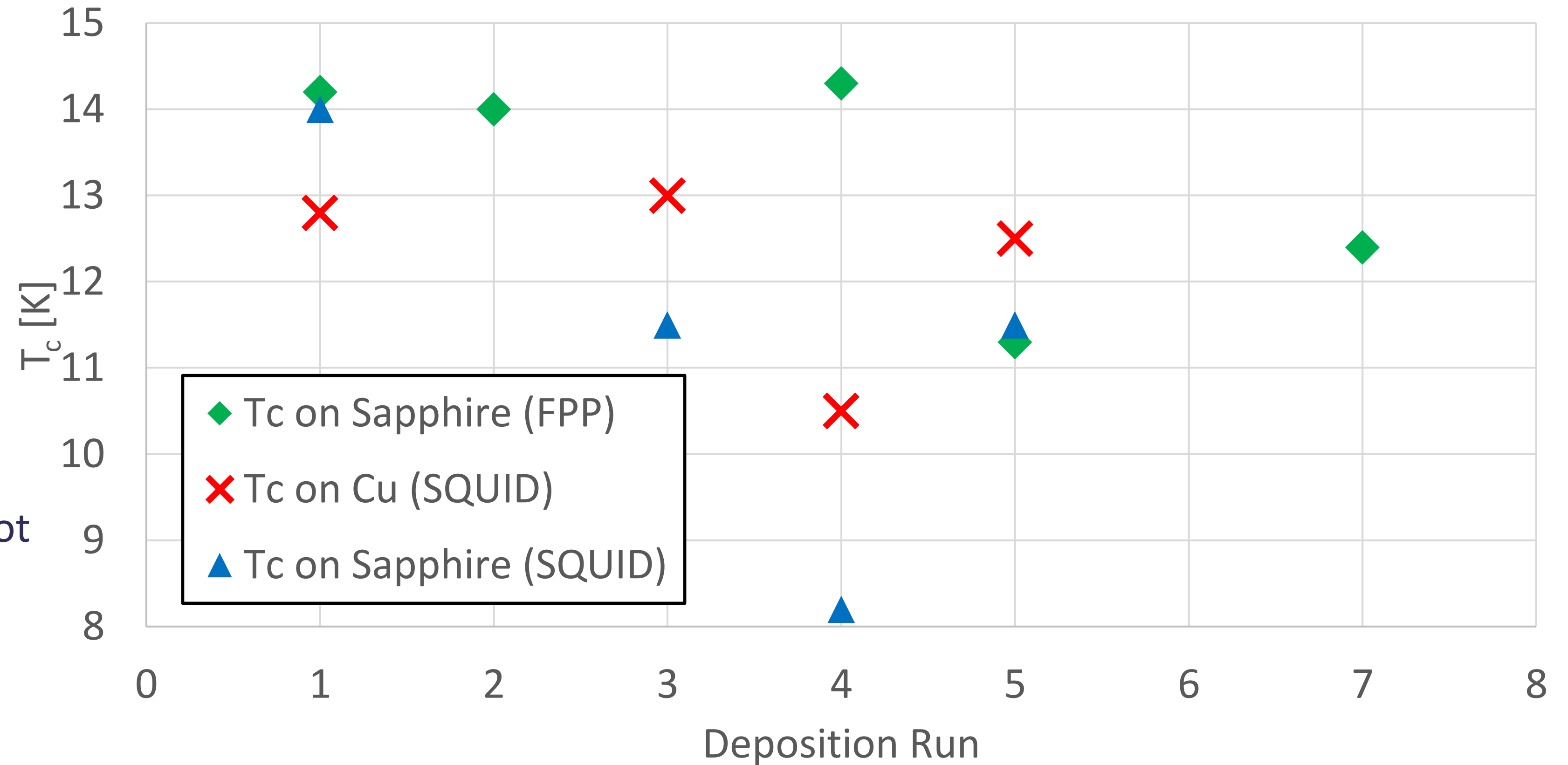
Deposition Summary

- In total 10 depositions have been done with T_c's measured for most sapphire substrates. A few samples were sent to Eugen Seiler For SQUID.

- Initial work was to investigate substrate temperature during deposition.

- T_c varied with no consistency in relation to substrate temperature.

- Last two depositions (9 and 10) repeated first deposition but were not superconducting.



