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BEYOND NICKEL-BASED SUPERALLOYS V: MATERIALS FOR EXTREME ENVIRONMENTS

Powder Metallurgical Synthesis of V_5SiB_2 and V_8SiB_4 Intermetallic Phases

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Introduction

The V–Si–B system provides a promising base for low-density refractory high-temperature materials, as it combines a vanadium-rich matrix strenghtened by silicide and borosilicide phases **[1,2]**.

While vanadium offers a lower density than Mo- and Nb-based systems and a high melting temperature, its limited oxidation resistance and lower strength compared to Mo- and Nb-based systems restrict the use of low-alloyed vanadium materials **[1]**.

Targeted formation of intermetallic phases, particularly V_5SiB_2 and the newly reported V_8SiB_4 phase, may improve microstructural stability and contribute to high-temperature strength **[2-4]**. However, monolithic microstructures are required to assess their individual strength and deformation behaviour. The objective of this work is to synthesise V_5SiB_2- and V_8SiB_4-rich V–Si–B alloys via powder processing and to characterise their microstructure and high-temperature mechanical properties.

Experimental Procedure

1 Mechanical Alloying

Elemental powders: **V** (99.5%) · **Si** (99.5%) · **B** (98%), weighed in a glove box under protective Ar atmosphere.

`steel balls and grinding jars`

`planetary ball mill`

`200 rpm` `20 h duration`

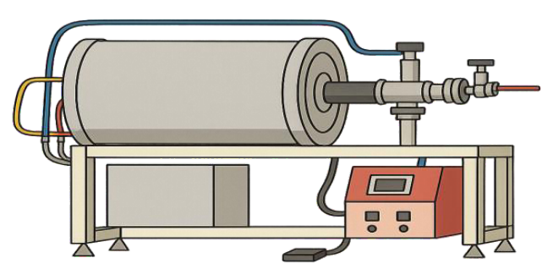
`reverse rotation direction every 15 min`

