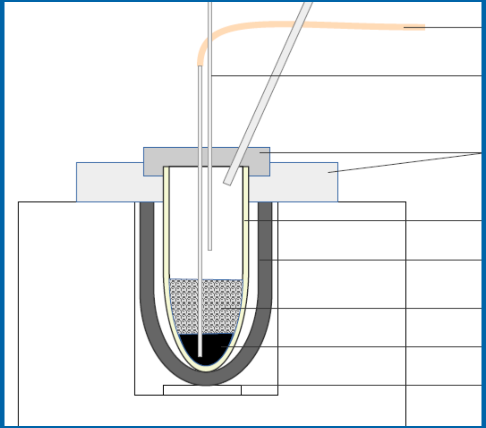
TECHNISCHE UNIVERSITÄT BERGAKADEMIE FREIBERG
Die Ressourcenuniversität. Seit 1765.

Karlsruher Institut für Technologie

Alternative Carbon use for Fayalitic Slag Valorization

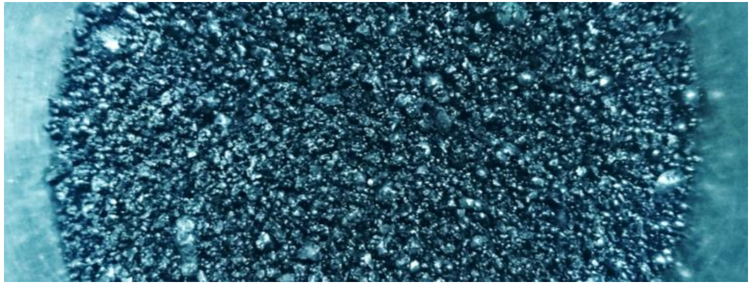


INEMET – Professorship of High-Temperature Processes in Metallurgy
Ludwig Blenau, Prof. Dr.-Ing. Alexandros Charitos

&

ITC – Institute for Technical Chemistry
Manuela Wexler, Werner Baumann, Prof. Dr.-Ing Dieter Stapf

