KME 705

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

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Outline

- KME 705
- $MoSi_2$-SiC and C-40 (Mo,Al)Si_2-SiC composites
- Cyclic oxidation of FS (in air) $MoSi_2$-ZrO_2 composite
- Summary and future work

Aim of KME 705

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

Planned activities in KME 705

- Pre-oxidation or final sintering (FS) of $MoSi_2$+15 vol.% ZrO_2 to counteract the negative influence of as-sintered surface on oxidation behaviour and mechanical properties.
- Evaluation of $MoSi_2$-based composites reinforced with SiC to lower 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.
- Develop standard method for fracture toughness K_{IC} measurement.

KME705 in 2015. 03 – 2016. 03:

1. $MoSi_2$- and C40 $(Mo,Al)Si_2$-based composites, reinforced with SiC particles, were subjected to sag testing at 1700˚C.
2. Cyclic oxidation of final sintered (FS) $MoSi_2$+15 vol.% ZrO_2 at 1200 and 1300˚C.
3. Development of SEVNB technique for K_{IC} for cylindrical testing bars at MoT Chalmers.

1. SiC reinforced $MoSi_2$ based composites

- $MoSi_2$+SiC and (Mo,Al)Si_2+SiC composites with moderate sintering density were prepared, using a powder metallurgy and pressureless-sintering (PLS) technique.
- Amounts of SiC additive are 5, 10, and 15%.
- Sagging test were performed at 1700°C in air, and compared with $MoSi_2$-ZrO_2 composite.

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1. SiC reinforced $MoSi_2$ based composites

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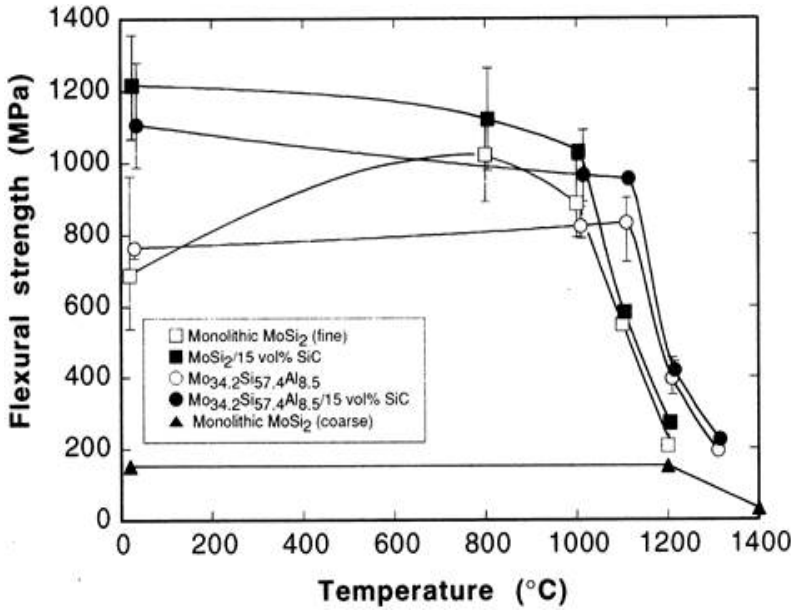
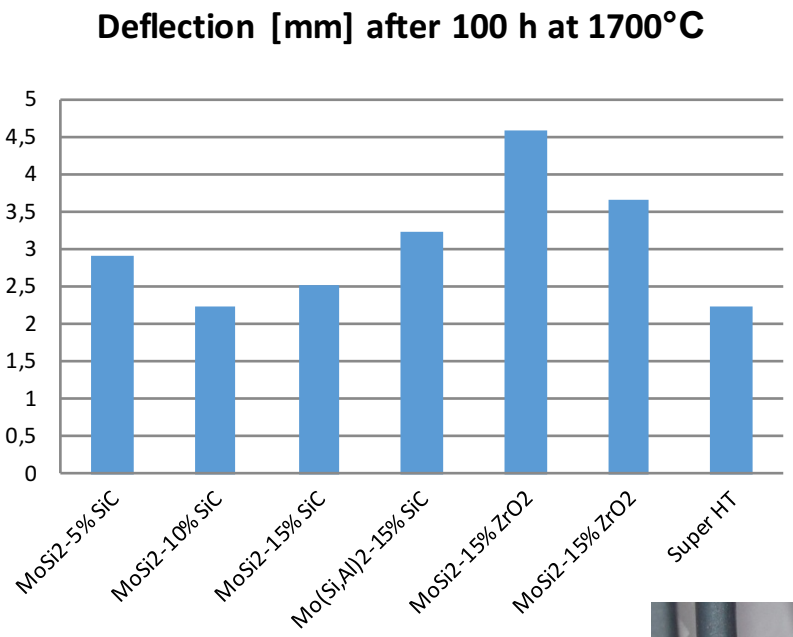
- Amounts of SiC additive were 5, 10, and 15 vol.%.
- Sagging tests were performed at 1700°C in air; $MoSi_2$-ZrO_2 composite and state-of-the-art Kanthal Super HT as reference for comparison.

