

In-situ MgO strengthening of spark plasma sintered Vanadium alloy

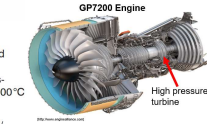
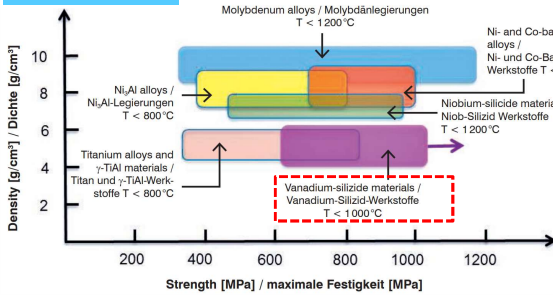
Ievgen Solodky¹, Georg Hasemann¹, Fabian Lanoy², Mathias Galetz² and Manja Krüger¹

¹Otto-von-Guericke-Universität Institut für Werkstoffe, Technologien und Mechanik (IWTM) Universitätsplatz 2, 39106 Magdeburg, Germany

²DECHEMA-Forschungsinstitut, Theodor-Heuss-Allee 25, 60486 Frankfurt am Main, Germany,



Motivation



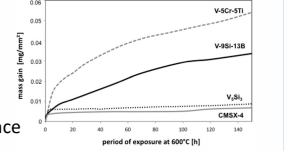
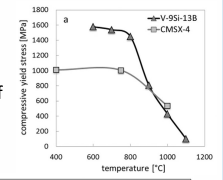
Advantages of V-based alloys

- ✓ High melting points (1900 °C)
- ✓ Low density ($\approx 6 \text{ g/cm}^3$)
- ✓ Higher compressive strength comparable to the strength of Ni-based superalloy CMSX-4 up to 900 °C
- ✓ Higher creep resistance comparable to a cobalt-nickel superalloy at 900 °C

Scientific challenges

- ✓ To improve oxidation resistance and to avoid V_2O_5 formation
- ✓ Increasing the strength of low-alloy vanadium alloys at $T > 600 \text{ °C}$
- ✓ Obtaining the ODS V-based alloy via powder metallurgy technique

The objective of this study was to investigate the effect of in-situ MgO reinforcement on the high-temperature strengthening of the alloy and its influence on the oxidation resistance of vanadium alloy.



M. Krüger, Scripta Materialia, 2016

Methodology

In-situ of MgO particles

Water solution of $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O} + \text{CH}_4\text{N}_2\text{O}$

Vanadium powder compact
Porosity 35-37 %

Infiltration

Infiltrated Vanadium powder compact

Combustion synthesis of MgO at 400-600 °C, 2h

V-xMgO (x=1, 2.5, 5 wt.%) powder compact

Spark plasma sintering

Pulsed DC power supply, Pressure, Graphite punch, Powder, Graphite die, Vacuum chamber, Pressure

$T=1300 \text{ °C}$, $P=50 \text{ MPa}$, $t=5 \text{ min}$

RT and HT compression test

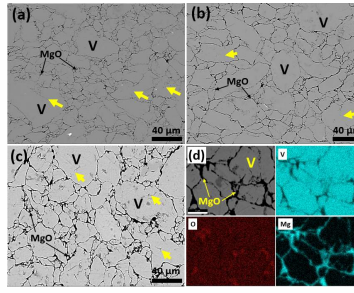
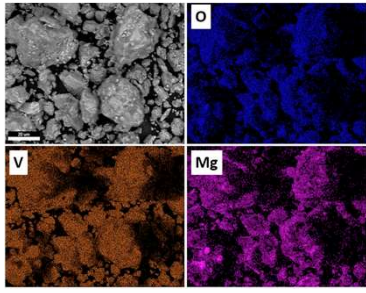
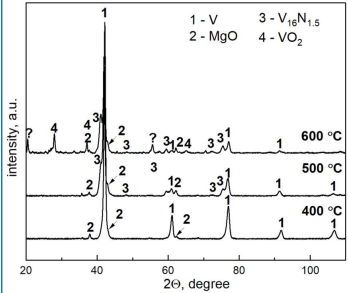
Oxidation tests

