
Appendix

A Crucible dimensions

Figure A1 shows a detailed sketch of the graphite crucibles used in the TGA furnace.

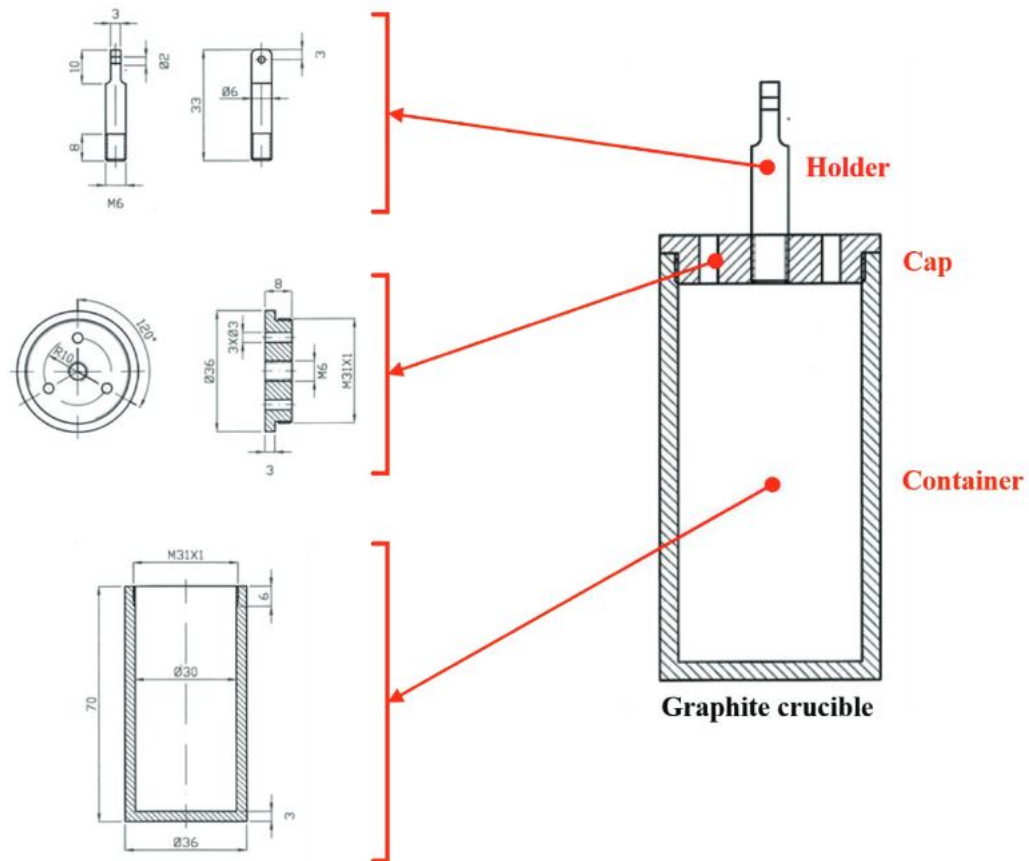


Figure A1: Sketch of graphite crucibles[15].

B Preheating of charcoal and limestone

Figure B1 shows the weight loss curves from pre-heating of charcoal heated to 1000°C.

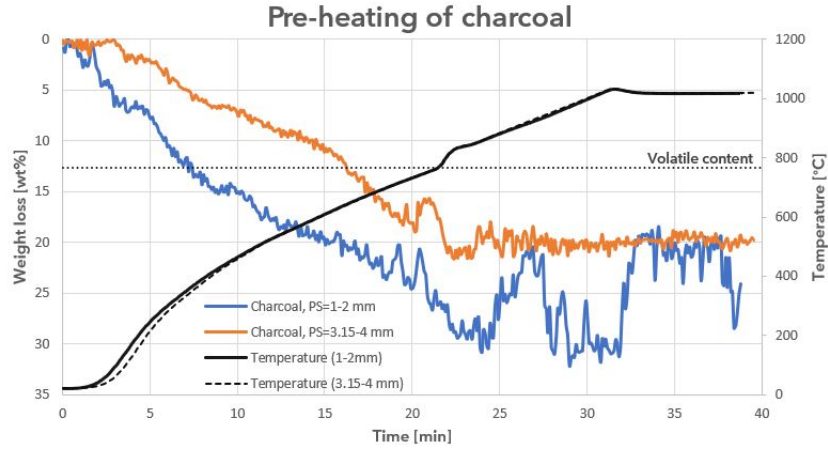


Figure B1: Preheating of charcoal.