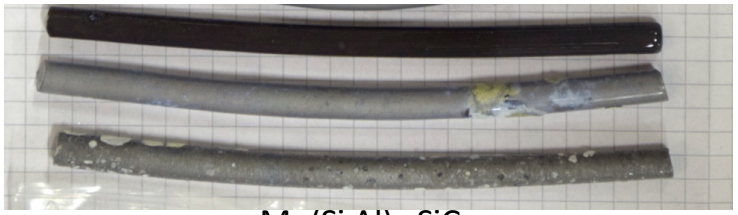
Koichi Niihara, Yoshikazu Suzuki
Materials Science and Engineering A261 (1999) 6–15



Sag test at 1700°C in air



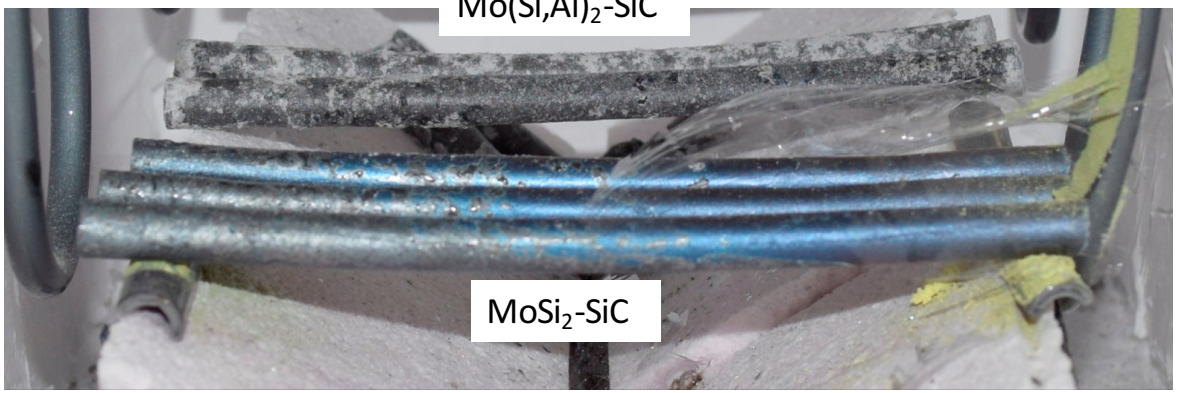
Material (as-sintered)	Sintered density (g/cm³)	% of T.D.
$MoSi_2$-5 vol% SiC	6.10	94.3
$MoSi_2$-10 vol% SiC	5.94	95.1
$MoSi_2$-15 vol% SiC	5.79	93.4
$Mo(Si,Al)_2$-5 vol% SiC	5.71	97.3
$Mo(Si,Al)_2$-10 vol% SiC	5.24	91.6
$Mo(Si,Al)_2$-15 vol% SiC	5.22	93.5



