KME 705

$MoSi_2$ matrix composites for components exposed to HT oxidation and hot corrosion

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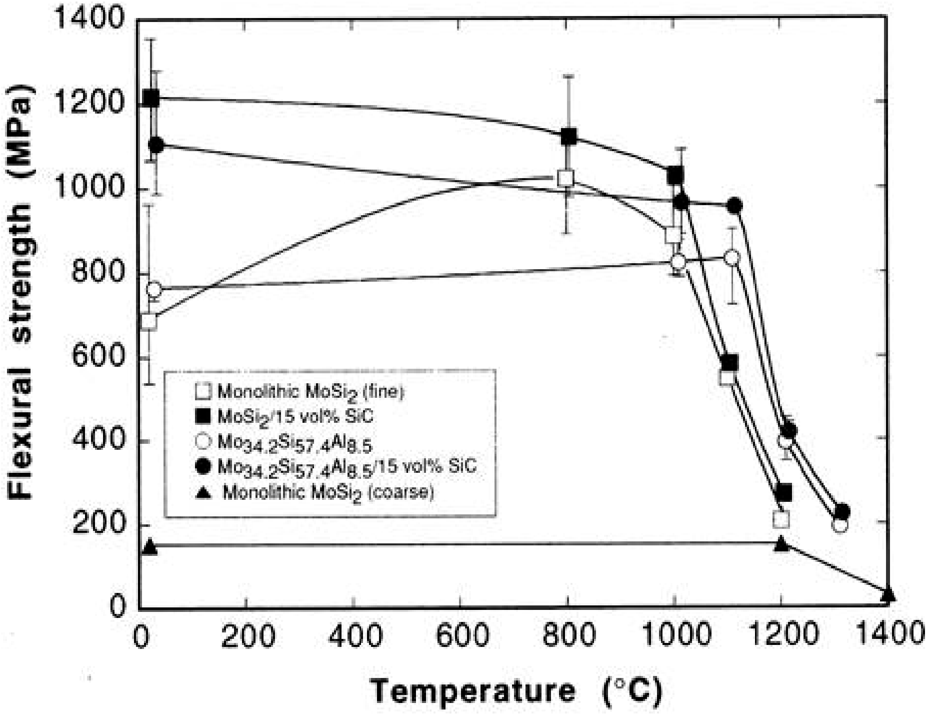
Aim of KME 705

- Produce $MoSi_2$-based composites with improved fracture toughness and mechanical properties over 1200˚C.
- Hot-corrosion resistance at T = 1200 – 1300˚C.

Planned activities in KME 705

- Evaluation of $MoSi_2$-based composites reinforced with SiC to decrease oxidation rates found for $MoSi_2$+15 vol.% ZrO_2 .
- Evaluation of $Mo(Si,Al)_2$-based composites reinforced with SiC to be used in dry atmosphere.



Koichi Niihara, Yoshikazu Suzuki
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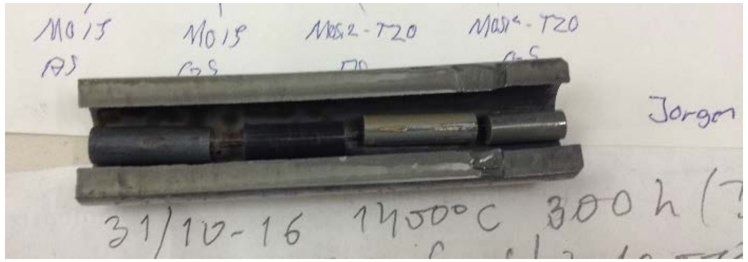
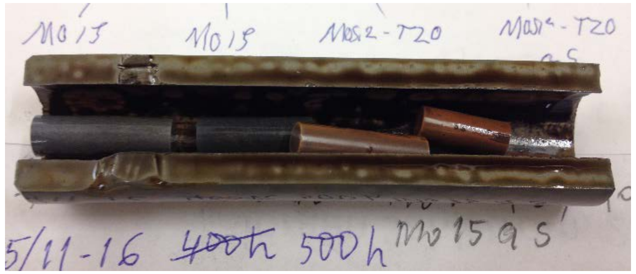
KME – 705 in 2016 period

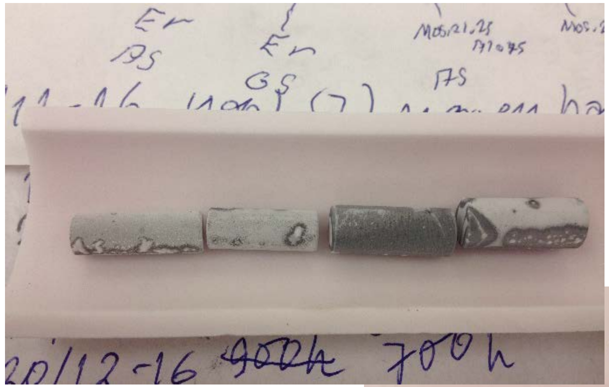
- $MoSi_2$+SiC and Mo(Si,Al)$_2$+SiC composites (5, 10, and 15 vol.% SiC) with moderate sintered density were prepared, using a powder metallurgy and pressureless-sintering (PLS) technique.
- Isothermal exposure at 1400°C for 1000 h and sagging test at 1700°C for 100 h in air were performed. $MoSi_2$-ZrO_2 composite and state-of-the-art Kanthal Super HT were taken as references for comparison.
- Materials were characterized with HV, Kc and microstructure before and after exposure and sagging tests.