Figure B2 shows the weight loss curves from preheating of limestone.

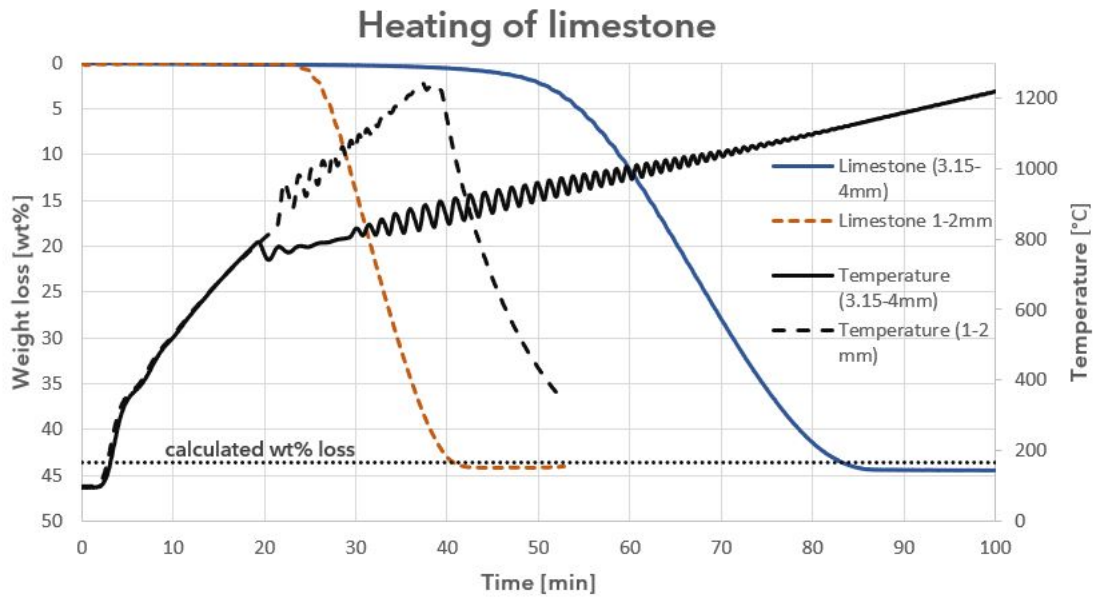


Figure B2: Preheating of limestone, performed in previous study [29].

C Full analysis EPMA

The following tables presents the full slag- and metal analysis performed in EPMA. Three randomly selected points at phases of interest were used in the analysis.

Table C1: Three point chemical analysis of the slag phases with EPMA

Exp	No.	{wt%}							
		Al ₂ O ₃	MgO	K ₂ O	MnO	SiO ₂	CaO	SO ₃	Total
1 Coke	1	10,432	0,598	0,868	29,755	44,751	12,345	0,436	99,185
	2	10,728	0,596	0,894	29,393	45,921	12,408	0,543	100,483
	3	11,108	0,633	0,899	29,009	45,48	12,808	0,504	100,441
	1avg	10,76	0,61	0,89	29,39	45,38	12,52	0,49	100,04
2 Coke	4	22,187	1,48	0,214	3,357	40,046	31,502	1,147	99,933
	5	21,873	1,521	0,159	3,474	39,38	31,05	1,104	98,561
	6	21,761	1,491	0,153	3,563	39,371	31,417	1,094	98,85
	2avg	21,94	1,50	0,18	3,46	39,60	31,32	1,12	99,11
2.1 Coke	37	29,795	0,508	0,002	3,043	31,999	34,912	1,632	101,891
	38	29,589	0,523	0,029	3,3	31,925	34,927	1,858	102,151
	39	30,999	0,582	0	3,172	30,97	34,832	1,887	102,442
	2.1avg	30,128	0,538	0,010	3,172	31,631	34,890	1,792	102,161
3 Coke	7	10,266	0,744	0,868	21,878	49,589	17,433	0,532	101,31
	8	10,151	0,763	0,796	22,437	50,283	17,595	0,62	102,645
	9	10,787	0,84	0,829	19,379	50,255	18,581	0,666	101,337
	3avg	10,40	0,78	0,83	21,23	50,04	17,87	0,61	101,76
4 Coke	10	23,772	1,267	0,059	2,268	37,1	33,771	1,084	99,321
	11	23,957	1,225	0,038	2,324	38,259	33,565	1,008	100,376
	12	24,332	1,087	0,039	1,947	39,188	32,679	1,375	100,647
	4avg	24,02	1,19	0,05	2,18	38,18	33,34	1,16	100,11
	25	0,126	0,838	0,045	62,971	32,665	4,188	0	100,833

