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Analysis of the melting behaviour of CaF_2 - free welding fluxes using Hot Thermocouple Technique

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INTRODUCTION

- CaF_2 → common constituent in Submerged Arc Welding (SAW) fluxes
- Maintains liquidus (<1400 °C) and viscosity (0.1-0.6Pa-s @ 1500 -1400 °C)
- Substitute with benign components → CaO, MnO etc.
- No compromise on properties → 3 fluxes from CaO - SiO_2 - Al_2O_3 - MnO
- CaO/SiO_2 = 1, Al_2O_3 =6%, MnO = (15, 20, 25)% → test melting behavior
- Benchmark with commercial SAW welding flux

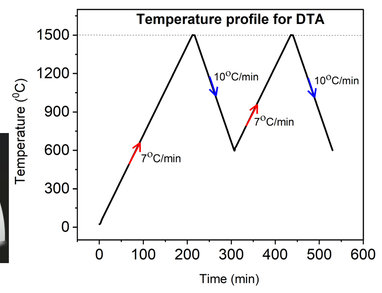
METHODOLOGY

Target composition
Master slag ($CaO-SiO_2-Al_2O_3$)
+
Requisite MnO

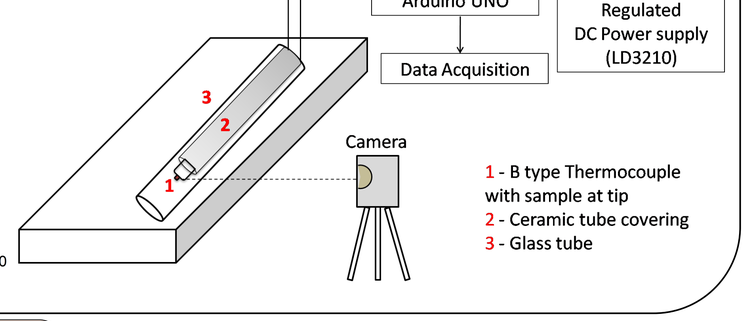
→ Pre-melted in IF steel crucible (Avoid MnO - graphite contamination)

