Deposition and Characterisation of V3Si films for SRF Applications

Science and Technology Facilities Council

Christopher.Benjamin@stfc.ac.uk

C. Benjamin[1,2], L. Smith[1,2], J. Conlon[1], O. B. Malyshev[1,2], R. Valizadeh[1,2]
D. Seal[2,3], N. Leicester[2,3], H. Marks[2,3], G. Burt[2,3]

1. ASTeC, STFC Daresbury Laboratory, Sci-Tech Daresbury, Warrington WA4 4AD, UK
2. The Cockcroft Institute, Sci-Tech Daresbury, Warrington WA4 4AD, UK
3. School of Engineering, Lancaster University, Lancaster, UK

Introduction

A15 materials are potential alternatives to Nb for next generation thin film SRF cavities. V_3Si is a promising candidate due to their high critical temperature (17 K) and upper critical field (24.5 T)[1].

V_3Si films have been manufactured by a variety of methods: Thermal diffusion, co-sputtering and single alloy targets, all with varying levels of success. Film quality, surface roughness, V-Si phases and other defects all hinder cavity performance.

Presented is the progress made on planar V_3Si thin films and initial results of a V_3Si split 6 GHz cavity at Daresbury Laboratory, UK.

V_3Si thin films on planar samples

Deposition Parameters	Units	
Voltage	[V]	566
Current	[A]	0.53
Power	[W]	300
Frequency	[kHz]	350
Pulse Length	[μs]	1.1
Deposition Length	[min]	180
S1 Substrate Temperature	[°C]	670
S2 Substrate Temperature	[°C]	710

Table 1: Deposition parameters and substrate temperatures for all depositions shown.