Fayalitic Slag



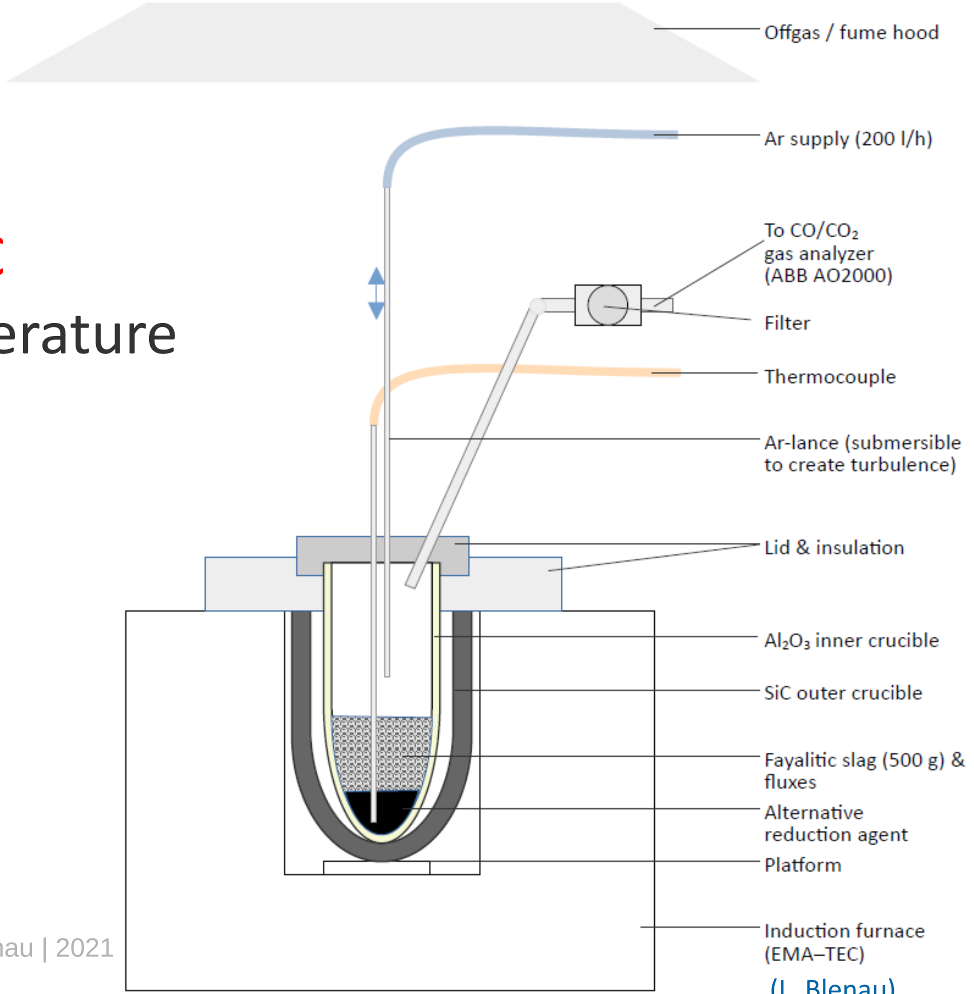
L. Blenau: Granulated fayalitic slag

Oxide (XRF)	Primary Slag (wt.-%)	Oxide (XRF)	Primary Slag (wt.-%)
MoO3	0.37	Al2O3	3.45
NiO	0.03	As2O3	0.10
PbO	0.23	BaO	0.12
PO4	0.50	CaO	2.34
SiO2	29.38	CoO	0.04
SnO2	0.06	Cr2O3	0.15
SO3	1.18	CuO	1.03
SrO	0.01	Fe2O3	2.27
TiO2	0.30	FeO	53.59
V2O5	0.01	K2O	1.47
ZnO	1.66	MgO	1.55
ZrO2	0.03	MnO2	0.16

D. John: Quay wall at Hayle, Cornwall

Experimental Setup

- Temperatures: 1450°C
- Duration: 5 h at temperature



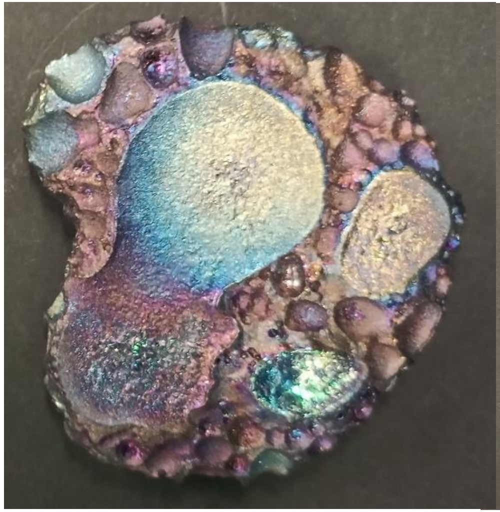
(L. Blenau)

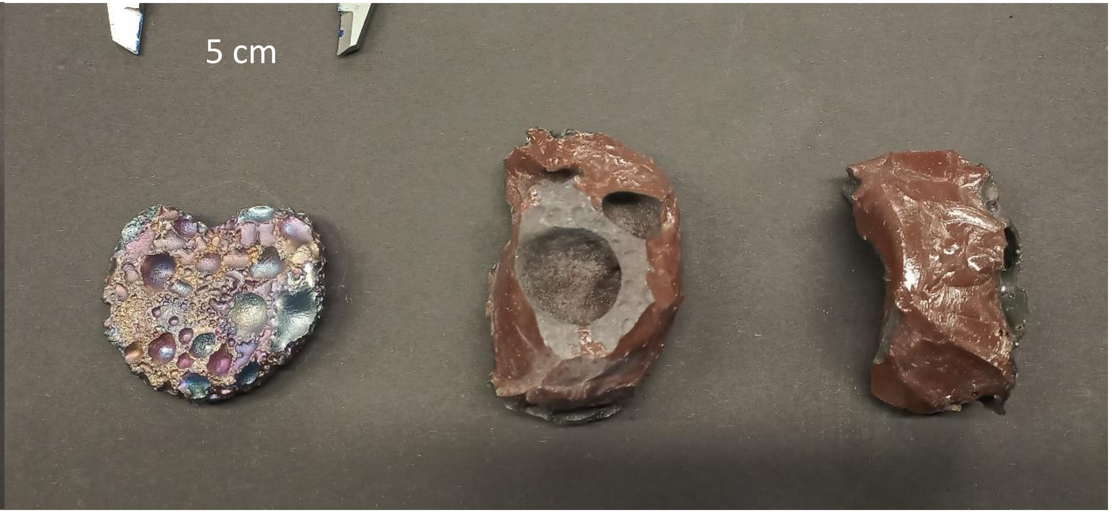
Graphite pellets: 1450°C, 5 h: Products

16.3 g loose material (graphite pellet rests + crucible material; Conversion X_C > 75.3 %)