Isothermal oxidation at 1400°C for 1000h

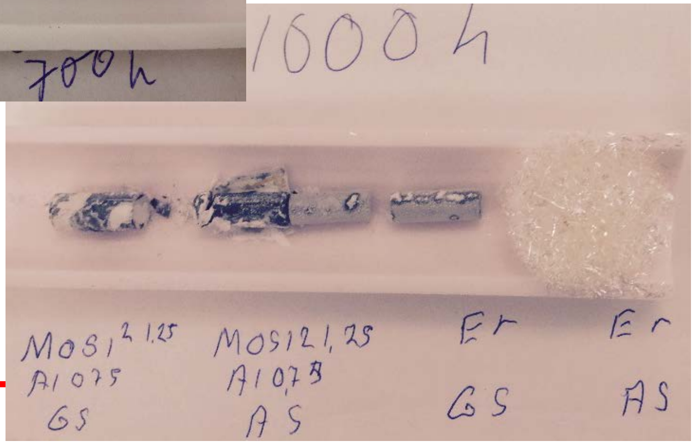


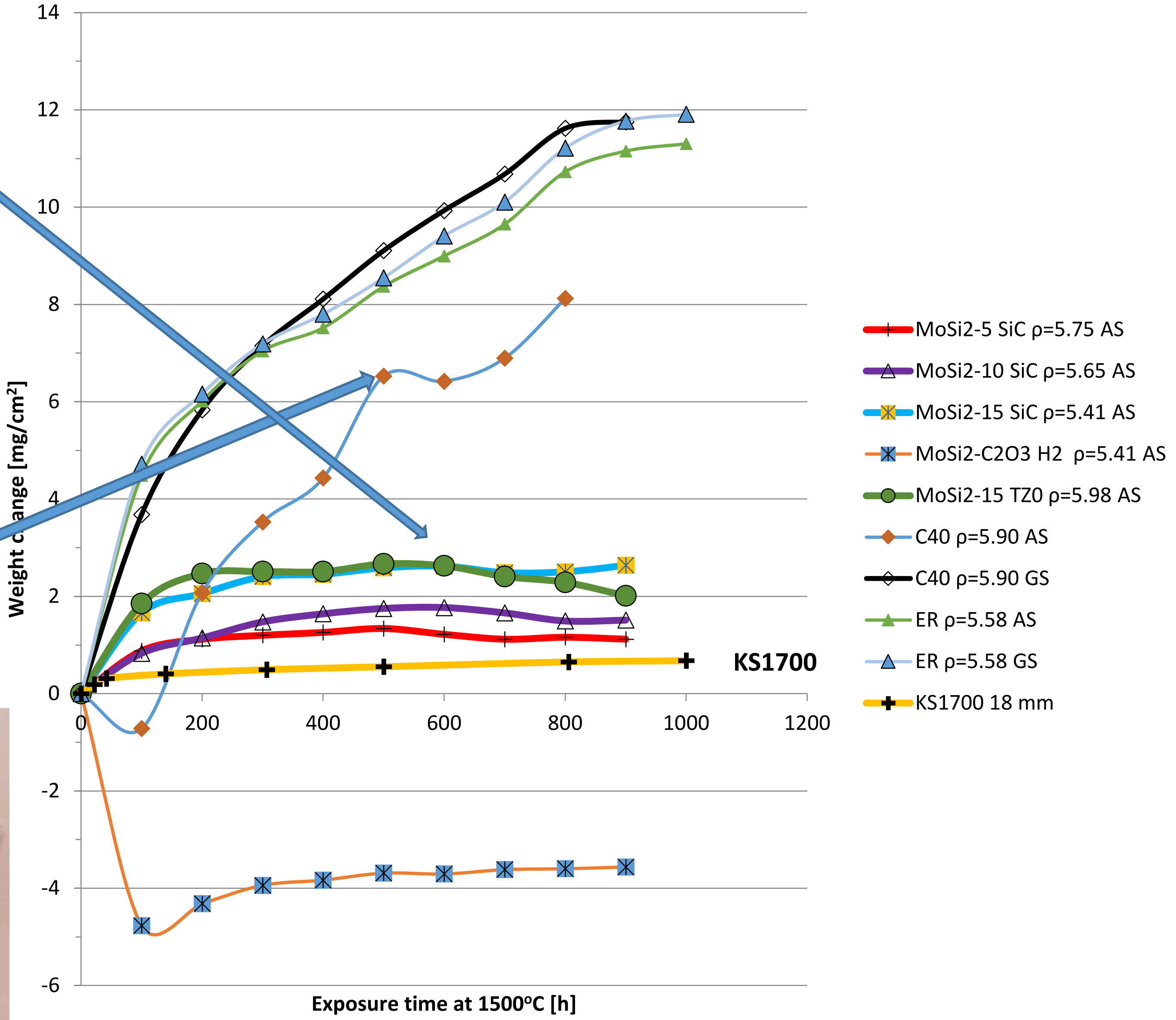
$MoSi_2$ + SiC
$MoSi_2$ + ZrO_2



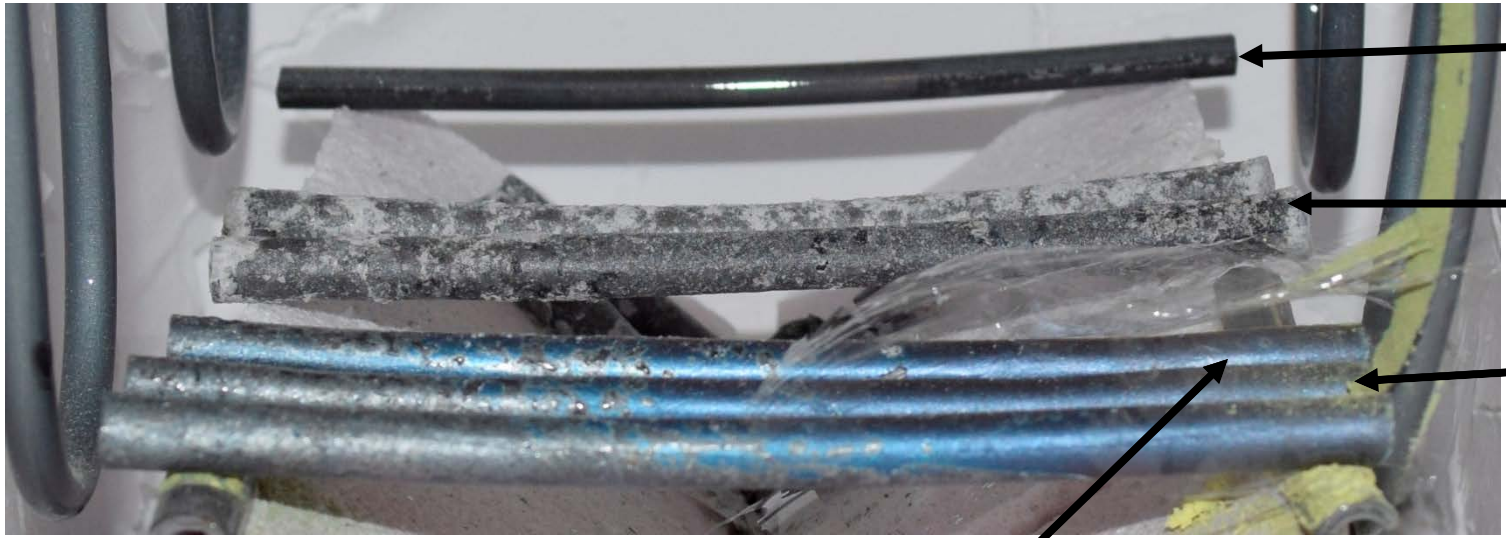