Kanthal Super HT

$MoSi_2$-ZrO_2

$Mo(Si,Al)_2$-SiC

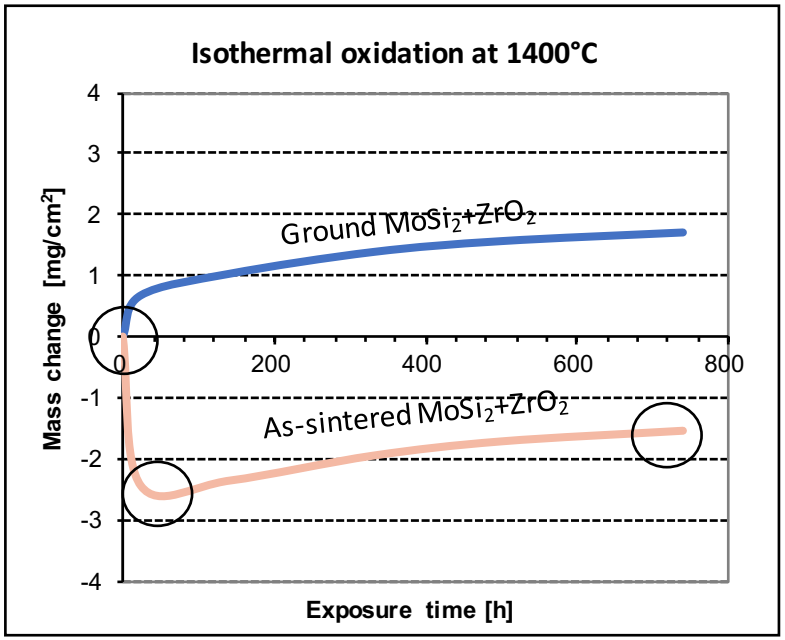


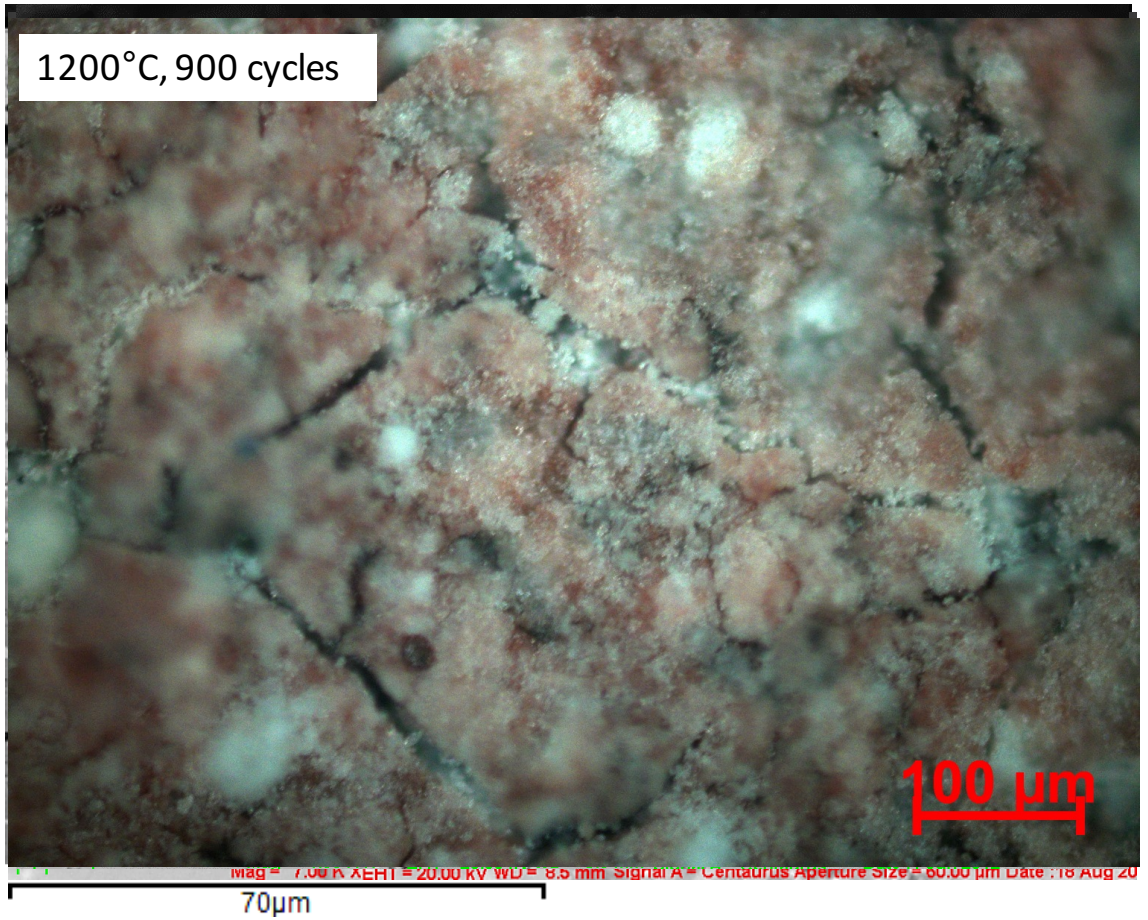
$MoSi_2$-SiC

$Mo(Si,Al)_2$-SiC samples oxidized heavily and broke upon handling or during the test.