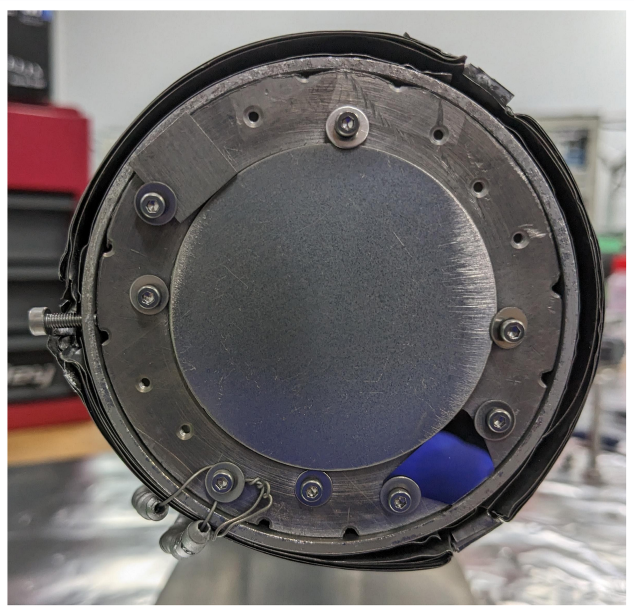

Figure 1: Photograph of a V_3Si thin film coated planar Cu sample

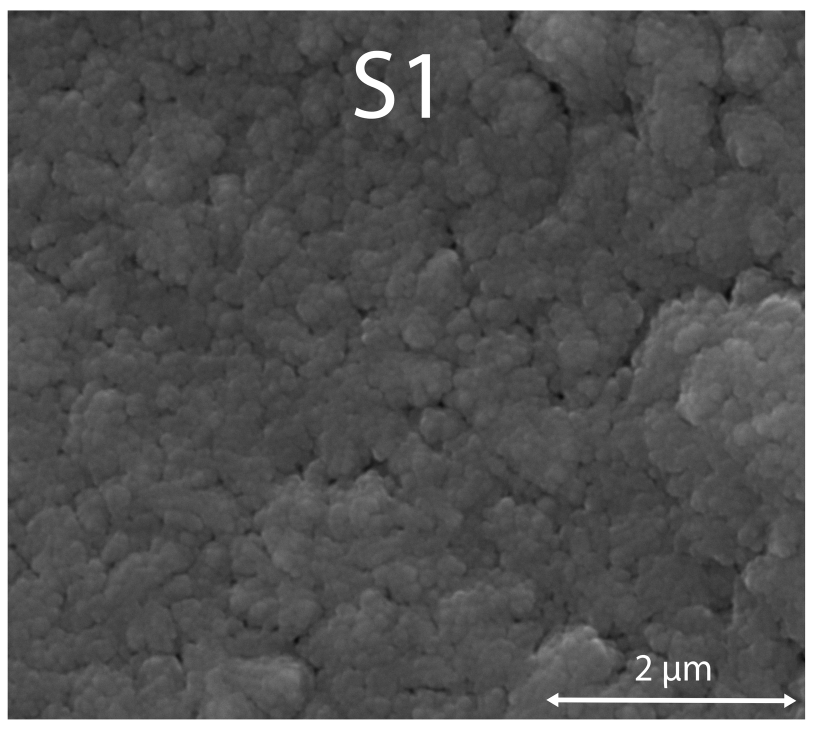

Figure 2: Secondary electron microscope image of a V_3Si thin film coated planar Cu sample (S1). Displays a grain structure with grain sizes of a few 100 nms.

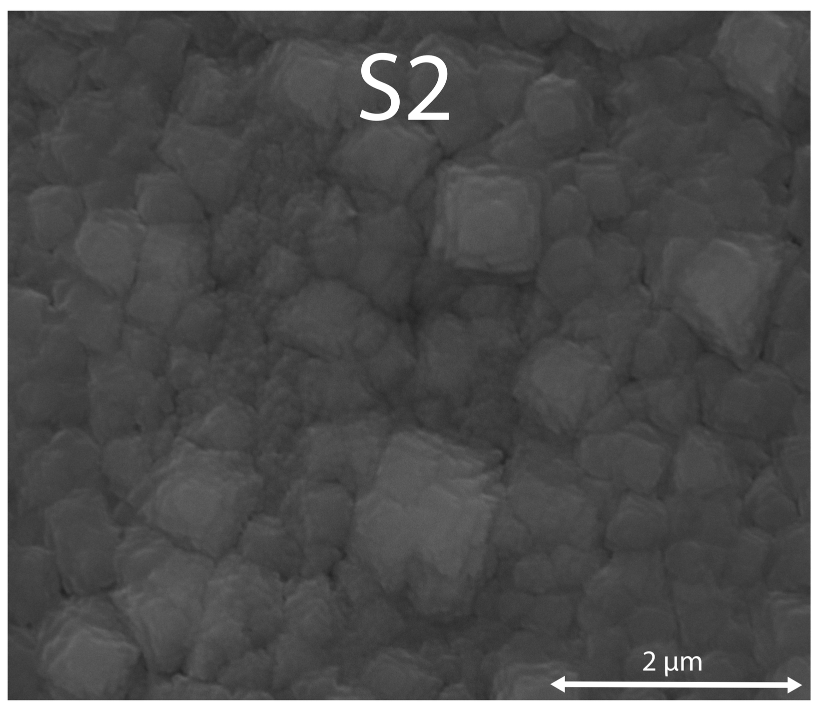

Figure 3: Secondary electron microscope image of a V_3Si thin film coated planar Cu sample (S2). The increased temperature compared to previous sample, S1, led to significant increase in grain size.