→ Benchmarked with commercial welding flux

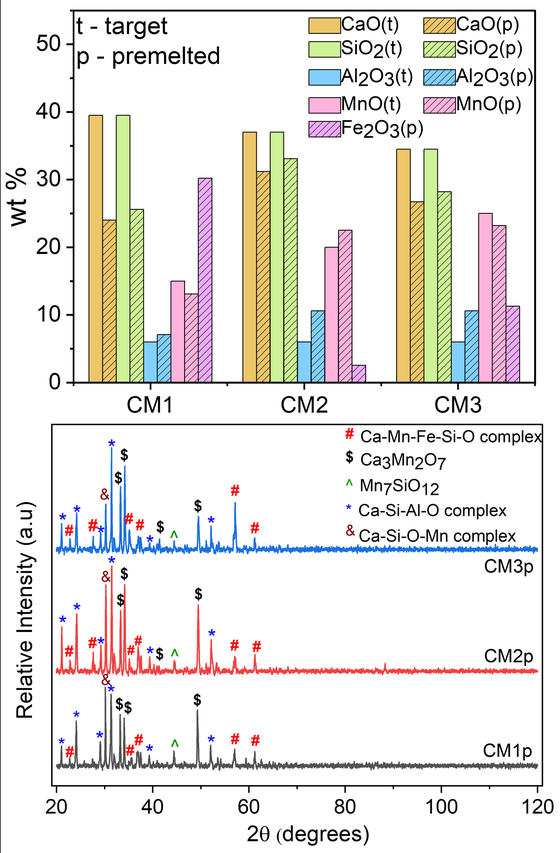
DTA



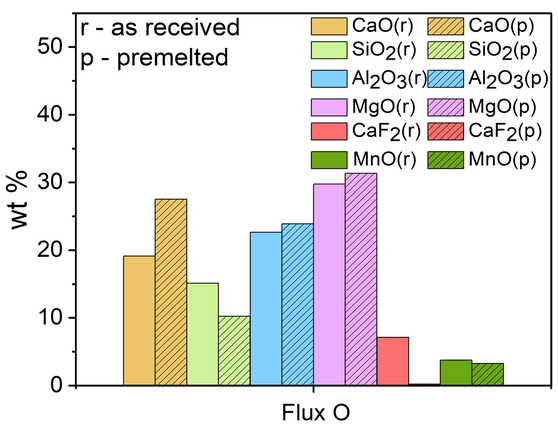
SHTT

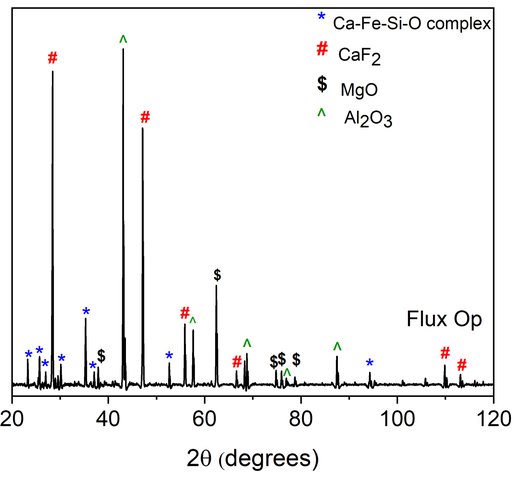


RESULTS AND DISCUSSIONS

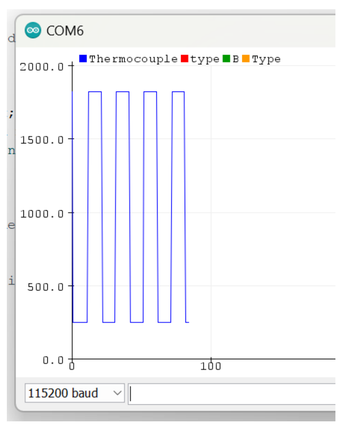


- Mn-Si-O complexes[2]
- Aids in reducing liquidus

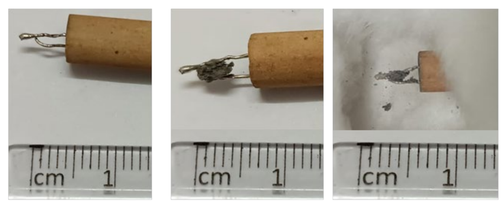


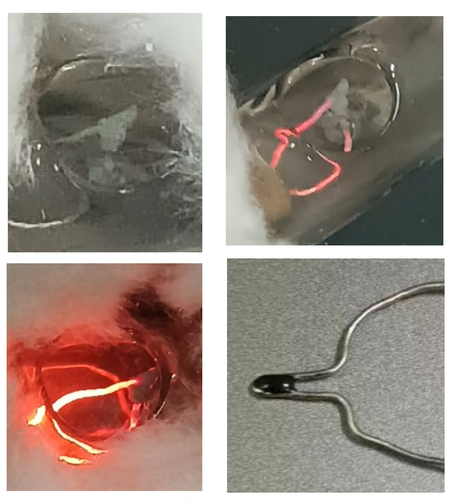


SHTT analysis