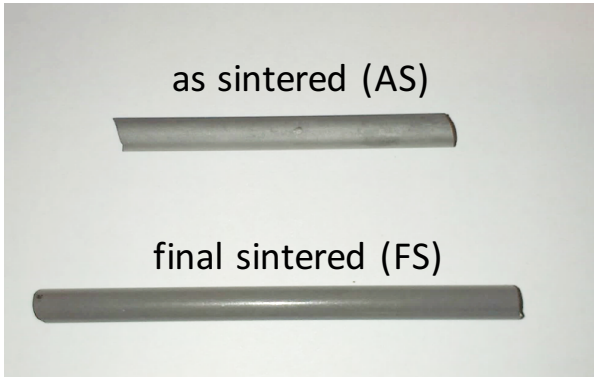
2. Cyclic oxidation of FS $MoSi_2$-ZrO_2 composite

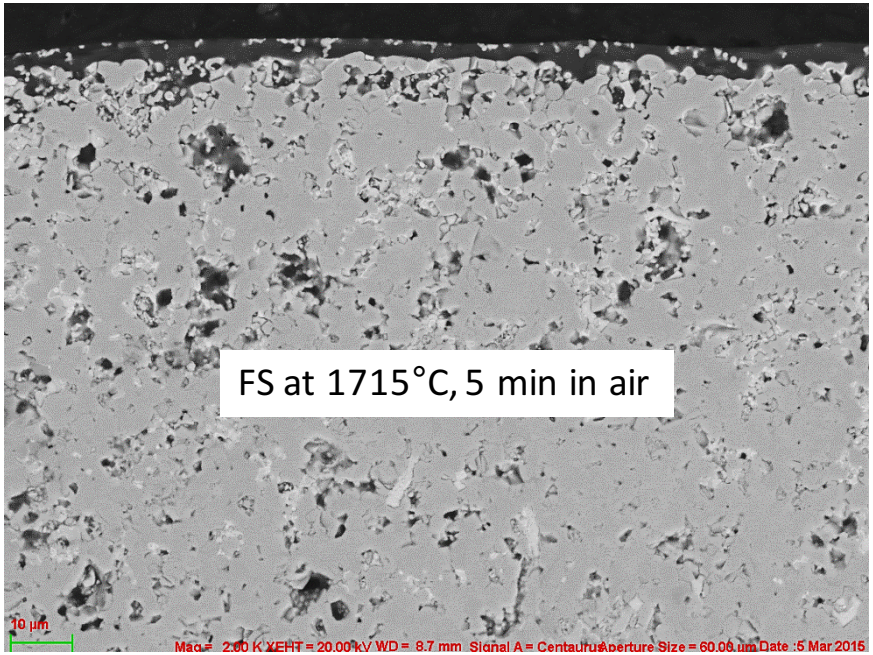
Oxidation of as-sintered $MoSi_2$ –ZrO_2 composite