Table C1 continued from previous page

5 Charcoal	26	0,242	0,855	0,027	62,89	32,606	4,282	0,028	100,93
	27	0,282	0,918	0,025	62,673	32,926	4,082	0,042	100,948
	5avg-light	0,217	0,870	0,032	62,845	32,732	4,184	0,023	100,904
	28	13,115	0,169	0,663	25,665	46,428	15,476	0,08	101,596
	29	13,037	0,147	0,755	25,535	46,611	15,563	0,106	101,754
	30	12,831	0,148	0,643	25,625	46,389	15,473	0,16	101,269
	5avg-dark	12,994	0,155	0,687	25,608	46,476	15,504	0,115	101,540
	5avg*	5,850	1,837	17,677	28,118	27,659	8,437	56,212	145,789
6 Charcoal	13	9,781	0,608	0,354	31,616	44,439	13,623	0,09	100,511
	14	9,852	0,658	0,355	30,343	44,422	13,587	0,061	99,278
	15	9,898	0,604	0,334	31,425	43,963	13,935	0,158	100,317
	6avg	9,84	0,62	0,35	31,13	44,27	13,72	0,10	100,04
7 Charcoal	31	0,193	0,934	0,013	61,941	32,828	5,704	0	101,613
	32	0,178	0,981	0,01	62,183	32,986	5,381	0,01	101,729
	33	0,206	0,934	0,015	62,321	33,04	5,357	0	101,873
	7avg-light	0,192	0,950	0,013	62,148	32,951	5,481	0,003	101,738
	34	12,716	0,219	0,388	24,923	45,879	17,633	0,163	101,921
	35	12,853	0,194	0,391	24,926	46,042	17,548	0,123	102,077
	36	11,982	0,222	0,342	25,906	45,86	17,559	0,022	101,893
	7avg-dark	12,517	0,212	0,374	25,252	45,927	17,580	0,103	101,964
	7avg*	6,190	0,591	0,188	44,193	39,266	11,369	0,052	101,848
8 Charcoal	16	10,601	0,852	0,2	25,989	45,208	17,017	0,064	99,931
	17	10,524	0,845	0,214	26,085	45,099	16,819	0,084	99,67
	18	10,322	0,837	0,251	25,924	43,676	16,677	0,087	97,774
	8avg	10,48	0,84	0,22	26,00	44,66	16,84	0,08	99,13
	40	0,249	0,514	0,01	63,432	32,594	5,724	0	102,523

Table C1 continued from previous page

5 Charcoal + S	41	0,23	0,342	0,011	61,012	31,924	6,052	0,01	99,581
	42	0,418	0,504	0,043	62,081	32,05	5,918	0,063	101,077
	5+S avg-light	0,299	0,453	0,021	62,175	32,189	5,898	0,024	101,060
	43	22,809	0	3,278	30,608	29,731	12,153	2,681	101,26
	44	21,797	0,05	3,202	31,47	30,155	12,382	2,699	101,755
	45	23,09	0,054	3,433	30,5	29,83	12,099	2,786	101,792
	5+S avg-dark	22,565	0,035	3,304	30,859	29,905	12,211	2,722	101,602
	5+S*	5,85	0,35	0,84	54,36	31,62	7,47	0,70	101,20
5.1 Charcoal + S	46	20,188	1,338	1,008	6	43,073	27,7	1,037	100,344
	47	19,008	1,302	0,935	6,228	42,854	28,149	1,148	99,624
	48	19,598	1,395	0,954	6,034	43,326	28,063	0,975	100,345
	5.1+S avg	19,598	1,345	0,966	6,087	43,084	27,971	1,053	100,104
8 Charcoal + S	55	25,082	1,517	0,031	1,769	37,474	33,894	1,921	101,688
	56	24,911	1,566	0	1,789	37,62	34,094	2,442	102,422
	57	25,136	1,609	0,052	1,862	36,999	33,713	2,381	101,752
	8+S avg	25,043	1,564	0,028	1,807	37,364	33,900	2,248	101,954
1. wallfoam Coke	19	10,641	0,61	0,952	28,418	47,85	12,496	0,44	101,407
	20	10,687	0,594	0,892	28,617	47,715	12,209	0,492	101,206
	21	10,656	0,594	0,901	28,566	47,723	12,242	0,508	101,190
	1.wall avg	10,661	0,599	0,915	28,534	47,763	12,316	0,480	101,268
4. lid Coke	22	15,329	1,238	0,751	7,976	51,342	22,148	0,646	99,43
	23	15,611	1,258	0,684	8,231	52,598	22,211	0,548	101,141
	24	15,54	1,156	0,697	7,696	52,398	21,931	0,653	100,071
	4.lid avg	15,493	1,217	0,711	7,968	52,113	22,097	0,616	100,214