Mo(Si,Al)$_2$





Sag test at 1700°C in air for 100 h

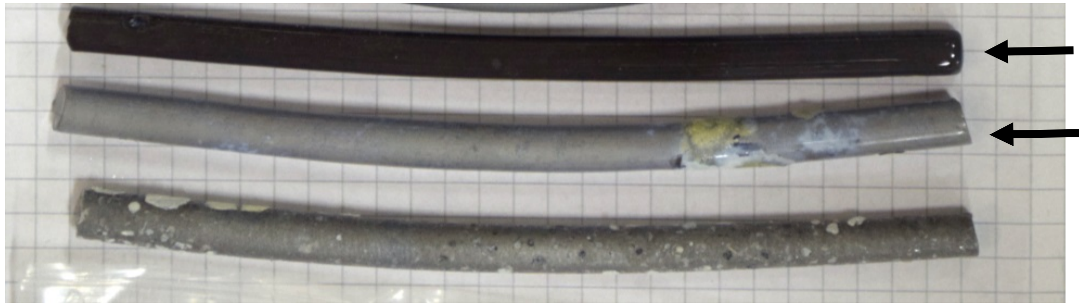


Kanthal Super HT

$Mo(Si,Al)_2$-10 SiC, -15 SiC

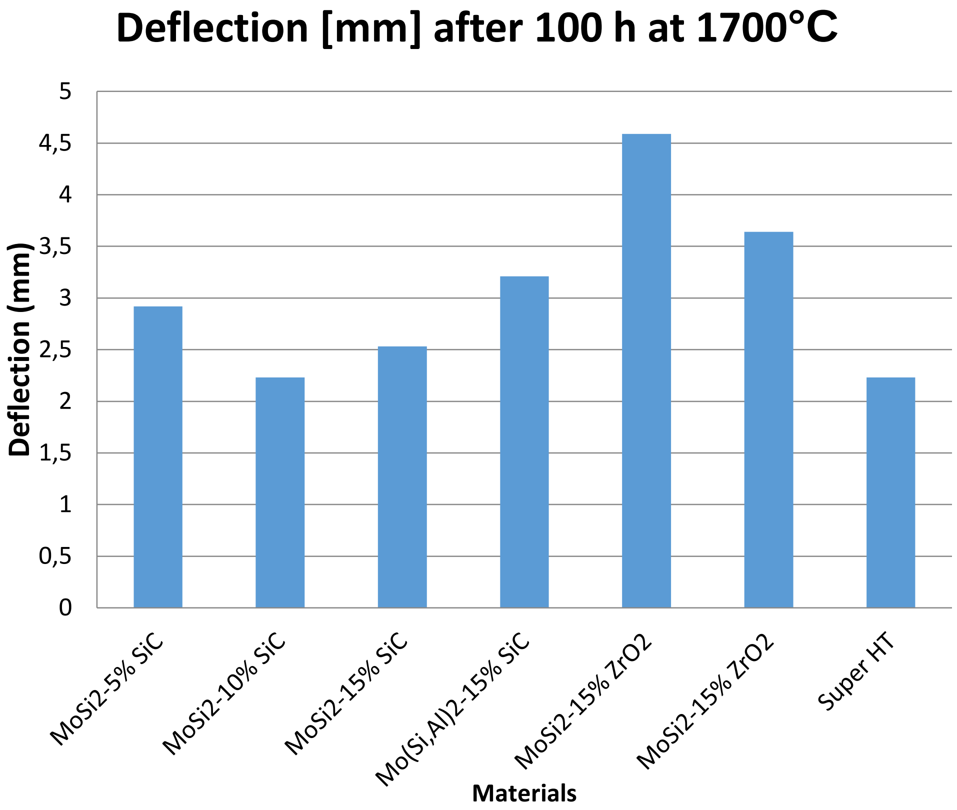