Final sintered (FS) $MoSi_2$-ZrO_2 composite





Mechanical properties

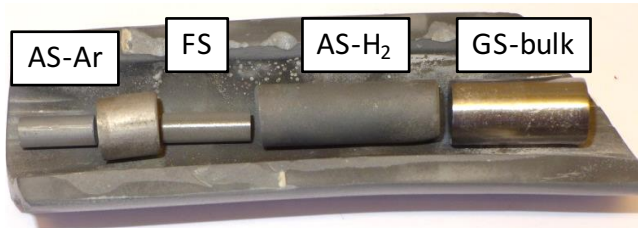
	σ_f, 1200°C (MPa)	σ_f, RT (MPa)	KIc (SEVNB) (MPa·$m^{1/2}$)	HV10 (GPa)	Relative density (T.D.)
$MoSi_2$-ZrO_2 (AS)	334 ± 13	320	4.4	9.5	98%
$MoSi_2$-ZrO_2 (FS)	427 ± 24	357	4.4	9.0	98%
Si_3N_4 (HP)	294 ± 29	629	5.2	13.5	100%

Cyclic oxidation of FS $MoSi_2$-ZrO_2 composite at 1200 and 1300°C

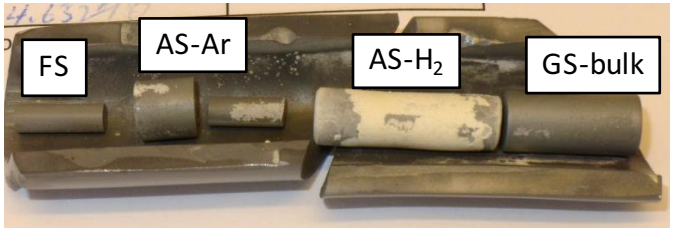
- Cyclic parameters: furnace heating to 1200 and 1300°C, in 10 min;
  furnace cooling to 100°C in ambient air, in 10 min.
- Testing materials:

Surface condition	Sintering density (g/cm3), T.D.%
AS – Ar $MoSi_2$-15vol%ZrO_2	6.03, 98% T.D.
As – H_2 $MoSi_2$-15vol%ZrO_2	6.09, 99% T.D.
FS $MoSi_2$-15vol%ZrO_2	6.03, 98% T.D.
Bulk GS (ground surface) $MoSi_2$-15vol%ZrO_2	6.10, 99% T.D.

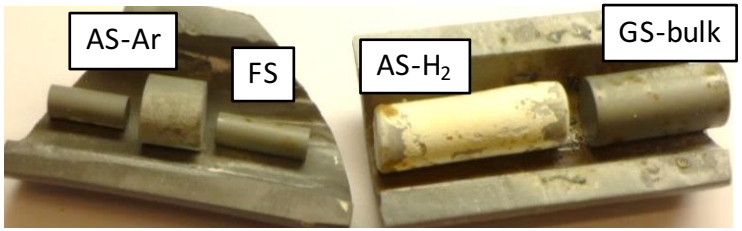
Cyclic oxidation of FS $MoSi_2$-ZrO_2 at 1200°C