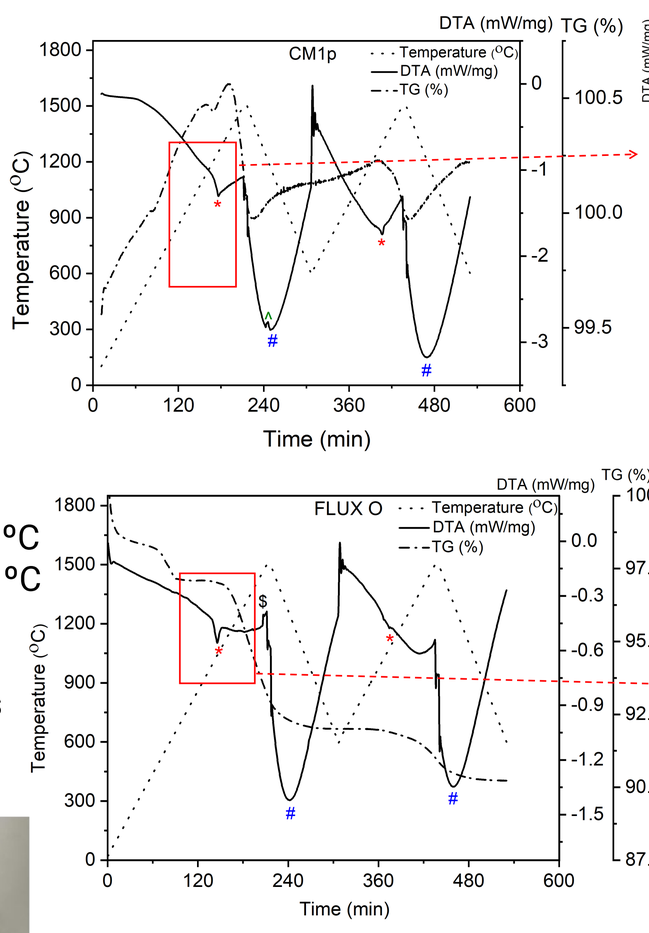
- Slow heating till 400 °C
- Continuous heating till 1000 °C
- Relay switching from ~1100 °C
- 10 sec switching interval
- PLX-DAQ data acquisition
- Repeated SHTT experiments for better accuracy

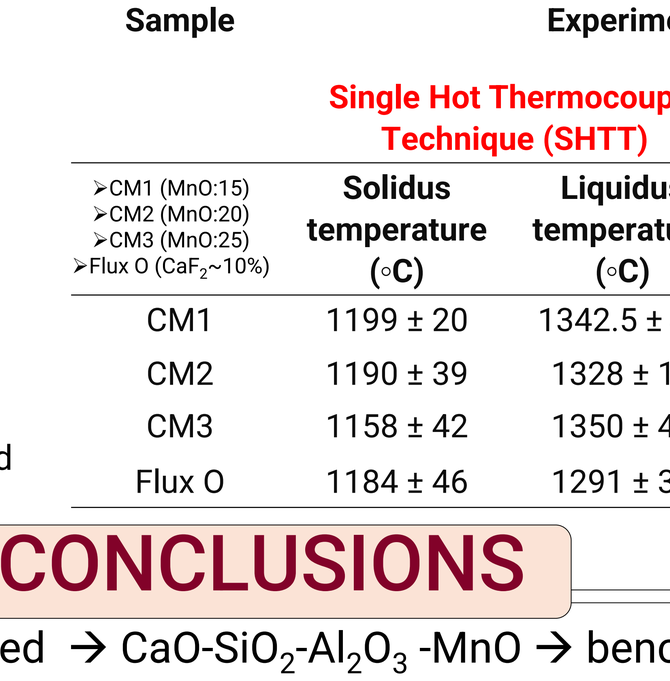




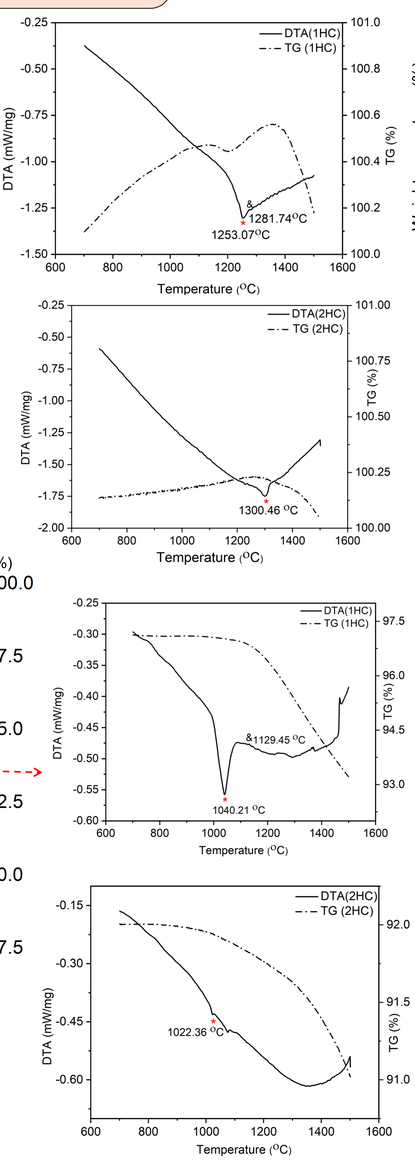
- CM series fluxes - premelted
- Commercial flux - as received (to understand CaF_2 effect)