Table C1 continued from previous page

*consists of both liquid and solid phases

Table C2: Three point chemical analysis of the metal

Exp	No.	{wt%}					
		Si	C	Mn	Fe	P	Total
1 Coke	1	9,107	0,826	86,462	3,828	-	100,223
	2	9,153	0,811	89,402	1,248	-	100,614
	3	8,317	0,768	82,552	7,842	-	99,479
	1avg	8,86	0,80	86,14	4,31	-	100,11
2 Coke	4	14,825	0,697	85,318	1,404	-	102,244
	5	13,315	0,758	86,337	1,196	-	101,606
	6	20,744	0,838	79,63	0,345	-	101,557
	2avg	16,29	0,76	83,76	0,98	-	101,80
2.1 Coke	40	10,121	0,693	87,997	1,518	0,008	100,337
	41	10,779	0,734	87,447	1,687	-	100,647
	42	10,13	0,695	88,281	1,52	-	100,626
	2.1avg	10,34	0,71	87,91	1,58	0,01	100,54
3 Coke	7	16,053	0,943	81,918	0,629	-	99,543
	8	12,473	0,811	88,232	1,028	-	102,544
	9	13,359	0,896	85,222	0,633	-	100,11
	3avg	13,96	0,88	85,12	0,76	-	100,73
4 Coke	10	15,336	1,054	83,174	0,624	-	100,188
	11	10,994	0,848	86,936	1,311	-	100,089
	12	8,562	0,869	76,19	14,718	-	100,339
	4avg	11,63	0,92	82,10	5,55	-	100,21
	25	3,417	0,649	63,937	27,782	0,341	96,126

Table C2 continued from previous page

5 Charcoal	26	3,279	0,639	66,926	27,737	0,249	98,83
	27	3,381	0,63	66,512	27,968	0,305	98,796
	5avg-light	3,36	0,64	65,79	27,83	0,30	97,92
	28	0,038	0,93	76,219	18,416	-	95,603
	29	0,028	0,938	76,151	18,257	-	95,374
	30	0,067	0,934	76,72	18,282	-	96,003
	5avg-dark	0,04	0,93	76,36	18,32	-	95,66
	5avg*	1,55	0,80	71,57	22,63	-	96,54
6 Charcoal	13	3,558	0,604	81,123	14,244	-	99,529
	14	3,916	0,775	83,056	10,716	-	98,463
	15	7,553	0,707	89,959	0,951	-	99,17
	6avg	5,01	0,70	84,71	8,64	-	99,05
7 Charcoal	31	3,223	0,618	61,063	33,714	0,286	98,904
	32	3,164	0,623	61,447	33,835	0,289	99,358
	33	3,056	0,634	62,25	33,254	0,449	99,643
	7avg-light	3,148	0,625	61,587	33,601	0,341	99,302
	34	0	0,842	68,438	27,687	-	96,967
	35	0	0,835	68,41	27,834	-	97,079
	36	0,01	0,839	69,101	27,333	0,015	97,298
	7avg-grey	0,003	0,839	68,650	27,618	0,015	97,125
	37	0	0,926	72,65	23,045	-	96,621
	38	0	0,929	71,933	22,973	-	95,835
	39	0	0,93	72,18	22,893	-	96,003
	7avg-dark	0,000	0,928	72,254	22,970	-	96,153
	16	8,389	0,742	80,638	9,805	-	99,574
	17	6,829	0,809	82,013	9,541	-	99,192