$MoSi_2$-5 SiC, -10 SiC, -15 SiC

Glass bobber

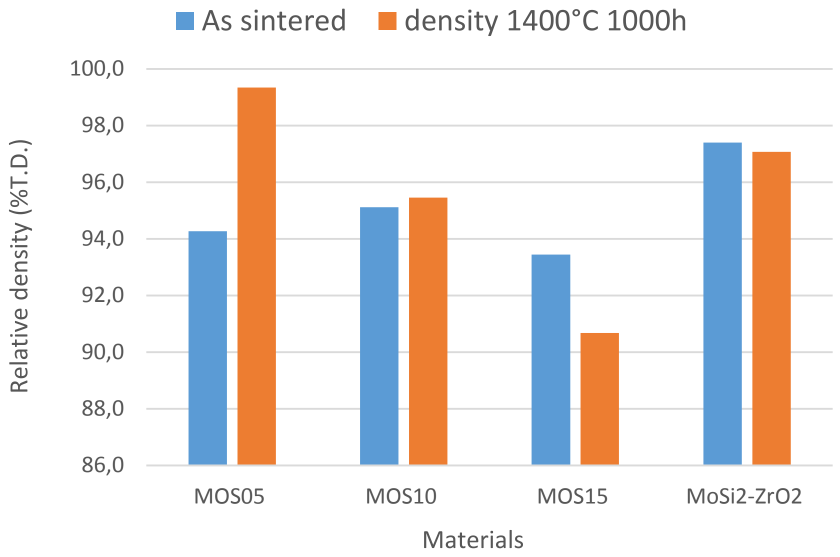


Kanthal Super HT

$MoSi_2$-ZrO_2



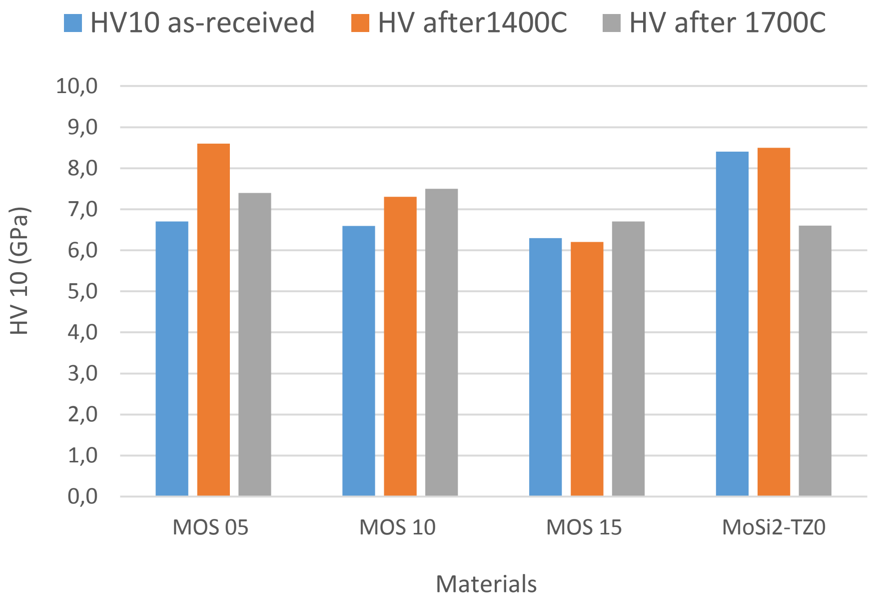
Property change after exposure at 1400°C for 1000h