2 Spark Plasma Sintering

`p = 50 MPa` `T = 1600 °C`

β = 100 K/min $t_{T_{max}}$ = 5 min

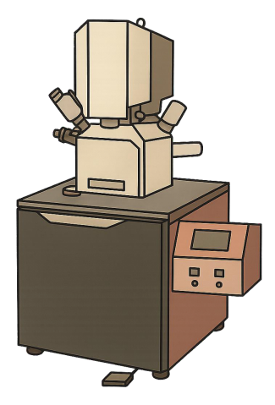
3 Heat Treatment

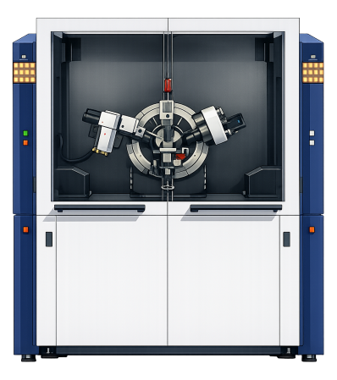


`T = 1400 °C` `t = 100 h`

`in vacuum`

4a Analysis

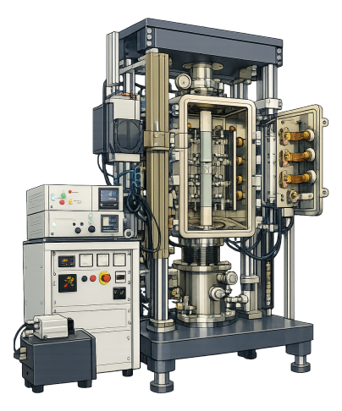




`ICP-OES` `XRD`

`SEM` `EDS` `EBSD`

4b Mechanical Testing

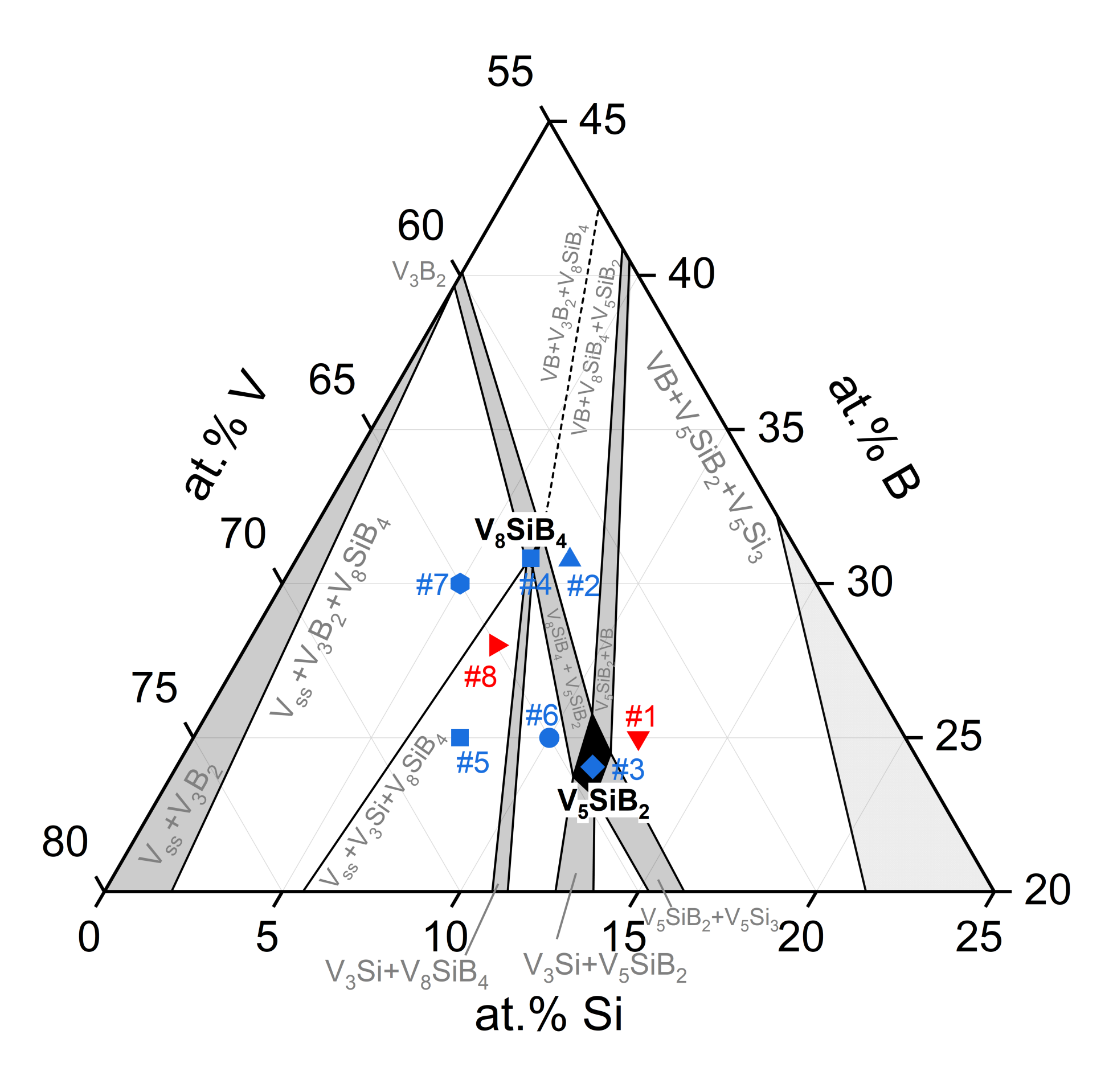


`compression tests` `creep tests`

`bending tests` `T = 1100–1500 °C`

`in vacuum`