Table C2 continued from previous page

8 Charcoal	18	6,425	0,757	81,91	10,13	-	99,222
	8avg	7,21	0,77	81,52	9,83	-	99,33
5 Charcoal + S	43	0	1,246	40,315	52,535	0,866	94,962
	44	0,006	1,169	38,054	54,36	1,418	95,007
	45	0,005	1,238	37,682	54,689	1,109	94,723
	5+S avg	0,00	1,22	38,68	53,86	1,13	94,90
5.1 Charcoal	46	16,43	0,675	69,208	13,557	0,088	99,958
	47	12,44	0,678	72,771	13,806	0,527	100,222
	48	9,995	0,719	74,253	13,394	0,511	98,872
	5.1+S avg	12,96	0,69	72,08	13,59	0,38	99,68
6 Charcoal + S	49	18,848	1,236	81,564	0,565	-	102,213
	50	17,327	1,216	81,574	0,525	-	100,642
	51	18,816	1,206	80,198	0,577	-	100,797
	6+S avg large droplet	18,33	1,22	81,11	0,56	-	101,22
	52	18,218	1,217	81,831	0,135	-	101,401
	53	18,019	1,357	81,007	0,155	-	100,538
	54	18,415	1,402	81,789	0,116	-	101,722
	6+S avg small droplets	18,217	1,325	81,542	0,135	-	101,220
	55	9,463	1,238	83,665	4,705	-	99,071
	56	9,195	1,275	82,617	4,716	0,007	97,81
	57	9,464	1,318	82,901	4,794	-	98,477
	7+S avg-light	9,37	1,28	83,06	4,74	0,01	98,46
	58	22,314	1,133	72,91	5,164	0,011	101,532

Table C2 continued from previous page

7 Charcoal + S	59	22,232	1,174	72,885	4,855	-	101,146
	60	21,912	1,142	73,117	5,057	0,005	101,233
	7+S avg-dark	22,15	1,15	72,97	5,03	0,01	101,31
	7+S avg**	15,76	1,21	78,02	4,88	0,00	99,87
8 Charcoal + S	61	19,956	0,678	73,325	9,228	0,071	103,258
	62	16,915	1,237	73,6	9,183	0,041	100,976
	63	18,851	1,249	73,062	8,939	0,002	102,103
	8+S avg large droplet	18,57	1,05	73,33	9,12	0,04	102,11
	64	16,569	1,23	82,494	0,52	-	100,813
	65	16,291	1,201	83,344	0,542	-	101,378
	66	16,644	1,226	82,849	0,562	-	101,281
	8+S avg small droplets	16,501	1,219	82,896	0,541	-	101,157
1. wallfoam Coke	19	8,079	0,767	90,648	0,491	-	99,985
	20	8,856	0,759	91,012	0,499	-	101,126
	21	8,28	0,768	90,666	0,444	-	100,158
	1. wall avg	8,405	0,765	90,775	0,478	-	100,423
4. lid Coke	22	11,512	0,829	89,114	0,189	-	101,644
	23	15,009	0,918	85,638	0,153	-	101,718
	24	13,976	0,894	85,796	0,2	-	100,866
	4. lid avg	13,499	0,880	86,849	0,181	-	101,409

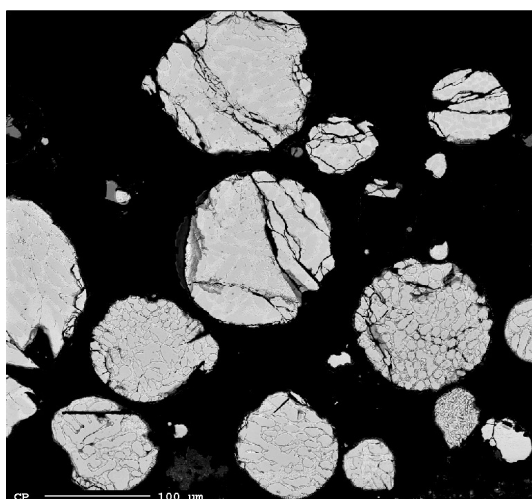
* 5 Coke - phase fraction light = 0.45 and dark = 0.55, obtained from imageJ