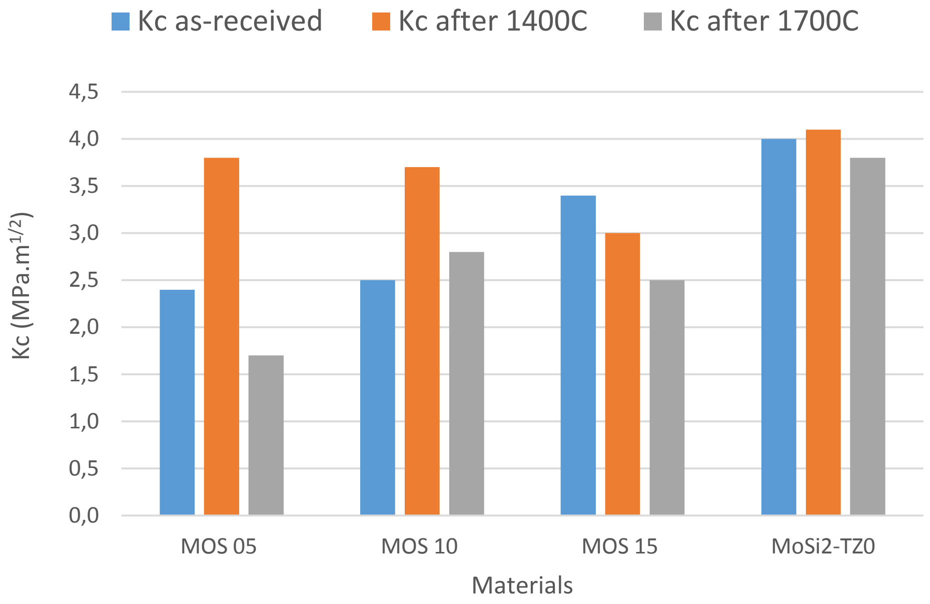


Density change

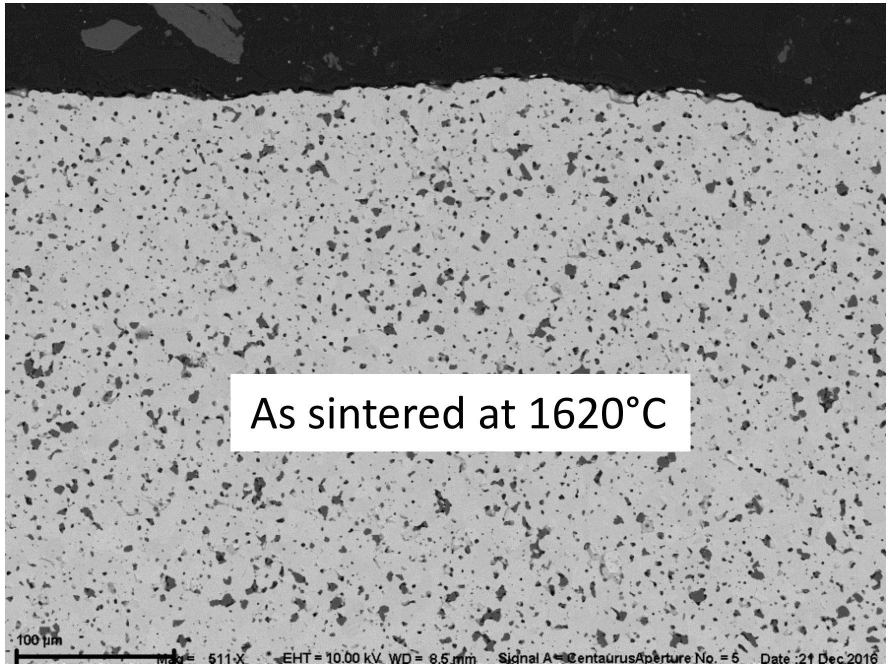
Hardness change

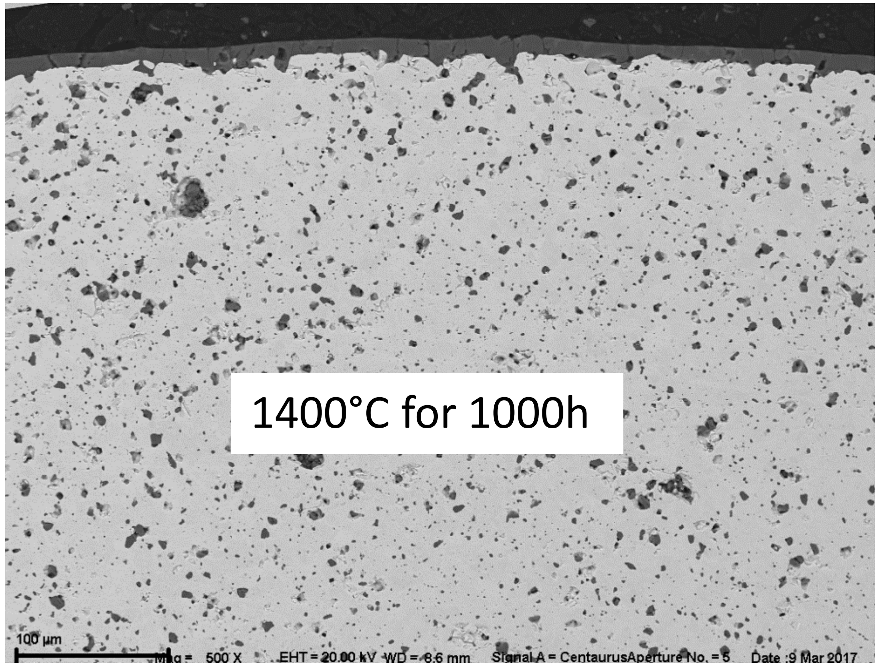
Toughness change

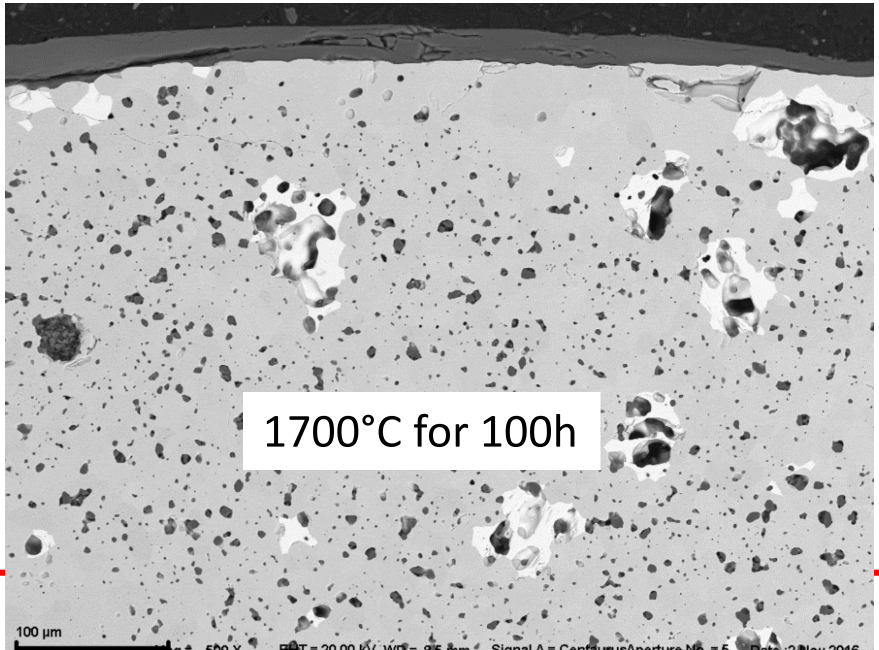


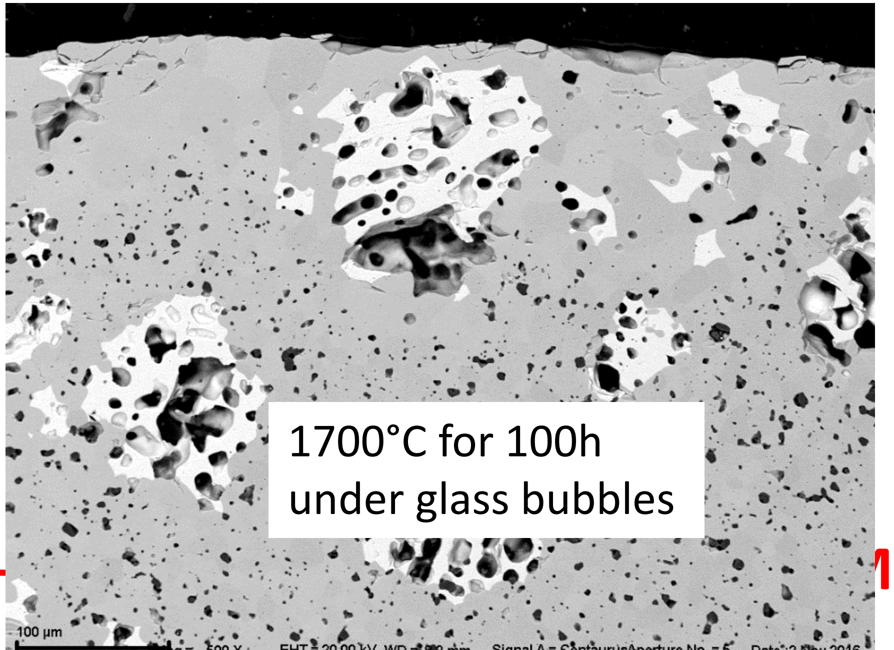


$MoSi_2$ + 10 vol.% SiC

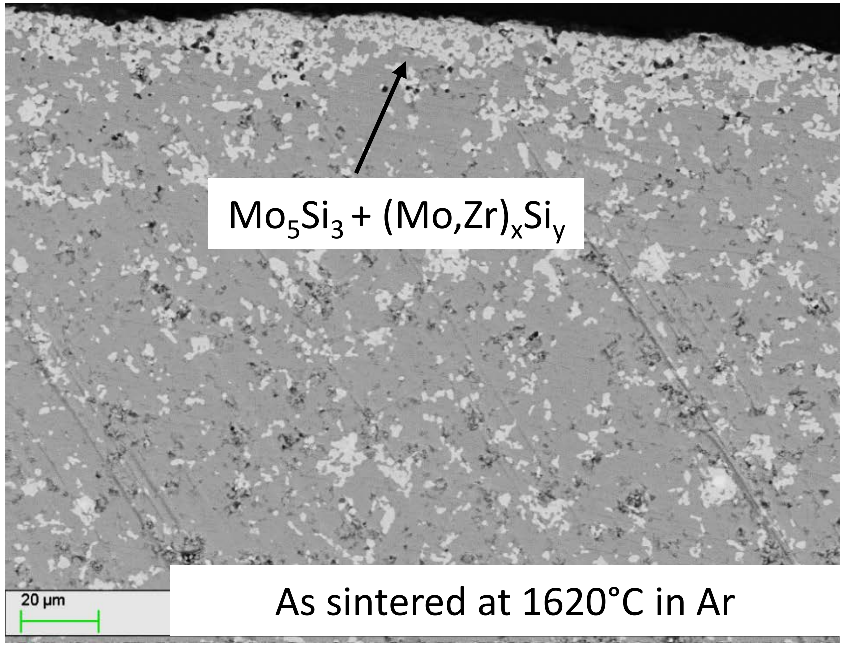


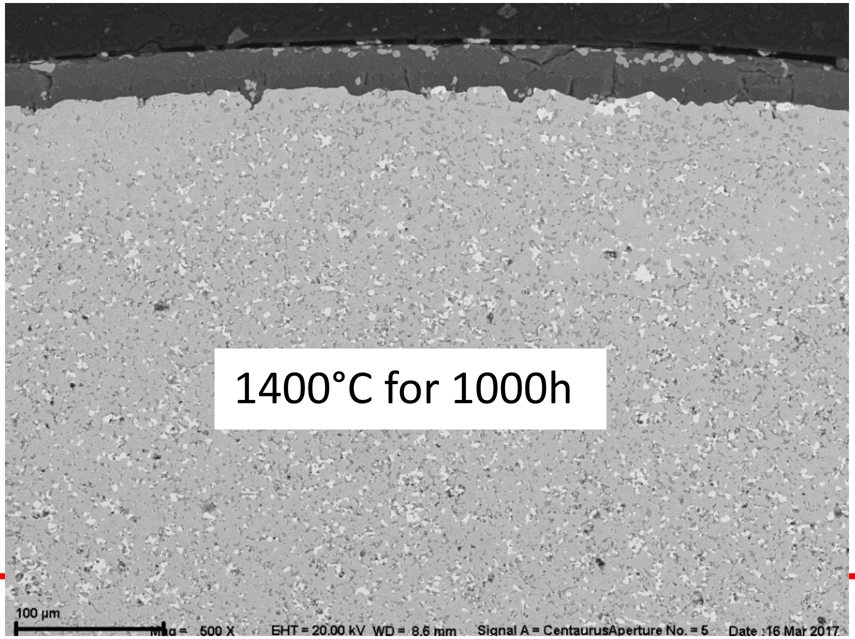


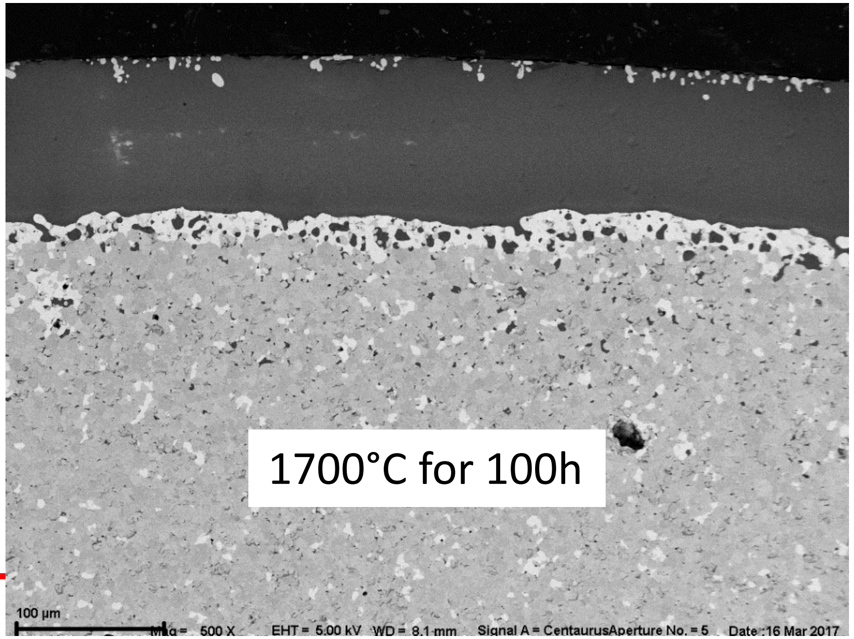




$MoSi_2$ + 15vol.% ZrO_2





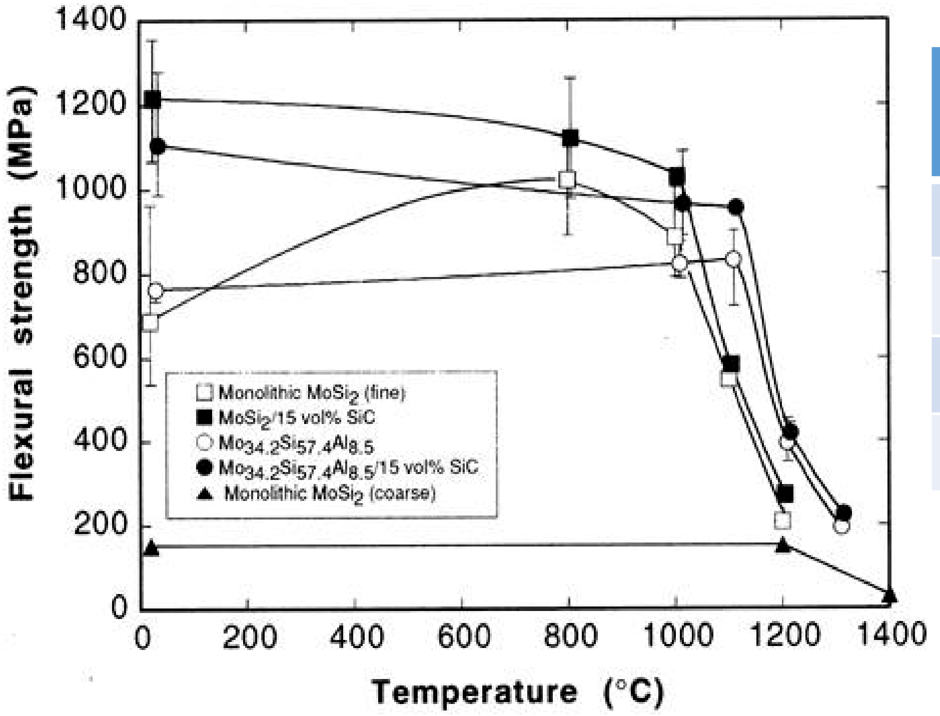


Summary

- Sintered density of 95%T.D. can be achieved in $MoSi_2$ + SiC composite materials ($MoSi_2$ + 10 vol.% SiC) using PLS technique at 1620°C in Ar.
- Thin uniform protective SiO_2 scale was formed on as-sintered $MoSi_2$ + SiC materials at 1400°C. The oxidation property of $MoSi_2$ + SiC is similar to that of **KS1700** and $MoSi_2$-ZrO_2 base materials.