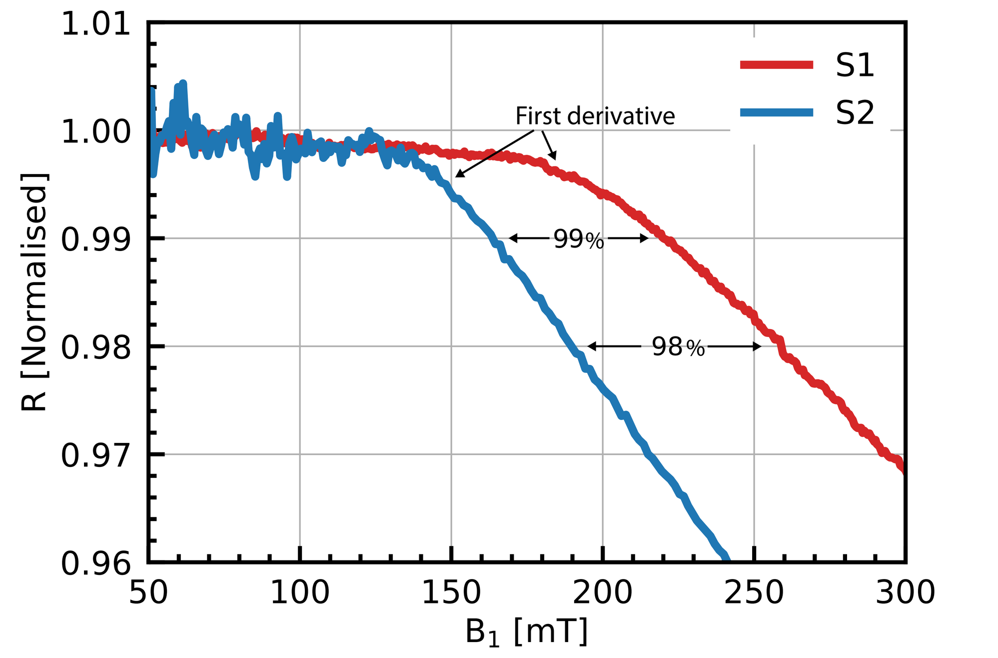

Figure 4: DC magnetic penetration measurements at 4.2 K for both S1 and S2 samples. First field penetration (B_{fp}) is extracted at three points.

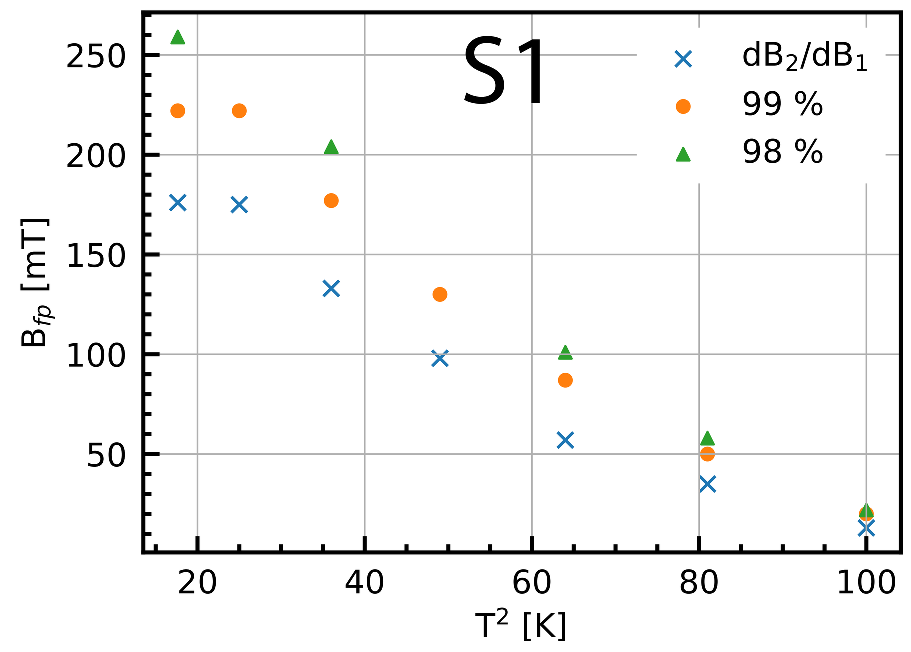

Figure 5: Extracted B_{fp} as a function of sample temperature for S1 using the DC magnetic penetration measurements