** 7+S Charcoal phase fraction light = 0.5 and dark = 0.5, visually estimated

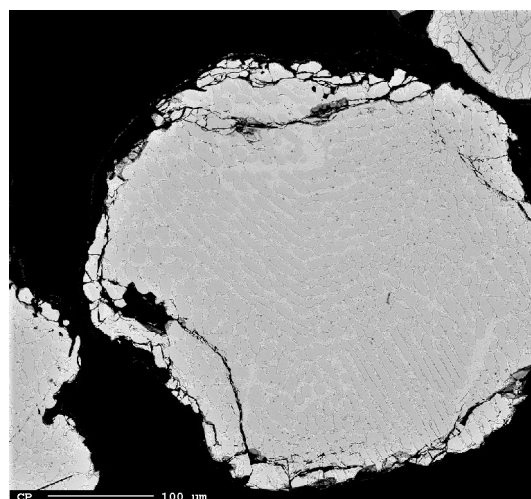
EPMA - Images



Figure C1: Metal phases in experiment 5 with charcoal depicted in EPMA.



(a) Small metal droplets



(b) Big metal droplet

Figure C2: Metal droplets from experiment 6+S, charcoal with sulfur slag, depicted with EPMA.

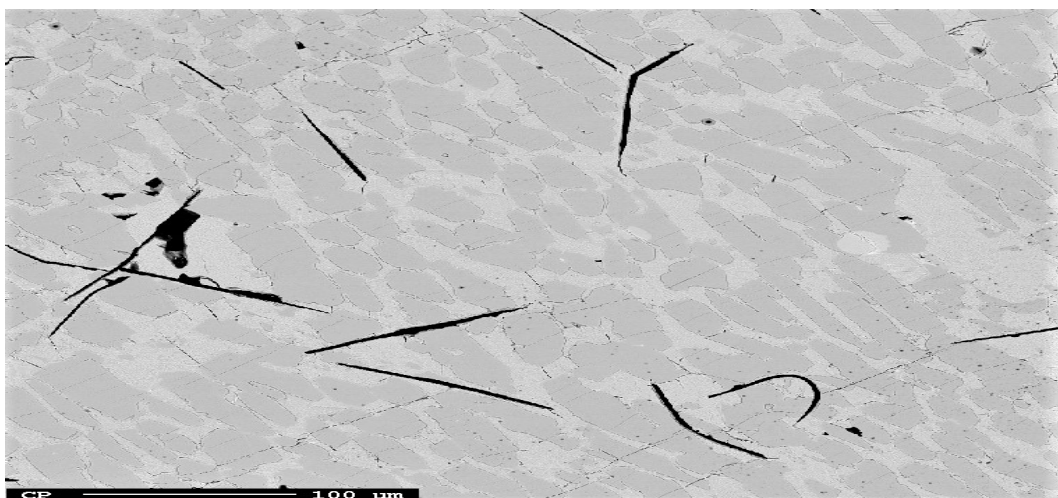


Figure C3: Metal phases from experiment 7+S, charcoal with sulfur slag, depicted with EPMA.