- $MoSi_2$+SiC composites ($MoSi_2$ + 10 vol.% SiC) have high creep resistance comparable to **Kanthal HT** material in sagging test at 1700°C in air, superior to MoSi2 + ZrO_2 composite.
- Under to the excellent protection of the SiC layer, further sintering and densification in $MoSi_2$ + SiC composites can happen during long time exposure at HT (e.g. at 1400°C), especially for lower SiC additive contents (< 10 vol.% SiC), which results in HV and Kc increase.
- SiC additives decomposed at 1700°C. Glass bubbles and pores on the surface were formed, as a result of the released gases from SiC decomposition. The $MoSi_2$ + SiC material is suitable for oxidation corrosion components under 1600°C.
- PLSed $Mo(Si,Al)_2$ materials were brittle in HT oxidation test due to the formation of Al-oxides in the base material and thick (Al,Si)- and Al-oxide scales on the surface. It is indicated that $Mo(Si,Al)_2$-based composites are not suitable for applications in HT oxidation environments. $Mo(Si,Al)_2$-based composites are more promising for applications in reducing atmospheres, under high gas velocities (Al_2O_3 not volatile such as SiO_2), and potentially in combustion gases.

Next work

- High temperature mechanical properties of PLSed $MoSi_2$ + SiC composites for comparison with hot pressed $MoSi_2$ + SiC (literature) and $MoSi_2$ + ZrO_2 (previous work).

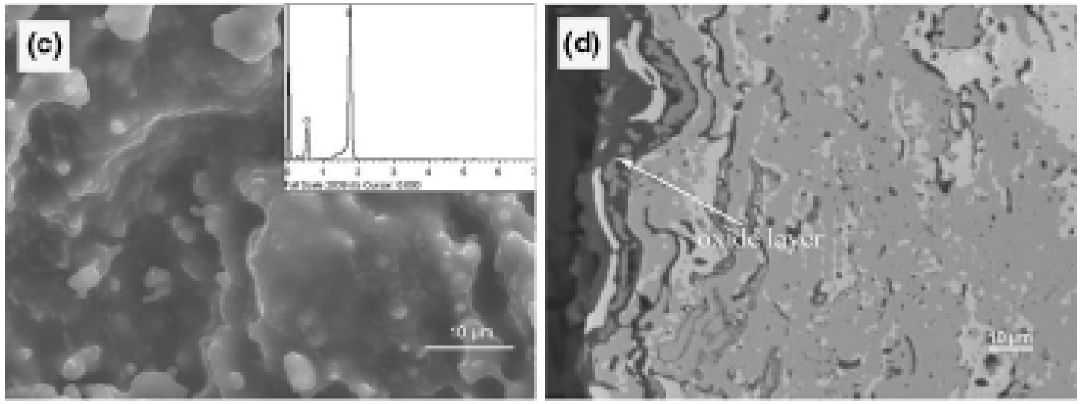


Material	4-point bend strength at RT [MPa]	4-point bend strength at 1200°C [MPa]
$(Mo,Cr)Si_2 + ZrO_2$	293 ± 25	200 ± 27
AS $MoSi_2 + ZrO_2$	-	334 ± 13
FS $MoSi_2 + ZrO_2$	357 ± 32	428 ± 24