0 cycle

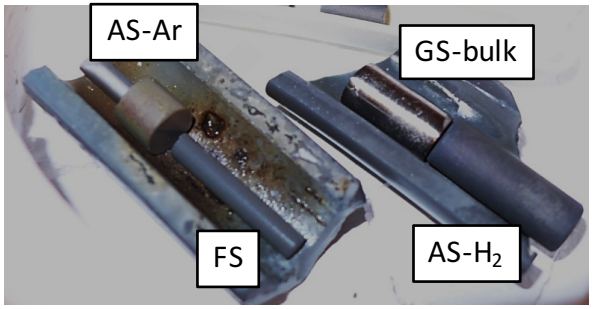


20 cycles

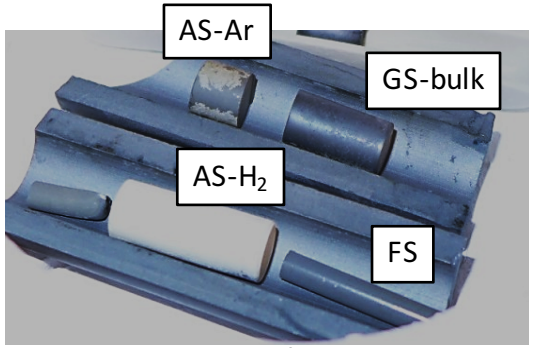


100 cycles

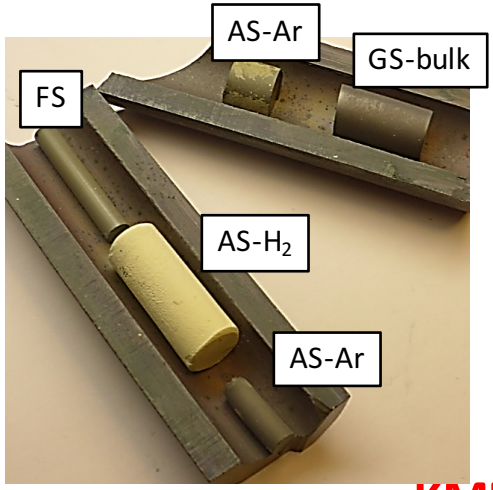
Cyclic oxidation of FS $MoSi_2$-ZrO_2 at 1300°C