Microstructure (SEM), chemical (SEM-EDS) and phase composition (XRD) studies

Results

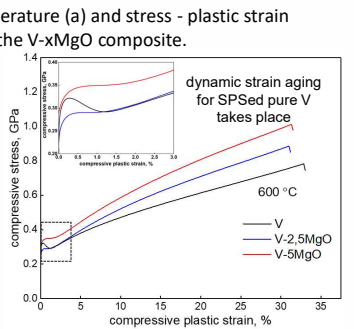
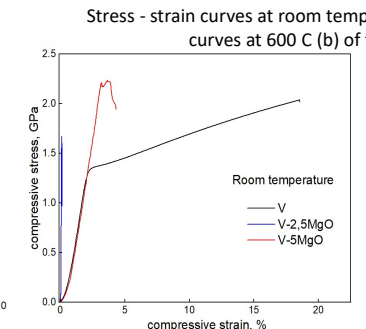
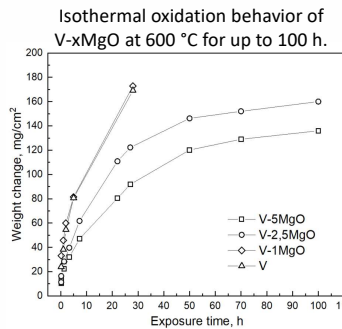
Effect of in-situ combustion synthesis temperature on the phase composition of the V- 5 wt.%MgO composite and MgO distribution.

Microstructure of SPSeD specimens with different MgO concentration: (a) 1 wt.%; (b) 2.5 wt.%; (c) 5 wt.% and (d) elemental mapping of the V-5MgO.

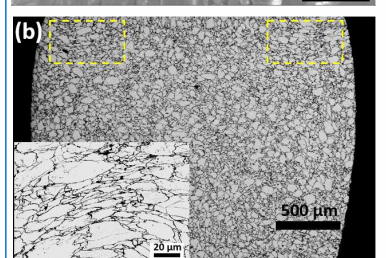
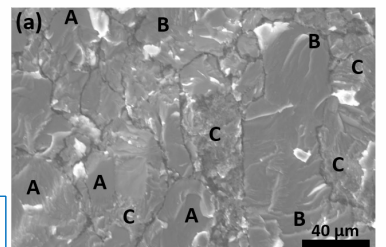


Sample ID	MgO, wt.%	Density, g/cm ³	HV10	Compressive yield stress, GPa	
				RT	600 °C
V	0	6.10	340±12	1.35±0.02	0.3±0.02
V-1MgO	1	6.02	580±14	-	-
V-2.5MgO	2.5	5.98	670±16	1.65±0.1	0.29±0.04
V-5MgO	5	5.85	745±15	2.18±0.07	0.35±0.01

- MgO is evenly distributed along the boundaries of the vanadium grains
- After SPS an almost non-porous state was achieved.
- The grain size of vanadium alloy after SPS is in the range of 5-75 μm



(a) fracture surface after RT compression of V-5MgO showing cleavage facets (at A), twinning (at B) and tearing (at C), and cross section (b) after compression at 600 °C.



Conclusions

- The in-situ formation of dispersed MgO particles in the amount of 1-5 wt.% in a porous vanadium body was performed by combustion synthesis at 400-600 °C.
- SPSeD V-xMgO composites consist of vanadium grains with dispersed MgO particles evenly distributed along the grain boundaries.
- Studies of oxidation resistance at 600 °C showed that the addition of MgO above 2.5 wt.% increases the oxidation resistance of the composite.
- It has been established that, along with V_2O_5 , MgO_6V_2 and $\text{Mg}_2\text{O}_7\text{V}_2$ are formed, which are presumed to enhance oxidative stability. However, the small amount of MgO in the composite does not completely prevent the formation of V_2O_5 .
- The addition of MgO increases the compression strength at room temperature from 1.35 GPa for pure vanadium to 2.18 GPa for the V-5MgO composite.
- Dispersion strengthening with oxide nanoparticles through in-situ combustion synthesis is a promising method for obtaining dispersion-strengthened V-Si-B alloys.