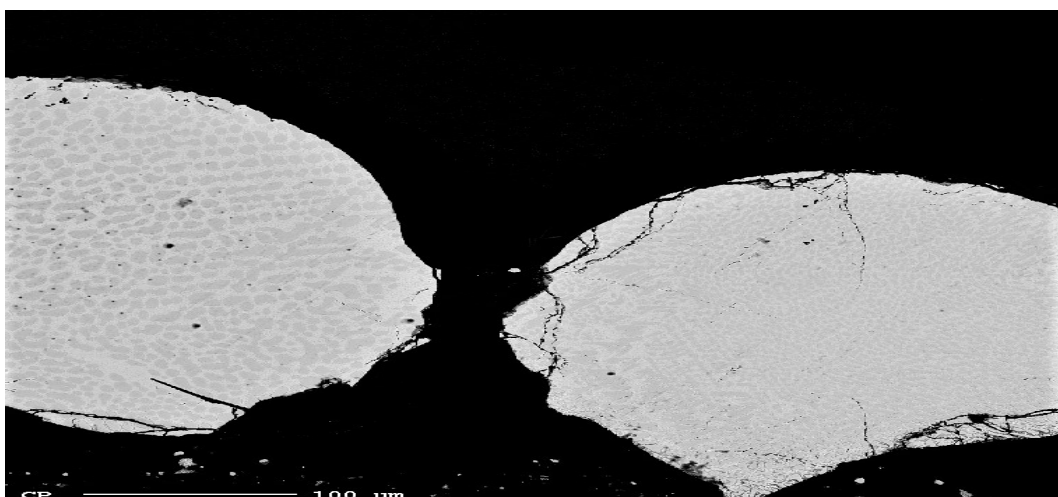


Figure C4: Metal droplets from experiment 8+S, charcoal with sulfur slag, depicted with EPMA.

D Chemical analysis - SEM EDS

Table D1: Chemical analysis for slag samples from SEM EDS - Not normalized results

	<i>Parameters</i>	<i>MnO</i>	<i>SiO2</i>	<i>Al2O3</i>	<i>CaO</i>	<i>MgO</i>	<i>K2O</i>	<i>TOT</i>	<i>R-ratio</i>
<i>1.Coke</i>	T1, 1-2mm	25.3	33.8	17.3	10.9	0.9	1.4	89.7	0.7
<i>2</i>	T2, 1-2mm	3.7	32.0	36.4	28.0	1.1	-	101.2	0.8
<i>3</i>	T1, 3-4mm	15.2	35.2	18.3	16.0	0.6	1.5	86.7	0.9
<i>4</i>	T2, 3-4mm	3.4	29.7	40.4	30.4	0.9		104.8	0.8
<i>5.Charcoal</i>	T1, 1-2mm	-	-	-	-	-	-	-	-
<i>6</i>	T2, 1-2mm	25.6	31.6	14.6	10.6	0.3	-	82.7	0.7
<i>7</i>	T1, 3-4mm	37.2	26.5	9.1	8.6	0.2	-	81.6	1.0
<i>8</i>	T2, 3-4mm	22.3	34	16.6	13.9	0.5	-	87.3	0.9
<i>1.droplet</i>	-	22.8	33.9	15.9	9.6	0.3	1.4	83.9	0.6
<i>4.lid</i>	-	7.4	41.8	26.2	20.3	0.9	1.7	98.3	0.8

Table D2: Chemical analysis for slag samples from SEM EDS - Normalized results

	<i>Parameters</i>	<i>MnO</i>	<i>SiO2</i>	<i>Al2O3</i>	<i>CaO</i>	<i>MgO</i>	<i>K2O</i>	<i>R-ratio</i>
<i>1.Coke</i>	T1, 1-2mm	28.2	37.7	19.3	12.2	0.9	1.6	0.7
<i>2</i>	T2, 1-2mm	3.6	31.6	36.0	27.7	1.1	-	0.8
<i>3</i>	T1, 3-4mm	17.5	40.6	21.1	18.4	0.6	1.7	0.8
<i>4</i>	T2, 3-4mm	3.2	28.4	38.5	29.0	0.9	-	0.8
<i>5.Charcoal</i>	T1, 1-2mm	-	-	-	-	-	-	-
<i>6</i>	T2, 1-2mm	30.9	38.2	17.7	12.9	0.3	-	0.7
<i>7</i>	T1, 3-4mm	46.6	32.3	10.6	10.3	0.3	-	1.0
<i>8</i>	T2, 3-4mm	25.5	39.0	19.0	15.9	0.5	-	0.9
<i>1.droplet</i>	-	27.2	40.5	19.0	11.4	0.4	1.6	0.6

Table D2 continued from previous page

<i>4.lid</i>	-	7.5	42.5	26.7	20.7	0.9	1.7	0.8
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Prosjektoppgave: Reduksjon av Mn-malm i høytemperatursovn i CO(g)-atomsfære. Bruk av høytemperatursovn TF1, rom E-214.

Prosjektoppgave: Reduksjon av Mn-malm i høytemperatursovn i CO(g)-atomsfære. Bruk av høytemperatursovn TF1, rom E-214.

[illegible]

	Sigmund Forberg
Oftlakere (navn):	

[illegible]

Herb Tangsted

Merete Tangstad
Ans. veileder