Target Phases

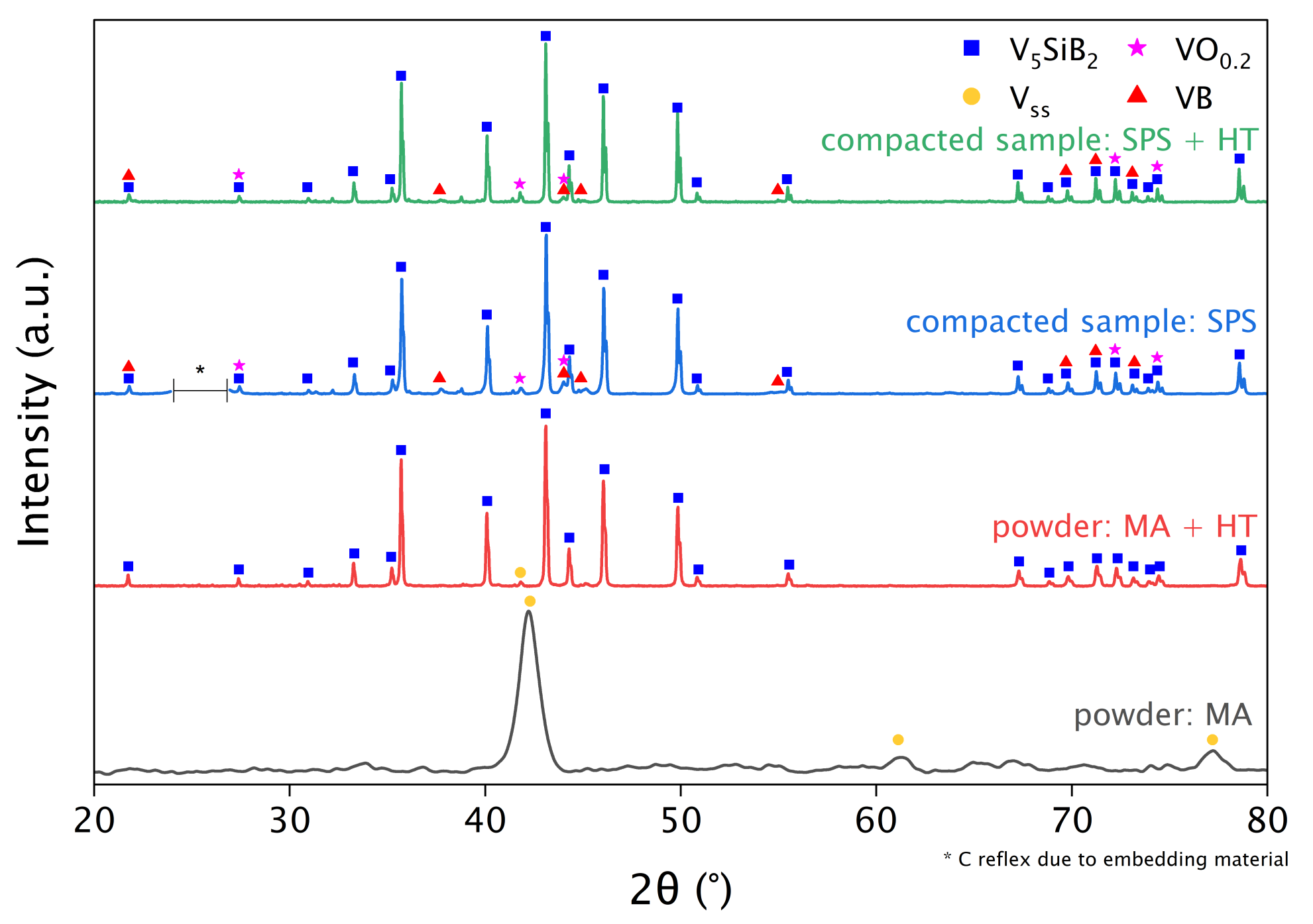


Isothermal section of the V–Si–B system at 1400 ℃ (modified based on **[5]**) showing the investigated alloy compositions #1–#8 and the target phases V_5SiB_2 and V_8SiB_4.

Compositions #1 and #8 were selected as V_5SiB_2- and V_8SiB_4-rich model alloys, respectively. Extended milling beyond 20 h showed no further alloying progress, while limiting the milling time helps to reduce Fe abrasion from the steel milling tools.