0 cycle

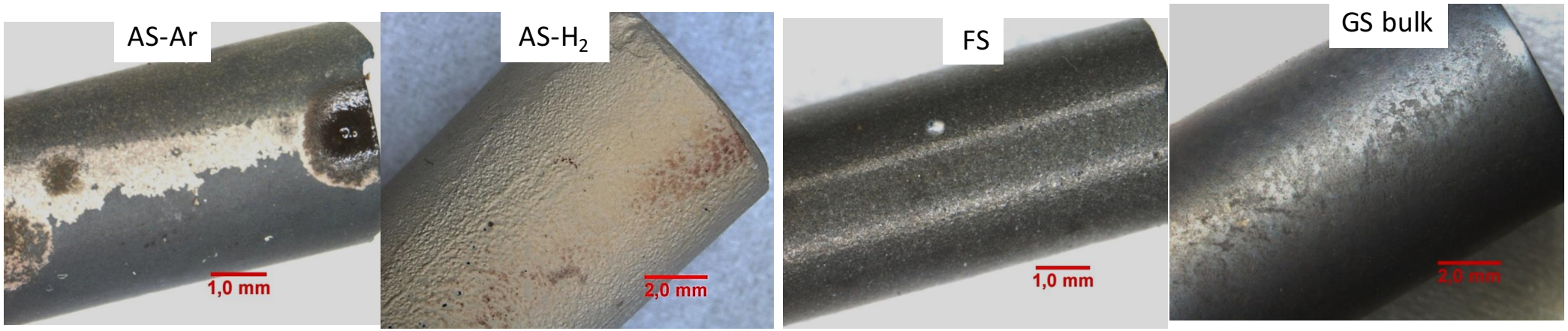


20 cycles

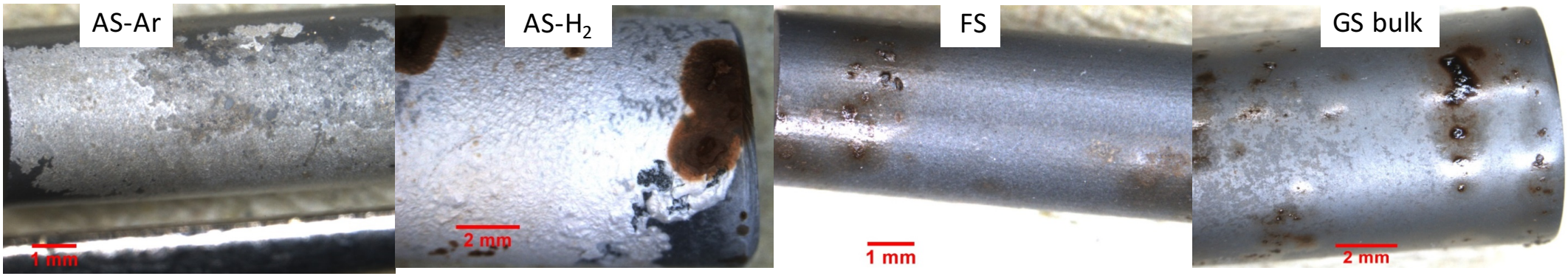


100 cycles

Cyclic oxidation of FS $MoSi_2$-ZrO_2 at 1200°C , 100 cycles



Cyclic oxidation of FS $MoSi_2$-ZrO_2 at 1300°C , 100 cycles



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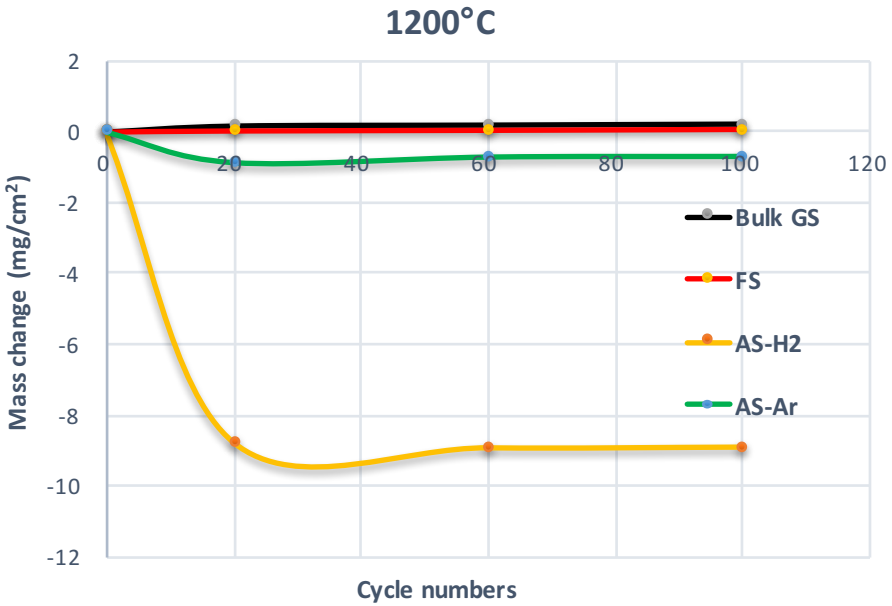
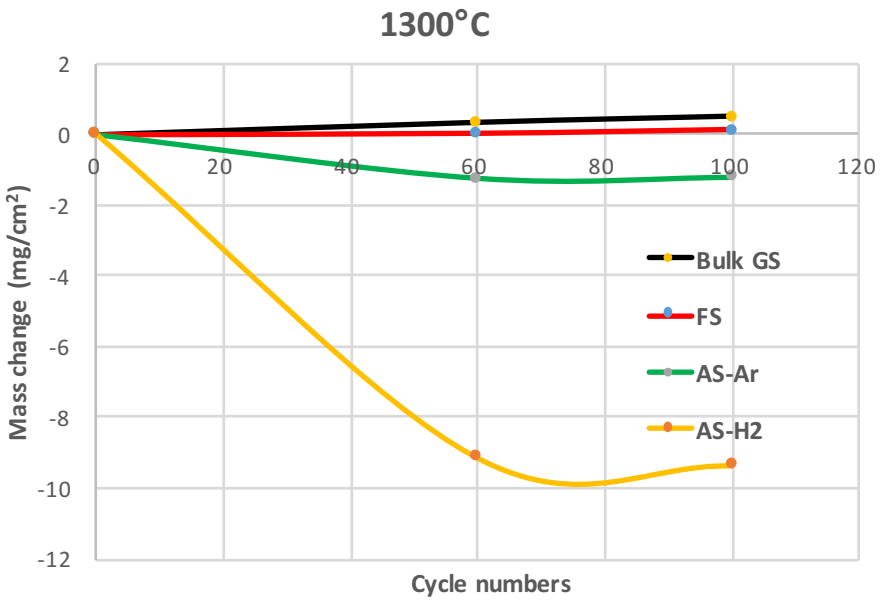
Cyclic oxidation of FS $MoSi_2$-ZrO_2 at 1200 and 1300°C





Summary and next work

- Pressureless sintered $MoSi_2$-10%SiC composite presents with lower deformation rate and high oxidation resistance at 1700°C.
- Since heavy oxidation occurred during sag testing PLS $Mo(Si,Al)_2$-10% SiC, final sintering should be performed in order to produce a protective Al_2O_3-layer prior to sag testing.
- Final sintered $MoSi_2$-15%ZrO_2 composite has excellent thermal chock and oxidation resistance at 1200, and 1300°C, respectively, compared with the as-sintered material.

Thank you !