51 g of C captured as CO/CO_2 through offgas (Conversion X_C ~ 77.5 %)

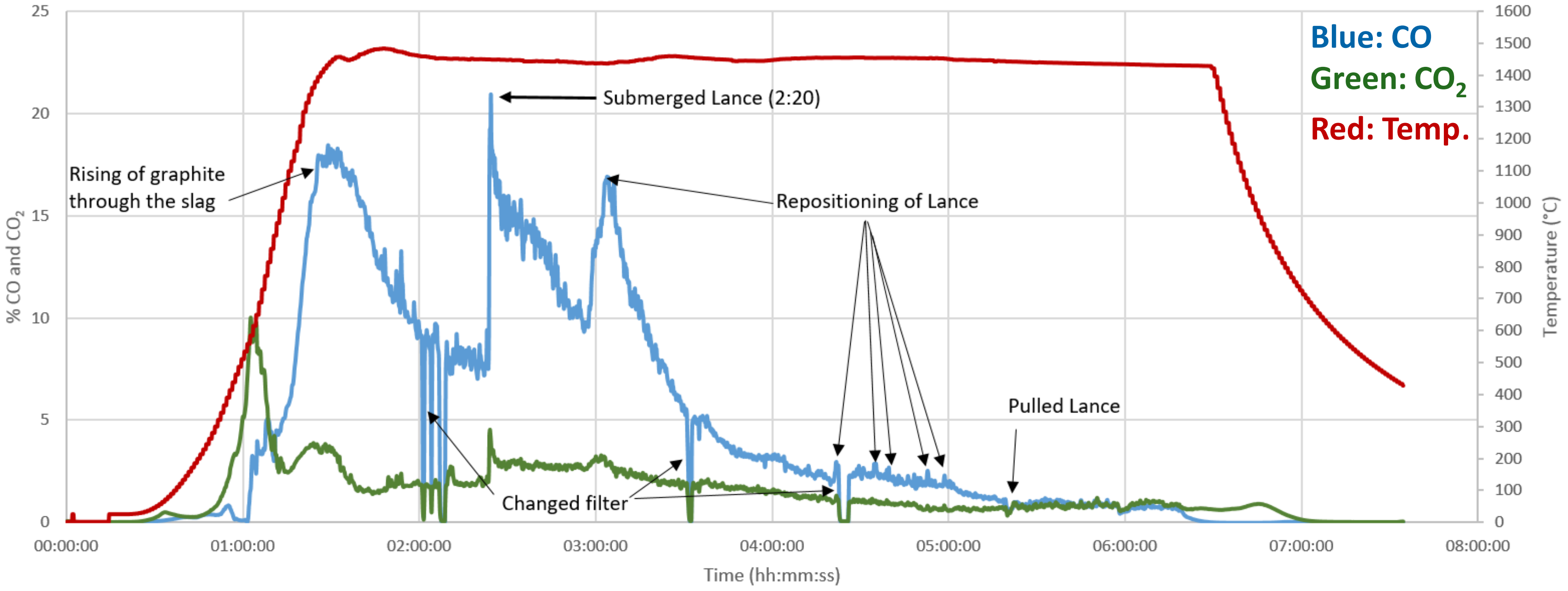
143.4 g Metal phase (not pure) with 91.5 wt.-% Fe (Conversion X_{Fe} ~ 67 %)





(L. Blenau)