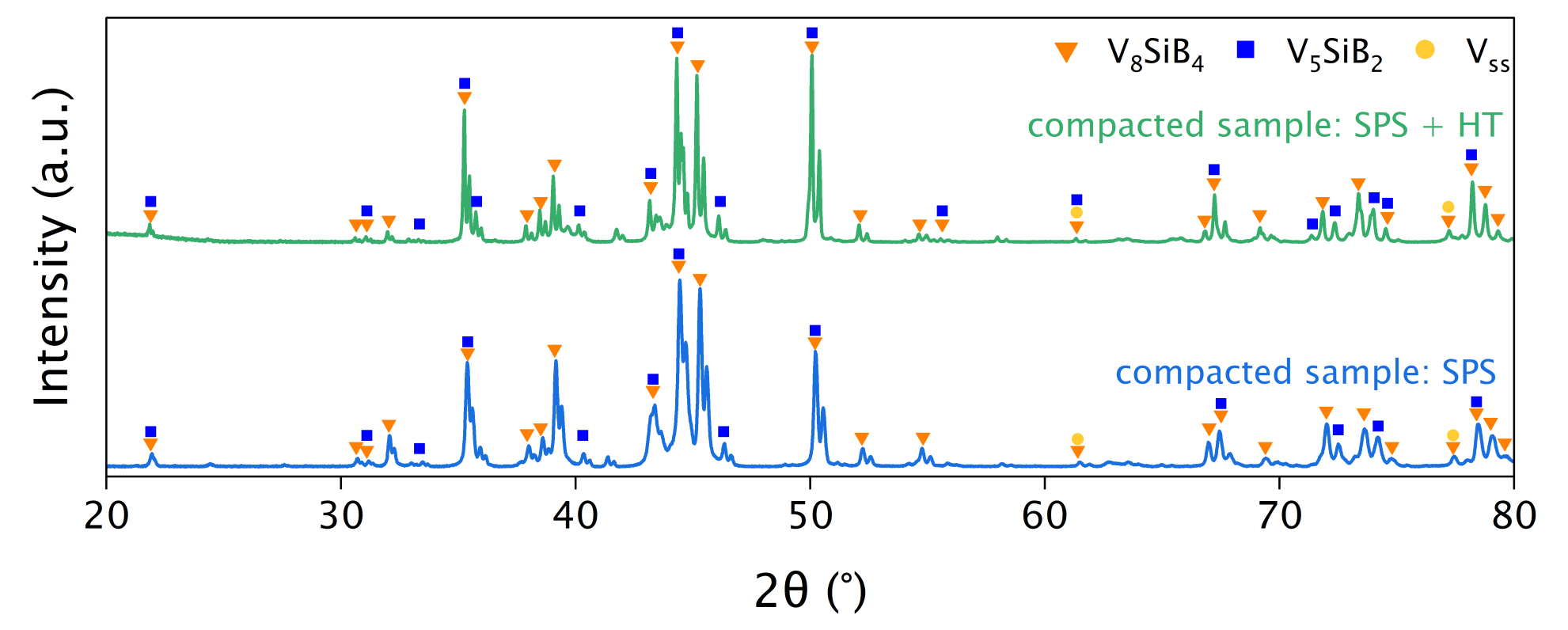
X-ray Diffraction

#1 V-12.5Si-25B, V_5SiB_2 fraction ≈ 95 wt.%



Diffractogram of alloy #1 at different processing stages.