HP Si_3N_4	629 ± 29	294 ± 29

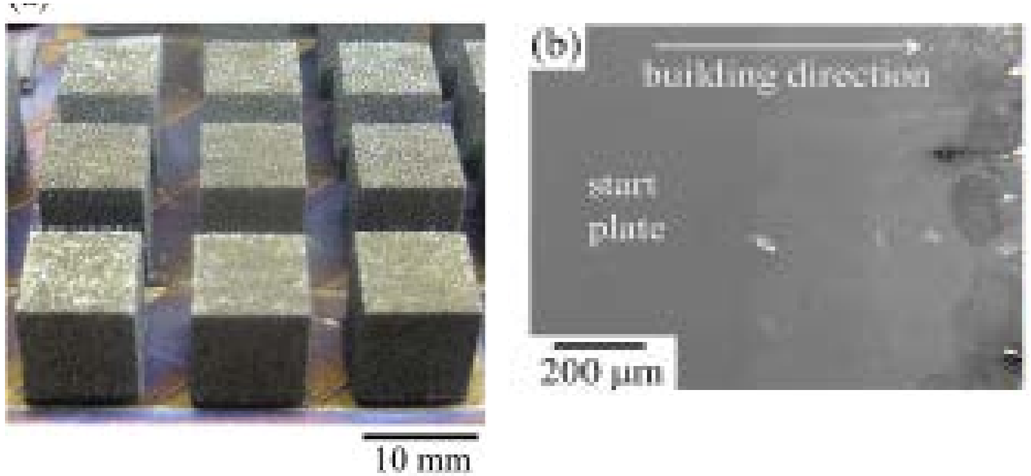
Thank you !

(Potentially) future work

- Investigations of alternative manufacturing methods, e.g. plasma spraying and additive manufacturing (AM or 3D-printing) for $MoSi_2 + ZrO_2$ and $MoSi_2$ + SiC composites , in addition to traditional PLS technique.



$MoSi_2$+20%ZrO_2 coating, after exposure at 1500°C, 7h.



$MoSi_2$ produced using SLM process on high-C steel plates.

Xiaoai Fei, et al, Oxidation Behavior of ZrO2 Reinforced MoSi2 Composite Coatings Fabricated by Vacuum Plasma Spraying Technology, Journal of Thermal Spray Technology, 1074—Volume 19(5) September 2010.

Koji Hagihara, et al, Successful additive manufacturing of MoSi2 including crystallographic texture and shape control, Journal of Alloys and Compounds, 696 (2017) 67-72.