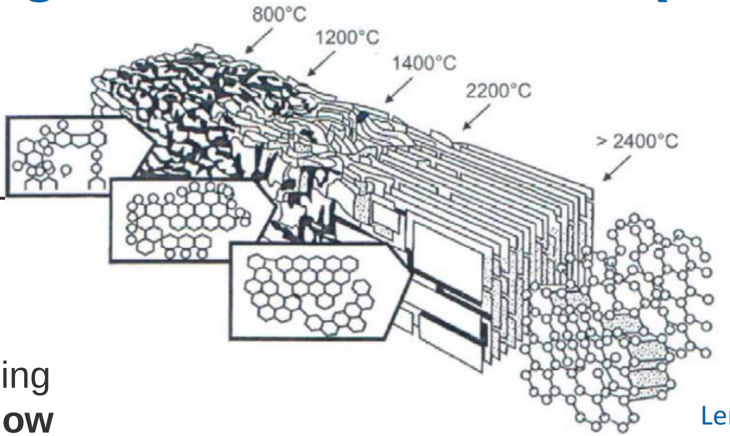
Graphite pellets at 1450°C, 5 h: Off-gas



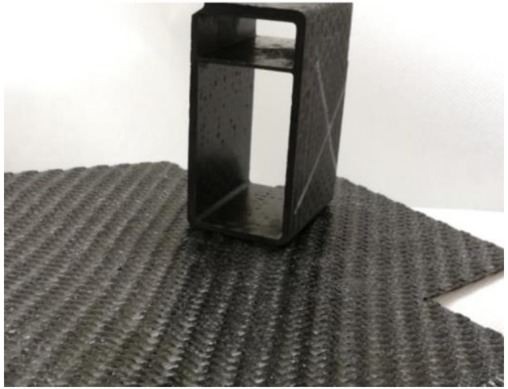
(L. Blenau)

Alternative Reduction Agent: Carbon Fibers (CF)

- 2019: **167.1 kt** [1]
- In: Aeronautics, wind energy, vehicle construction etc.
- In conjunction with Polymers as Carbon-fiber-reinforced polymer (**CRP**)
- Either Polyacrylnitril (**PAN**) or **Tar** based
- Different degrees of carbonatisation and graphitisation at <3000°C and added sizing
- **High stiffness, high tensile strength, low weight to strength ratio**, high chemical resistance, high temperature tolerance
- There is **no viable process** for CF reutilisation or removal [2]



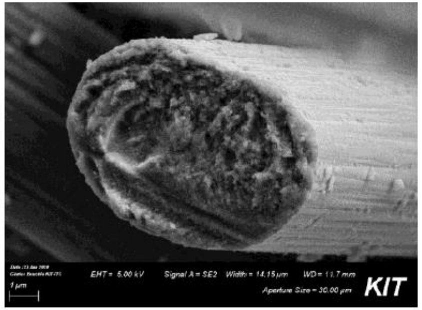
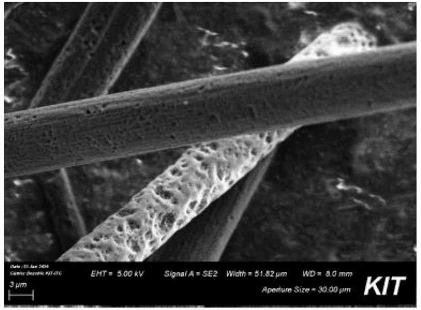
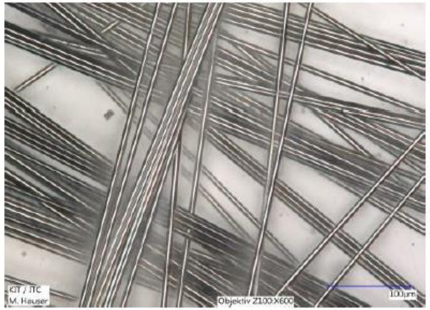
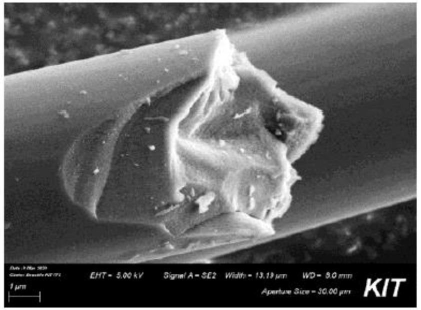
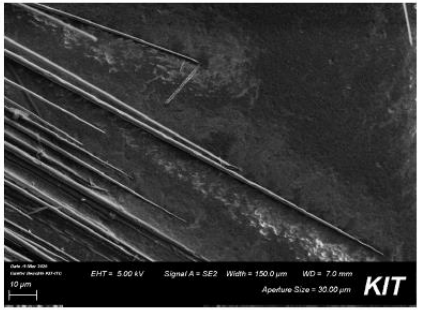
Lengsfeld, H. et al. (2019)