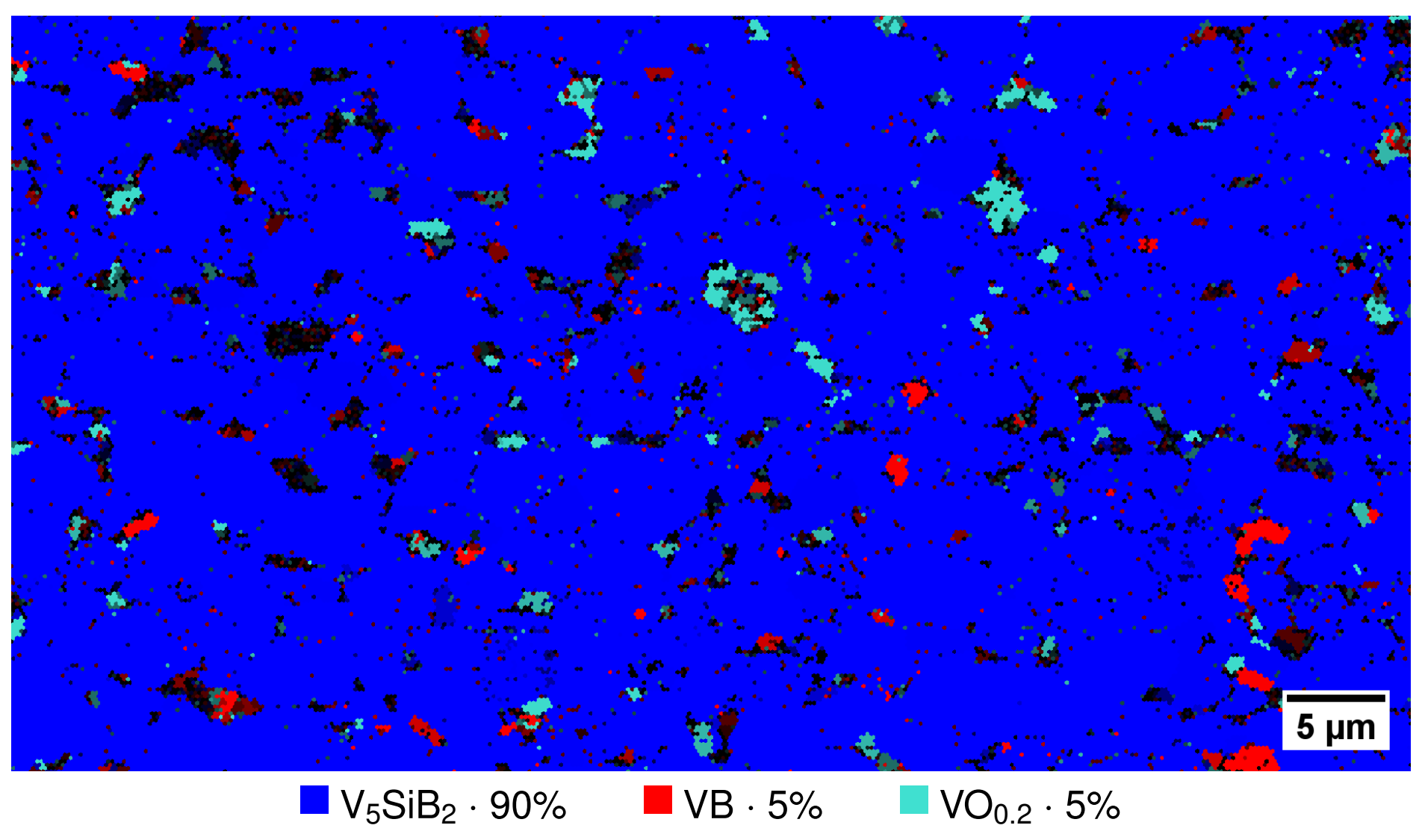
#8 V-7Si-28B, V_8SiB_4 fraction ≈ 80 wt.%



Diffractogram of alloy #8 at different processing stages.