DTA analysis

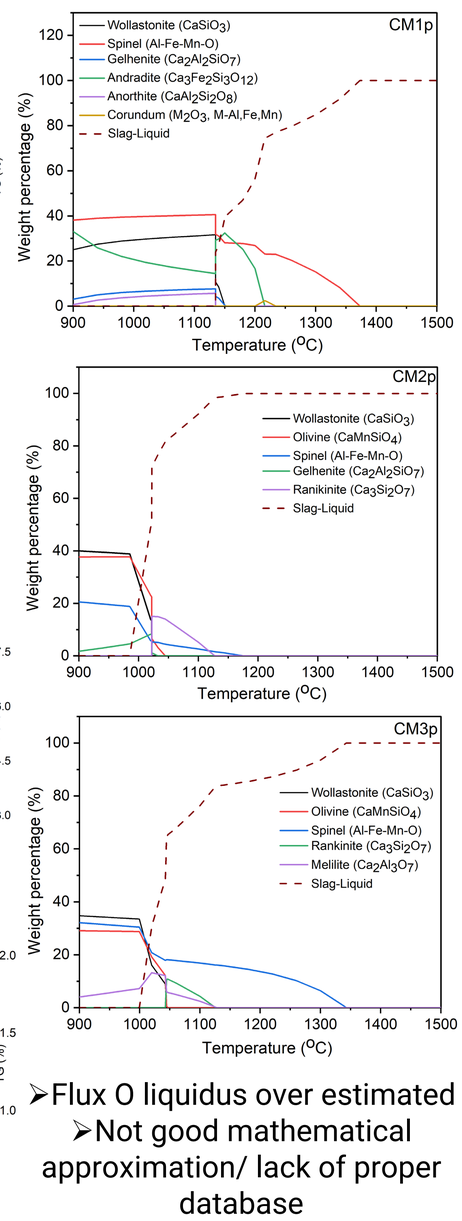




- Downward peaks – endothermic
- '*' - Solidus
- '&' - Liquidus



FactSage ™ estimations



- Flux O liquidus over estimated
- Not good mathematical approximation/ lack of proper database

Sample	Experimental measurements				FactSage™ Estimations
	Single Hot Thermocouple Technique (SHTT)		Differential Thermal Analysis (DTA)		
➢CM1 (MnO:15) ➢CM2 (MnO:20) ➢CM3 (MnO:25) ➢Flux O (CaF_2~10%)	Solidus temperature (◦C)	Liquidus temperature (◦C)	Solidus temperature (◦C)	Liquidus temperature (◦C)	Liquidus Temperature (◦C)
CM1	1199 ± 20	1342.5 ± 40	1276.76	1281.74	1434.2
CM2	1190 ± 39	1328 ± 14	1202.69	1320.26	1317.74
CM3	1158 ± 42	1350 ± 43	1291.98	1325.20	1381.34
Flux O	1184 ± 46	1291 ± 34	1031.28	1129.45	~1400*

*Value estimated from Ref [3]

CONCLUSIONS

- Possible CaF_2 free welding flux alternatives identified → CaO-SiO_2-Al_2O_3 -MnO → benchmarked with a commercial flux
- Effect of varying MnO studied → DTA, SHTT, FactSage™ melting behaviour estimations
- Liquidus values in desired range for welding fluxes (<1400 °C); comparable with welding fluxes
- SHTT fabricated and tested → can also be used for solidification studies

REFERENCES

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