M. Wexler (KIT): Carbon-fiber-reinforced polymer (CRP) component

[1] CCeV Marktberichte 2015-2019
[2]: LAGA (2019): Entsorgung faserhaltiger Abfälle, Abschlussbericht (https://www.laga-online.de/documents/bericht-laga-ausschuss-entsorgung-faserhaltige-abfaelle_juli-2019_1574075541.pdf)

Alternative Reduction Agent: Carbon Fibers (CF)

	Untreated		Thermally stressed
PAN-based			
Tar-based			

M. Wexler et. al. 2020 (KIT)

Alternative Reduction Agent: Carbon Fibers (CF)

- Varied:
  -Fiber types: **Sigrafil** and **Nippon**
  -Fiber geometry: **Powder**, **6 mm**, **6 cm**
  -Fiber to Slag ratio: **66 g** / **33 g** of CF per 500 g of fayalitic slag

- **Reused** leftover fibers: Even higher reaction rate (larger surface area)

- Compared with „**Blaskohle**“ (Coke powder) used in EAF steelmaking

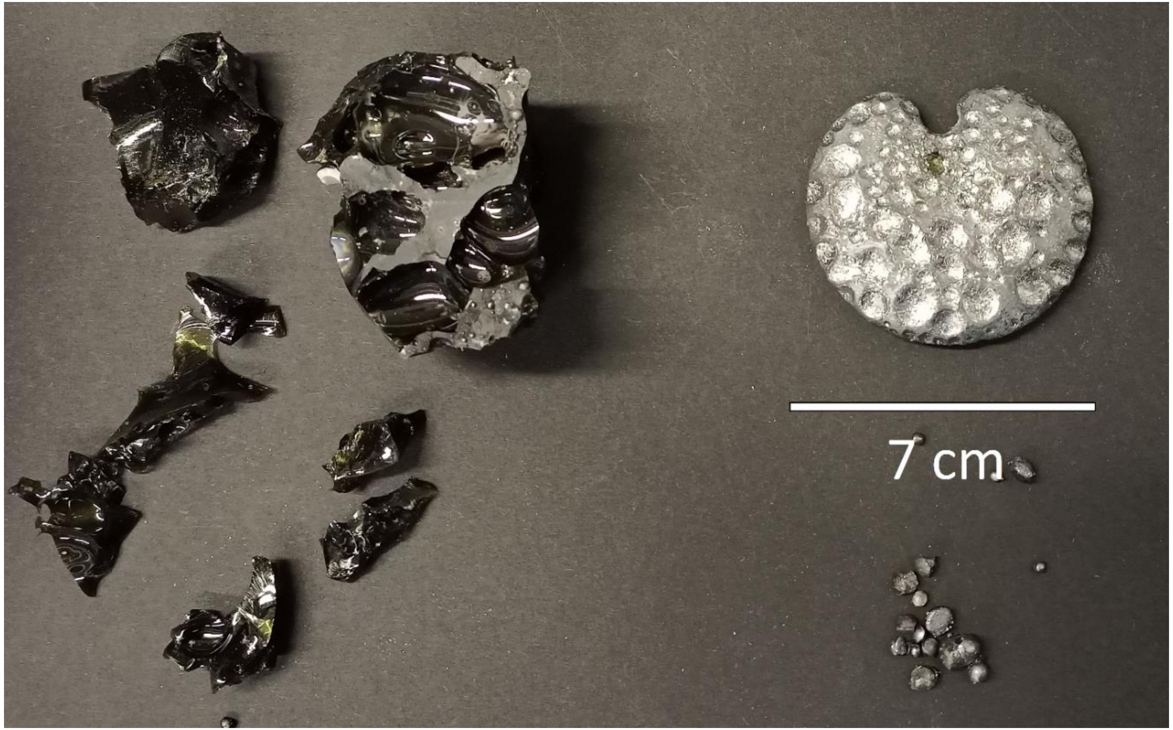
L. Blenau: Carbon fibers 6 mm (top left) and 6 cm (top right)