Microstructure

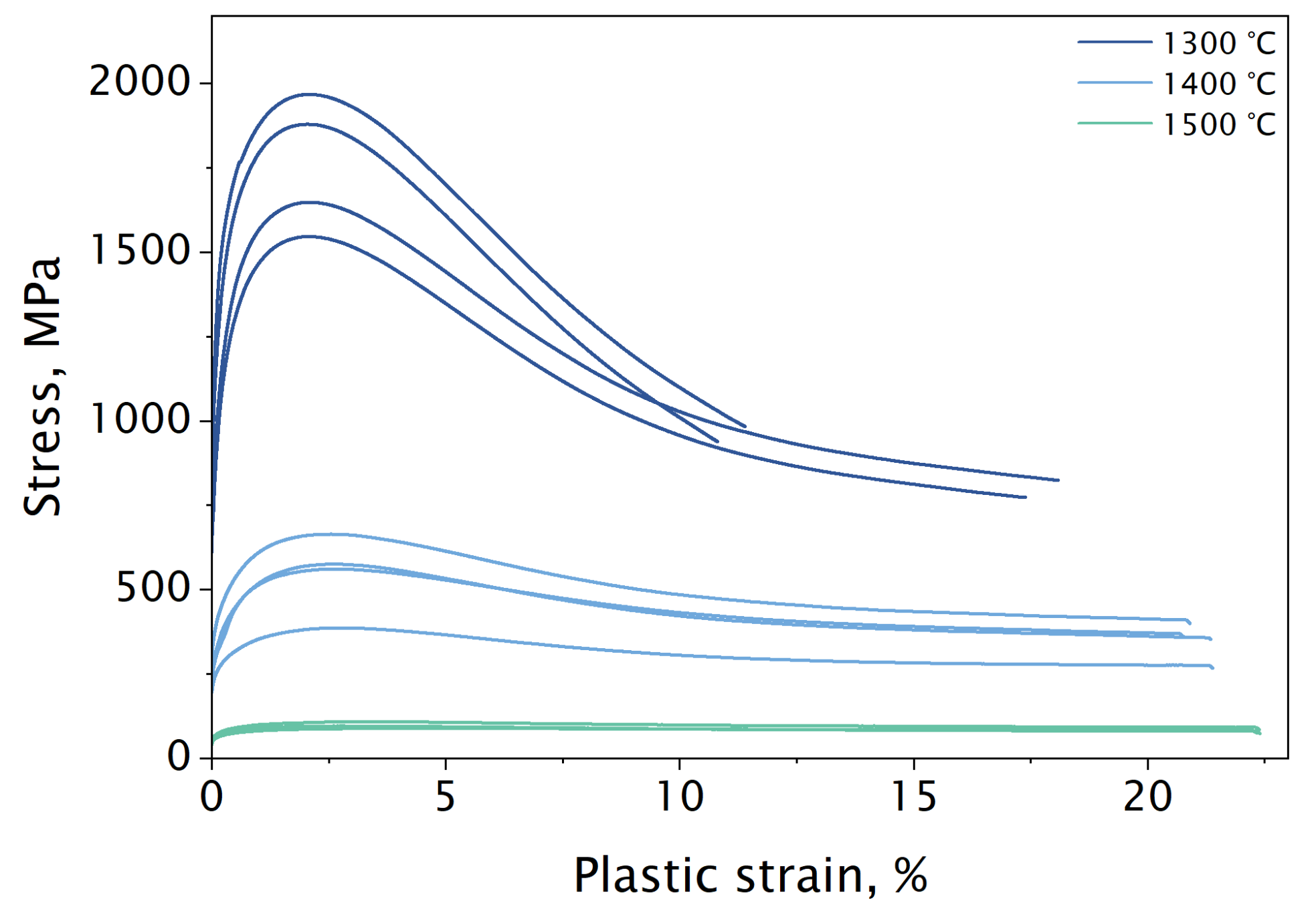
#1 V-12.5Si-25B



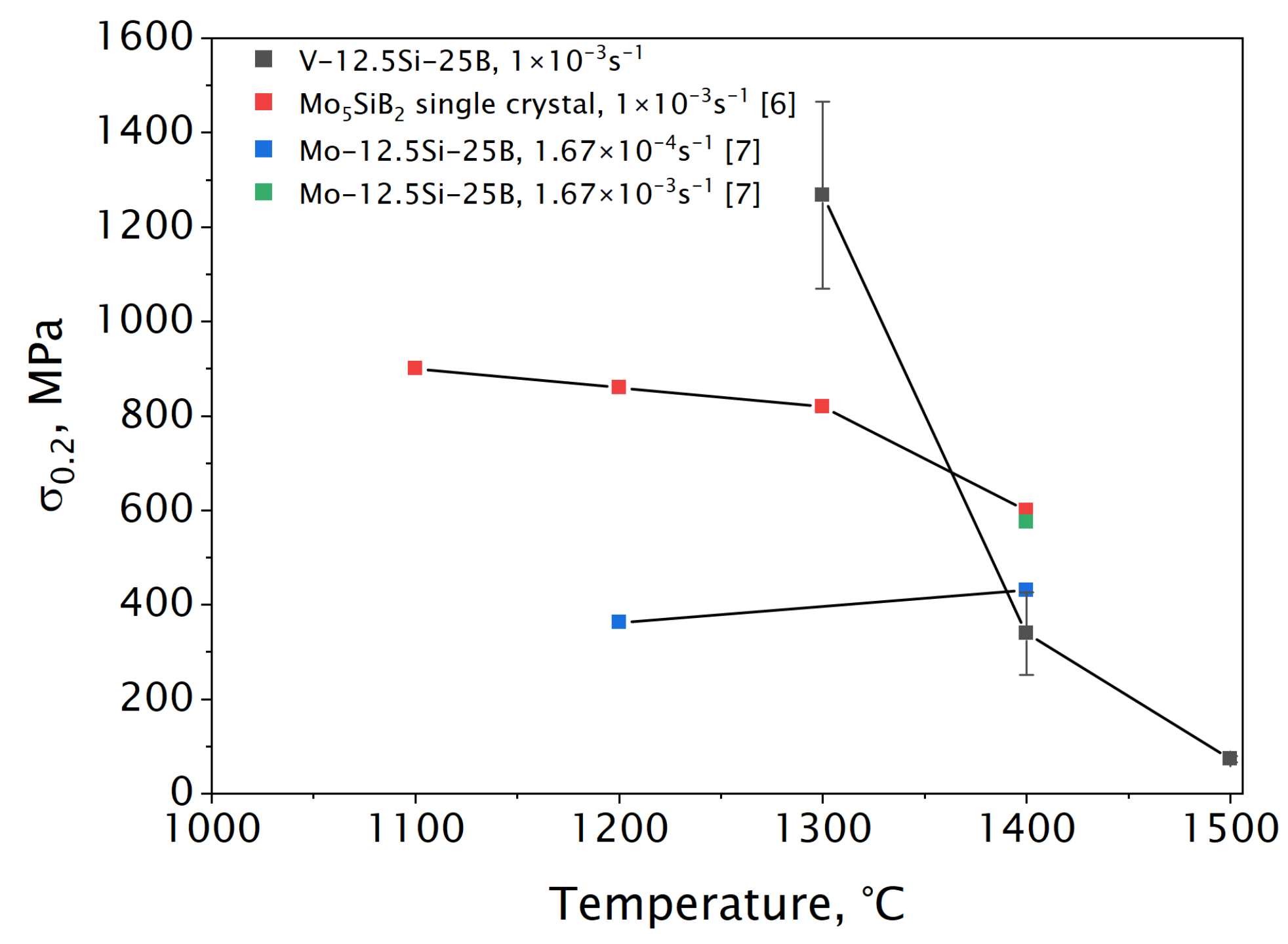
EBSD phase map with confidence index (CI) of alloy #1 showing a dominant V_5SiB_2 phase.

Mechanical Properties

#1 V-12.5Si-25B



Stress–plastic strain curves of #1 V-12.5Si-25B tested at different temperatures.



Temperature dependence of the compressive $\sigma_{0.2}$ values of #1 V-12.5Si-25B determined from the stress–plastic strain curves compared to literature data of single crystals and powder metallurgical processed materials. Literature values were estimated from graphical data and are approximate.

Key Findings

- Three-point bending tests indicate a BDTT for alloy #1 at approximately 1375 ℃.
- High fractions of V_5SiB_2 and V_8SiB_4 can be achieved by powder metallurgy.

Future Prospects

- Creep tests on alloy #1 are currently ongoing to analyse the creep mechanisms and activation energies.
- High-temperature mechanical testing of alloy #8 is in preparation to study the BDTT and stress-strain-behaviour of the V_8SiB_4 phase.

Acknowledgements & References

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