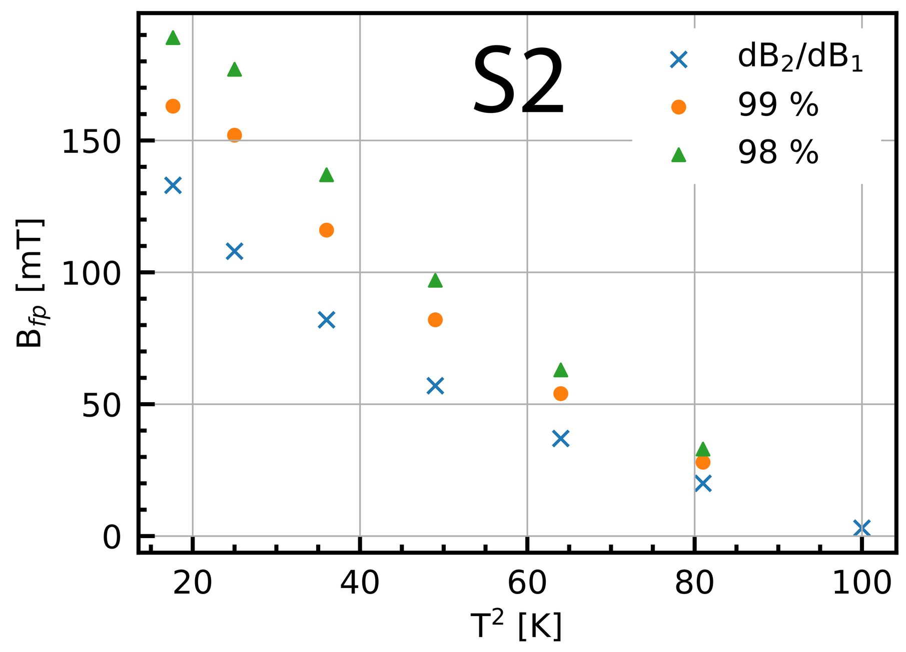

Figure 6: Extracted B_{fp} as a function of sample temperature for S2 using the DC magnetic penetration measurements

Planar: results and discussion

VSi films were deposited on two 50 mm oxygen free high conductivity (OFHC) copper disks, using pulsed DC magnetron sputtering, labelled S1 and S2. The substrate temperature varied between the two samples.

Secondary electron microscopy of the surfaces (fig. 2 and fig. 3) show a significant variation in grain size, structure and uniformity. Energy dispersive X-ray spectroscopy (EDX) results were:

S1 - V : 71% and Si : 29 %

S2 - V : 76% and Si : 24 %

Both samples were tested using The Magnetic Penetration Facility (MPF)[2] at Daresbury Laboratory, where a significant variation in superconductivity between the two samples was observed.

Figure 4 - shows the variation between the two samples at 4.2 K with the complete field penetration measurements as a function of temperature in figures 5 and 6.