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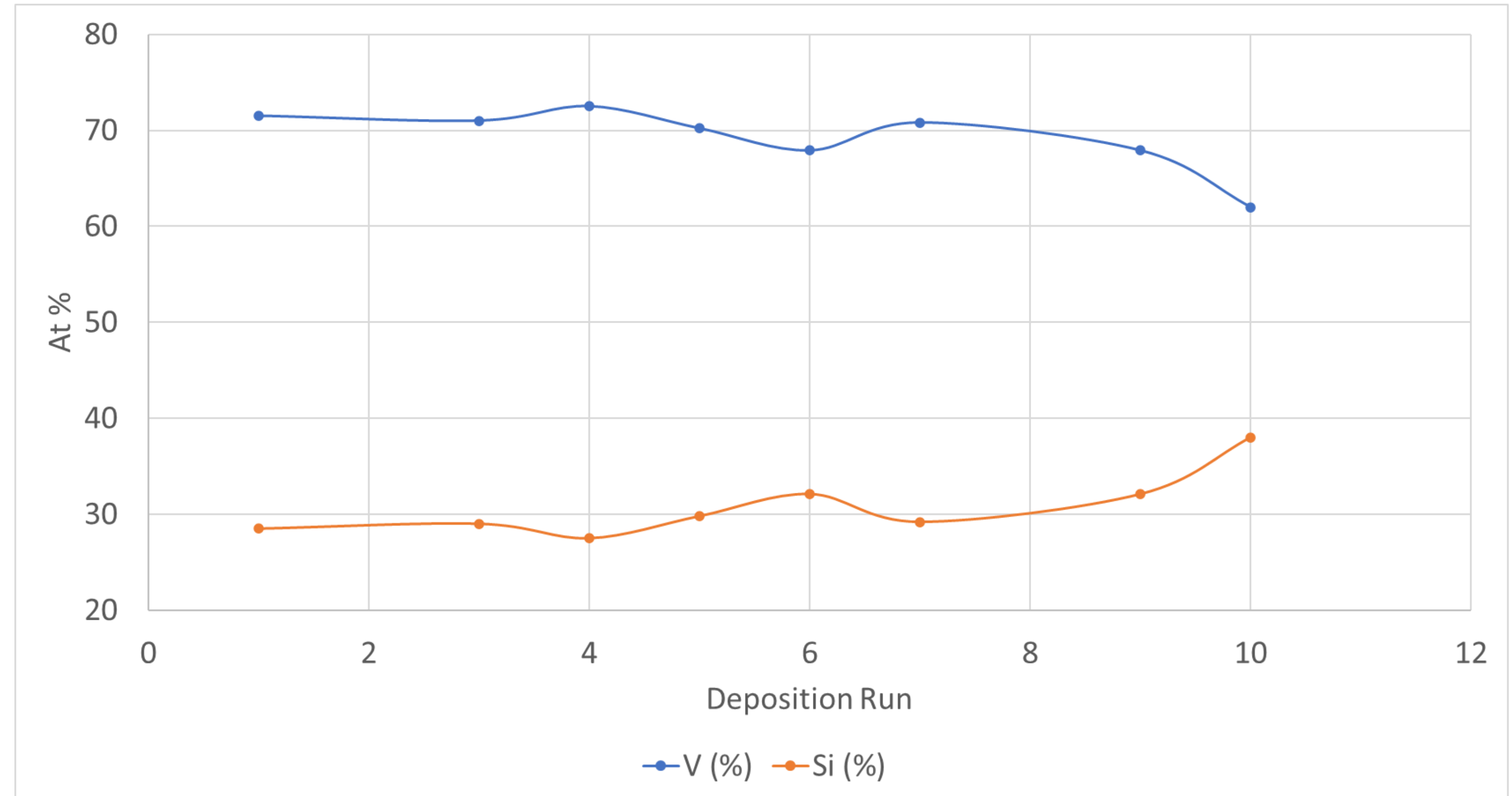
Composition variation

- Energy dispersive x-ray analysis shows a change in composition over time.
- All samples Si rich but at% increasing over time.
- Resulting in later depositions definitely not the desired A15 phase.
- Target removed and replaced with a fresh one.



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Next steps

- Full characterisation of surface and bulk can now be achieved with SIMS, SEM, XPS and EDX. In conjunction with superconducting testing facilities.

- A fresh V_3Si target has been loaded into the system. First set of depositions will investigate composition and reproducibility of the film.

- Investigation into substrate temperature, post-annealing and HiPIMS.

- Adapt the system to allow for the 100 mm diameter samples for the RF choke cavity system to measure surface resistance managed by Dan Seal.

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Thanks for listening

Acknowledgements

STFC: Reza Valizadeh, Oleg Malyshev, Liam Smith, James Colon and Daniel Seal

Institute of Electrical Engineering SAS: Eugen Seiler for the SQUID measurements

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