L. Blenau: „Blaskohle“ (coke powder)

66 g Nippon 6 cm fibers at 1450°C, 5 h: Products

21.84 g fiber remnants (44.16 g; Conversion X_C ~ 67 %)

147.95 g Metal phase (93.57 wt.-% Fe, Conversion $\mathbf{X_{FE}}$ **~70.6 %**)



L. Blenau: Glass phase (left) and iron phase (right)

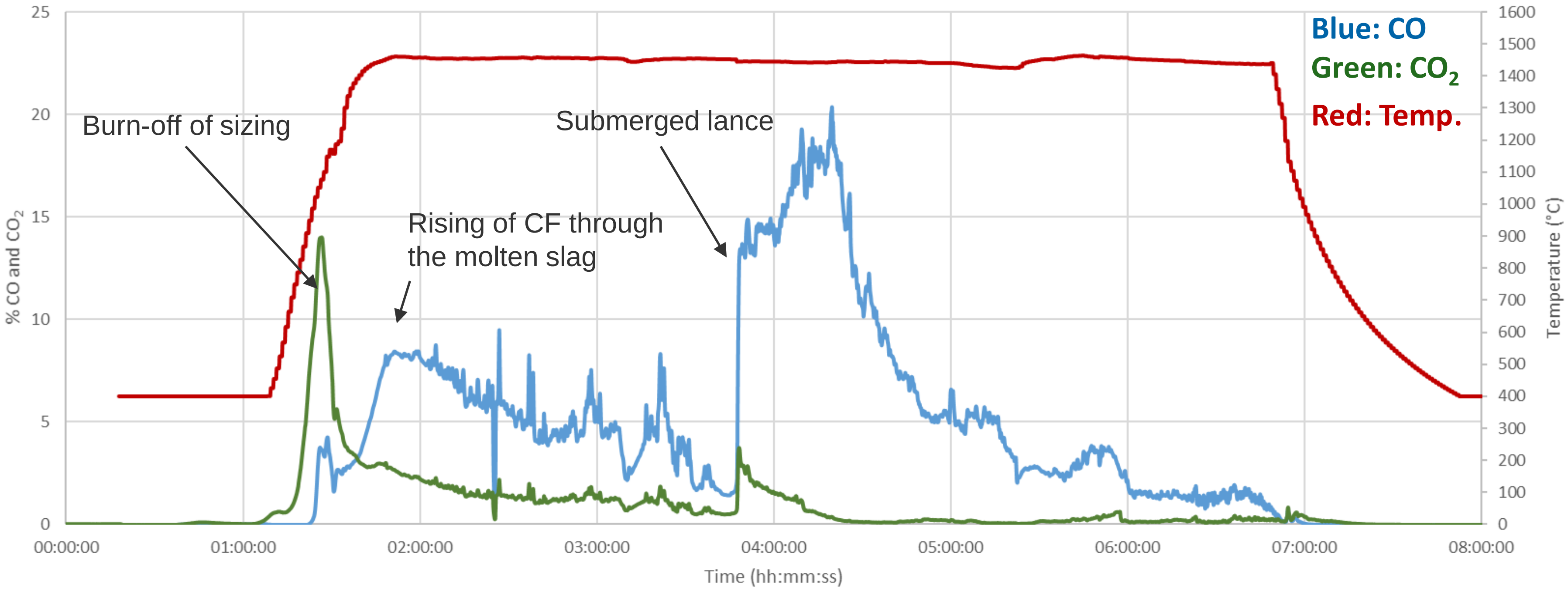
Carbon Fiber Conversion (1450°C, 5 h)

Sigrafil 6 mm fiber remnants

Nippon 6 cm fiber remnants

Ludwig Blenau: CF after one reduction experiment

Sigrafil 6 mm at 1450°C, 5 h: Off-gas



(L. Blenau)

Secondary Slag = Glass phase

The Slag was analysed via XRF (Bruker S8 TIGER)