V_3Si thin film on a split 6 GHz cavity

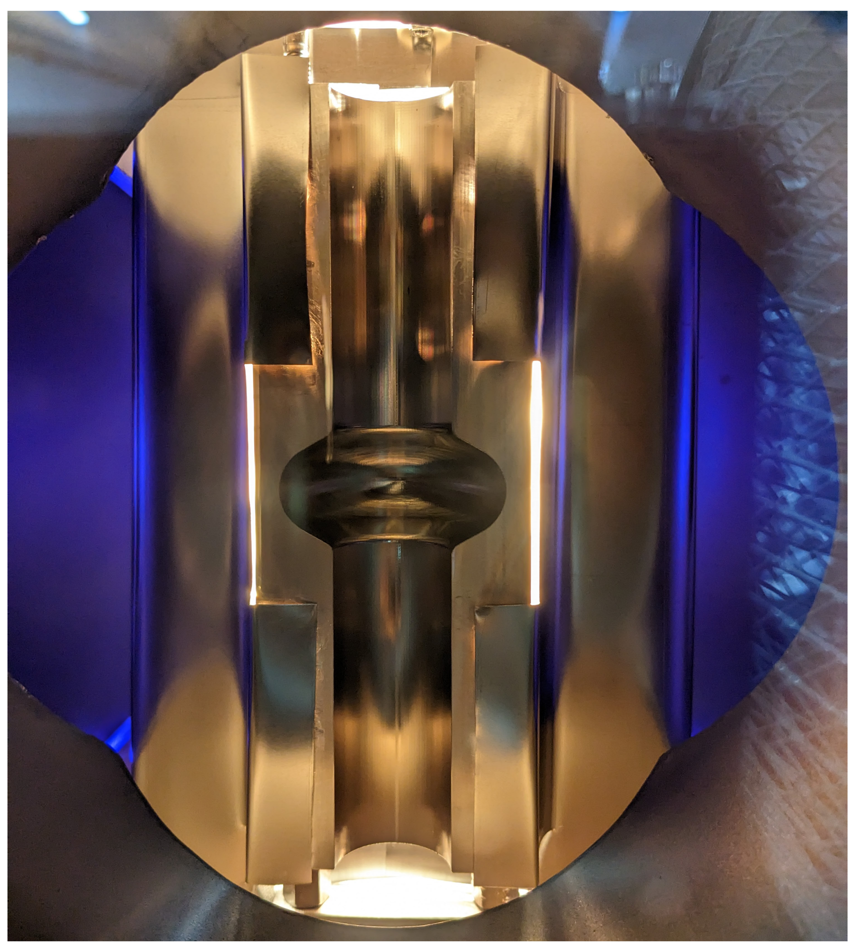

Figure 7: Photograph of the split 6 GHz cavity during depositon

Figure 8: Photograph of the split 6 GHz cavity after deposition

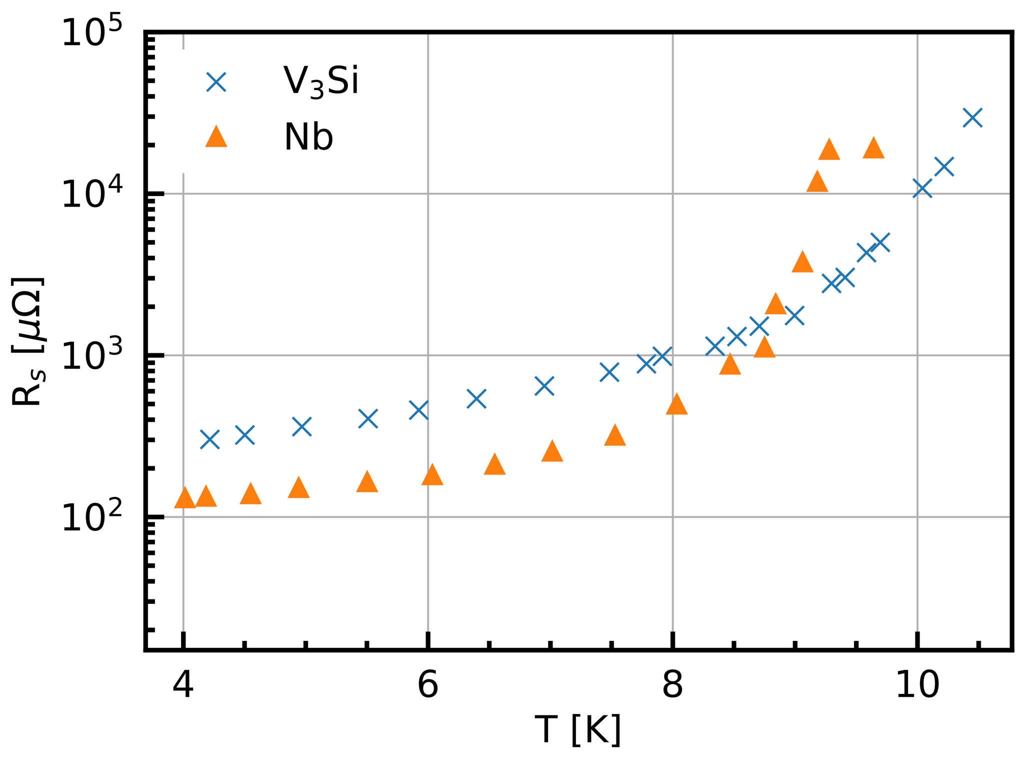

Figure 9: The surface resistance as a function of temperature for Nb and VSi coated split cavity

Split 6 GHz Cavity

Nb and then V_3Si was deposited using the the parameters listed in Table. 1. Cavity temperature was 400 C and 530 C during deposition for Nb and V_3Si respectively.

The cavity was tested at Daresbury laboratory in a low power RF facility measuring surface resistance (R_s)[3]. A superconducting transition is observed. However the results are both dominated by residual resistance of the system. The cavity underwent mechanical finishing but no polishing techniques would could explain the high R_s. Further work is required.

Conclusion

This work highlights the promise of V_3Si as a potential alternative to Nb thin films for SRF applications. Planar depostions results show high performance in DC conditions and further improvements through post processing and HiPIMS may result in more uniform and stiochiometric films.

First RF tests of V_3Si at Daresbury laboratory show a Rs a factor of 2 higher than the Nb deposition. However, improvements in the cavity heating stagae and chemical polishing steps are being established which will reduce residual resistance of the cavity.

References and Acknowledgements

[1]A.-M. Valente-Feliciano, Superconducting RF materials other than bulk niobium: a review, 10.1088/0953-2048/29/11/113002.

[2]D. A. Turner et al., A facility for the characterisation of planar multilayer structures with preliminary niobium results, 10.1088/1361-6668/ac7fbf.

[3]T. Sian et al., Split Thin Film SRF 6 GHz Cavities, 10.18429/JACoW-LINAC2022-THPOGE09.