Oxides	1450°C Graphite Pellets (wt.-%)	1450°C Nippon 6 cm Carbon Fibers (wt.-%)
Al2O3	32.09	29.29
SiO2	46.65	49.37
SO3	0.08	0.15
K2O	1.13	1.18
TiO2	0.58	0.61
V2O5	0.04	0.03
Cr2O3	0.22	0.24
MnO	0.28	0.28
FeO	10.04	9.25
CuO	0.11	0.12
SrO	0.01	0.01
ZrO2	0.27	0.60
PbO	0.00	0.00
CaO	8.49	8,86

Achim Hering: Mineral wool

Metal Phase = Pig Iron

The Pig Iron was analysed via ICP-OES (Varian 725-ES) and CS

Elements	1450°C Graphite Pellets (wt.-%)	1450°C Nippon 6 cm Carbon Fibers (wt.-%)
As	0.01	0,06
Co	0.06	0.01
Cu	2.03	1.71
Fe	91.59	93.57
Mo	0.45	0.47
Ni	0.09	0.09
P	0.07	0.12
Pb	0.03	0.02
Zn	0.01	0.01

Carbon 2.40%, Sulphur < 1%

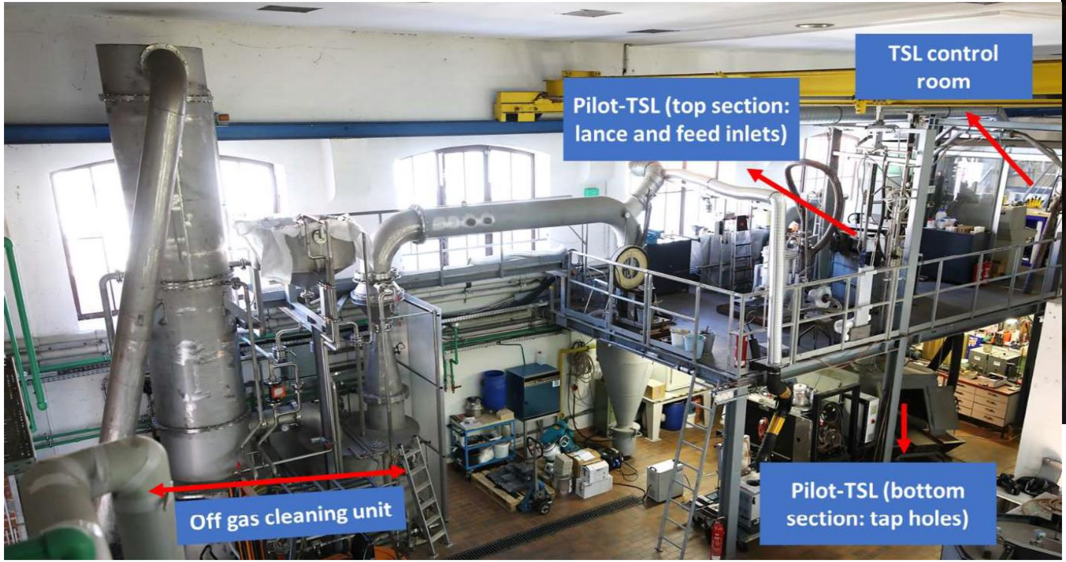
Carbon 3.93%, Sulphur 0.75%

ThyssenKrupp Steel Europe: Steel coils

Conclusion

- **> 70 %** of all available **Fe** can be seperated per batch, consuming 67 % of the used CF (Nippon 6 cm)
- All fibertypes and geometries work comparably well (up to **90 % CF conversion**, up to 74 % Fe valorisation)
- CF slighly **higher reaction rate than graphite** pellets, „Blaskohle“ (petrol coke) outperformes both
- **Glassy secondary slag has viscosities needed for mineral wool production** and is low in critical elements.
- High temperature, turbulence and a **constant molten reaction mixture** is key for high conversion rates.

Outlook – Future Plans



L. Blenau: Pilot Scale Top Submerged Lance (TSL) Furnace tap (top) and off-gas cleaning unit (left)

Thank You!

Tel.: +49(0)3731 39-2051
ludwig.blenau@inemet.tu-freiberg.de

Institute for Nonferrous Metallurgy and Purest Materials (INEMET)
TU BERGAKADEMIE FREIBERG
Leipziger Straße 34, 09599 Freiberg

In cooperation with:

Institue of Technical Chemistry (ITC)
KARLSRUHE INSTITUTE OF TECHNOLOGY
Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen