Performance Comparisons between Thermal Barrier Coating (TBC) Compositions at various Temperatures and Proportions

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Introduction

TBC's are designed to insulate structural elements below it from the additional thermal stressed being placed upon modern gas turbine engines. Ensuring they are operating within their design parameters is essential in lengthening service lifespan of hot section components [1, 2].

Figure 1| Phase names and compositions present in YSZ, CMAS Systems[1]

Type	Name	Nominal formula
Intrinsic crystallization	Anorthite	$CaAl_2Si_2O_8$
	Diopside	$CaMgSi_2O_6$
	Cristobalite, tridymite	SiO_2
	(Pseudo)wollastonite	$CaSiO_3$
	Melilite	$(Ca)_2(Al,Mg)(Al,Si)SiO_7$
	Spinel	$MgAl_2O_7$
Reprecipitation	Fluorite	$(Zr,RE,Ca)O_{1.x}$
	Tetragonal ZrO_2	$(Zr,RE,Ca)O_{1.x}$
	Celsian	$(Ba,Sr,Ca)Al_2Si_2O_8$
Reactive crystallization	Zircon	$ZrSiO_4$
	CaZr-cyclosilicate	$Ca_2ZrSi_4O_{12}$
	Calcium zirconate	$CaZrO_3$
	Apatite	$(Ca,RE)_4(RE,Zr)_6(SiO_4)_6O_2$
	Garnet	$(Ca,RE,Zr)_3(Zr,Ti,Mg,Al,Fe)_2(Si,Al,Fe)_3O_{12}$
	Cuspidine	$(RE,Ca,Hf,Mg)_4(Si,Al)_2O_{9.x}$
	CaRE-cyclosilicate	$Ca_3RE_2Si_6O_{18}$
	Silicocarnotite	$Ca_3RE_2Si_3O_{12}$

Figure 2| Schematic of TBC and TBC Coatings[1]

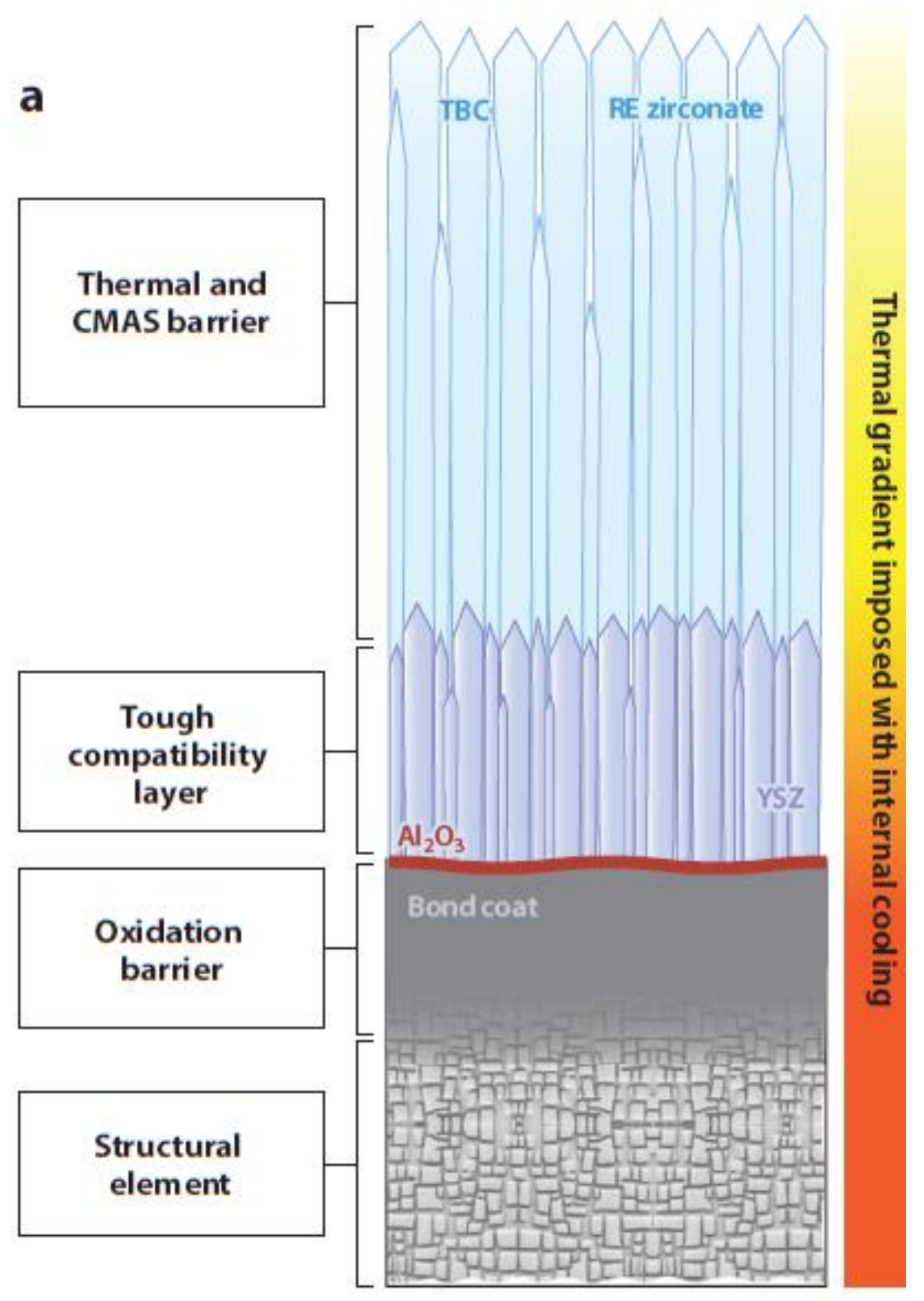


Figure 3| TBC Prior to CMAS Reaction[1]

Poerschke DL, et al. 2017.
Annu. Rev. Mater. Res. 47:297–330

Results

Figure 7| Solid Composition at 1.0% ZrO_2

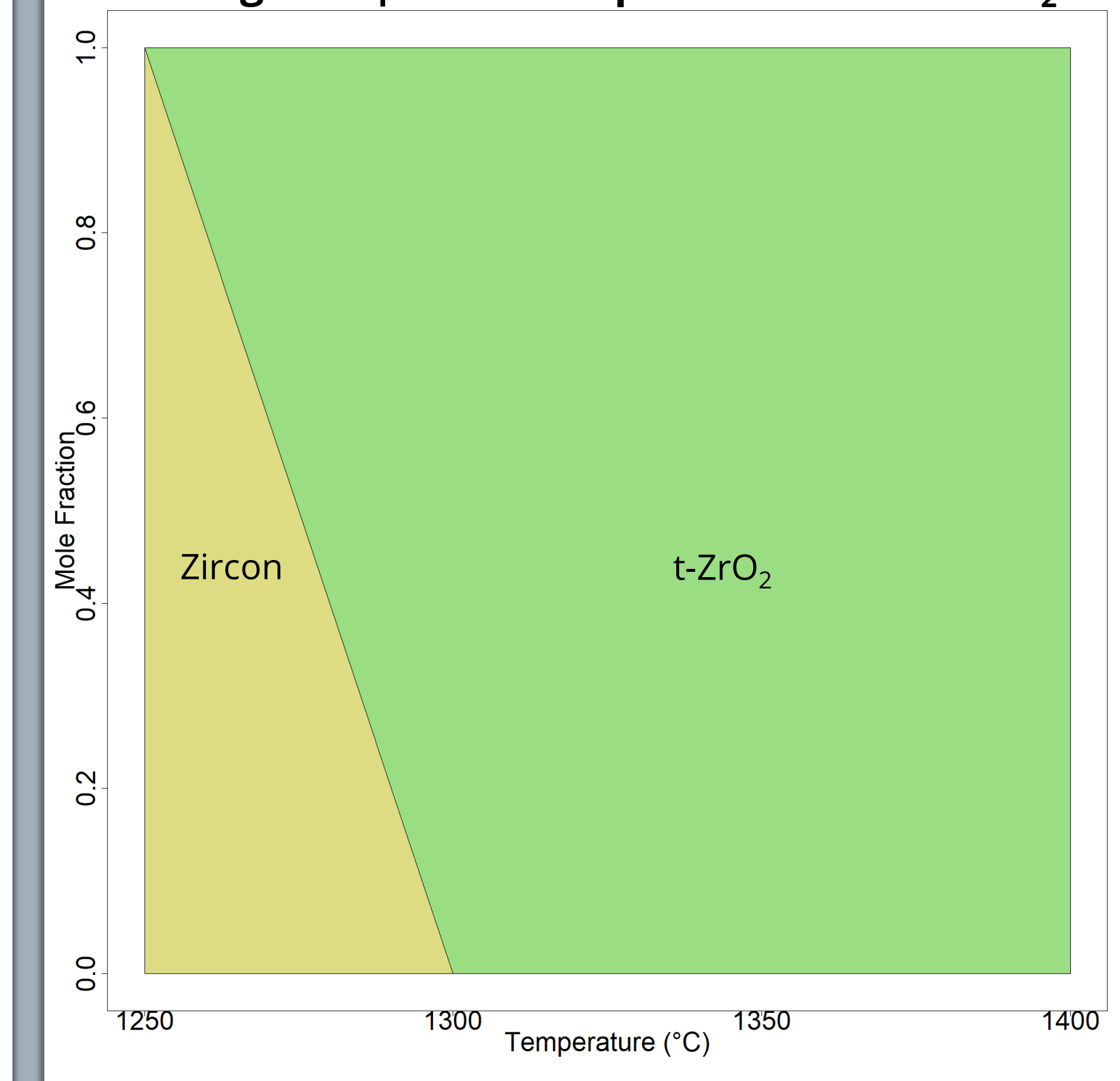


Figure 8| Solid Composition at 2.5% ZrO_2

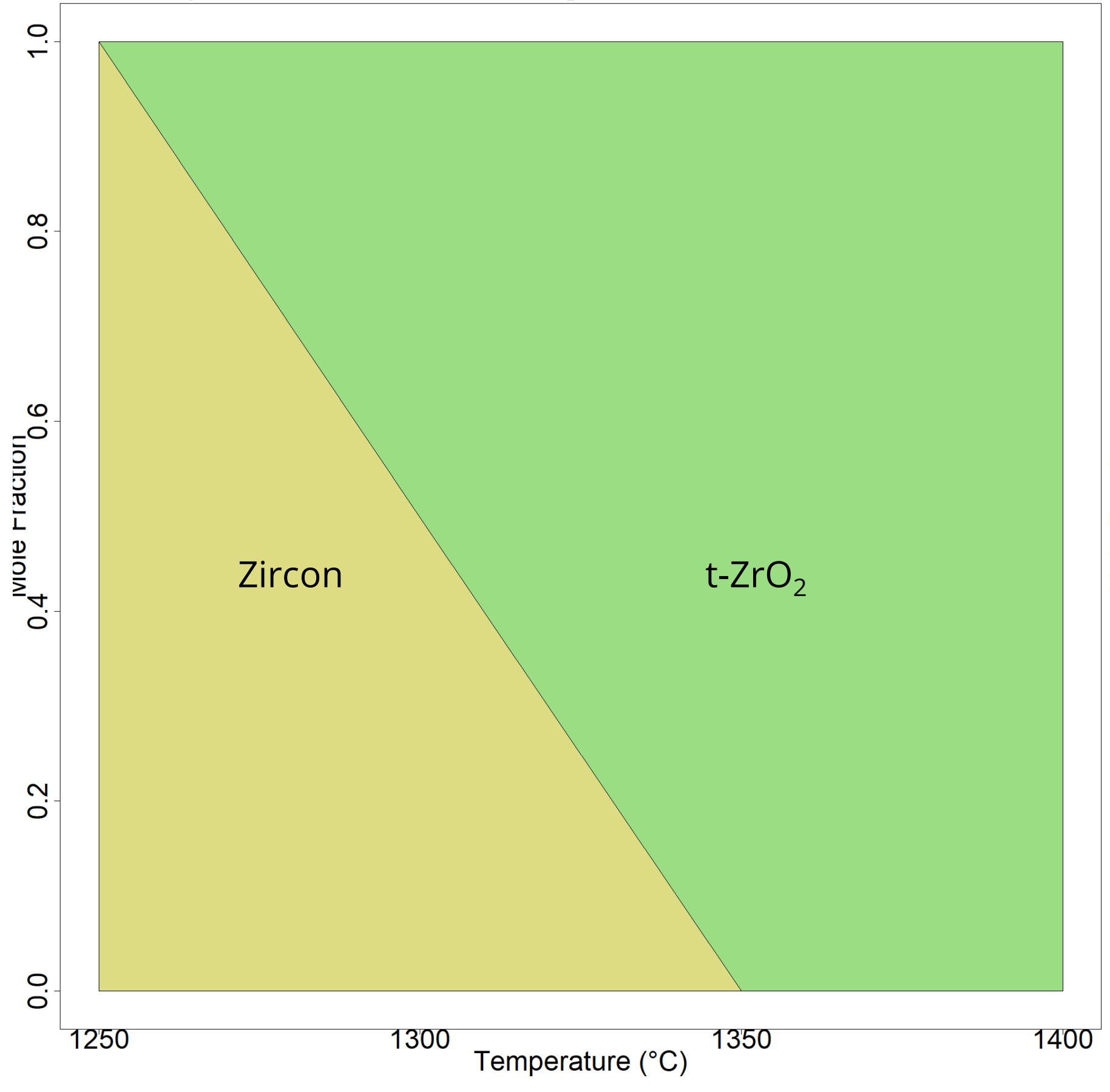


Figure 9| Solid Composition at 5.0% ZrO_2

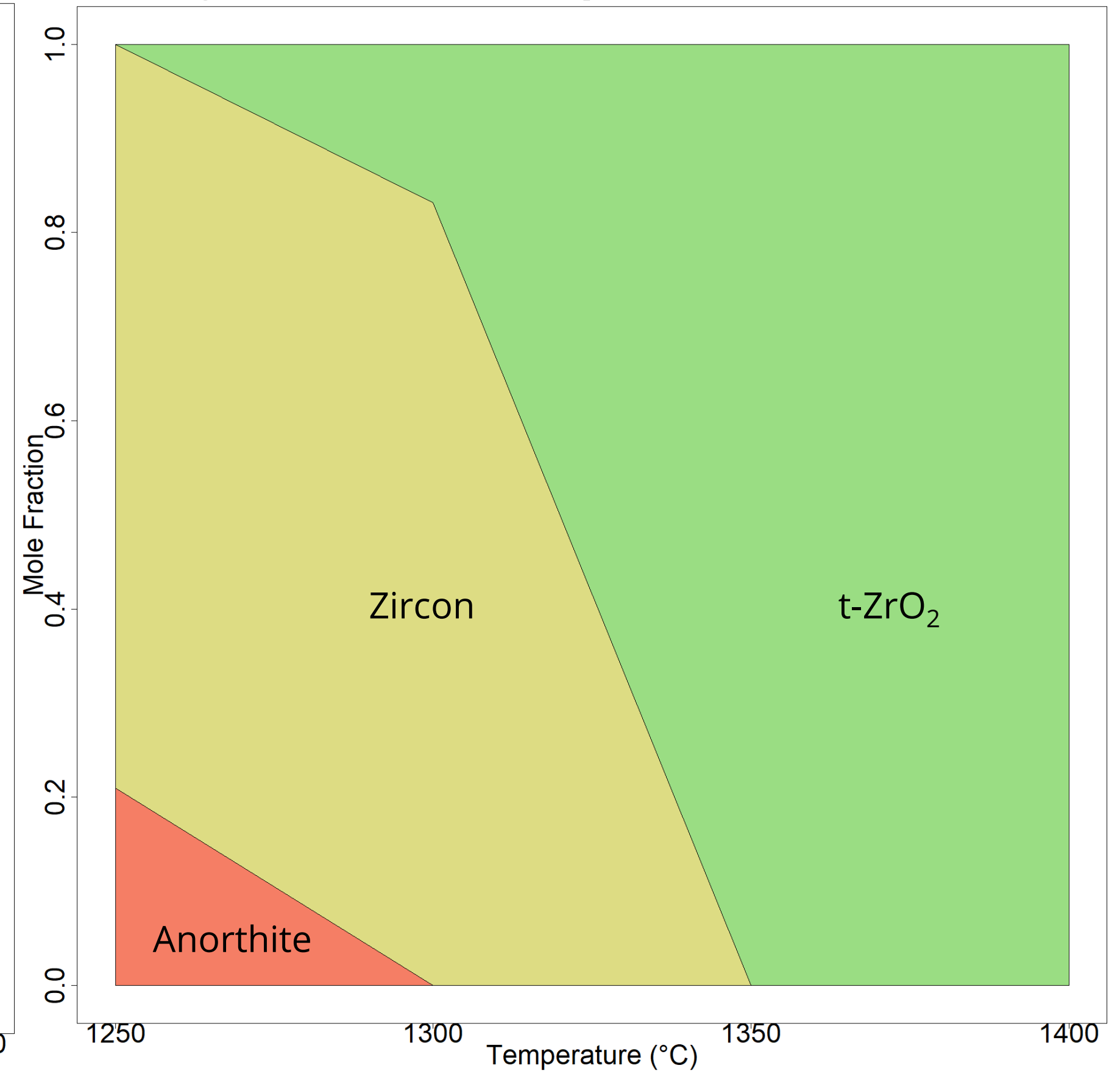


Figure 10| Solid Composition at 8.0% ZrO_2

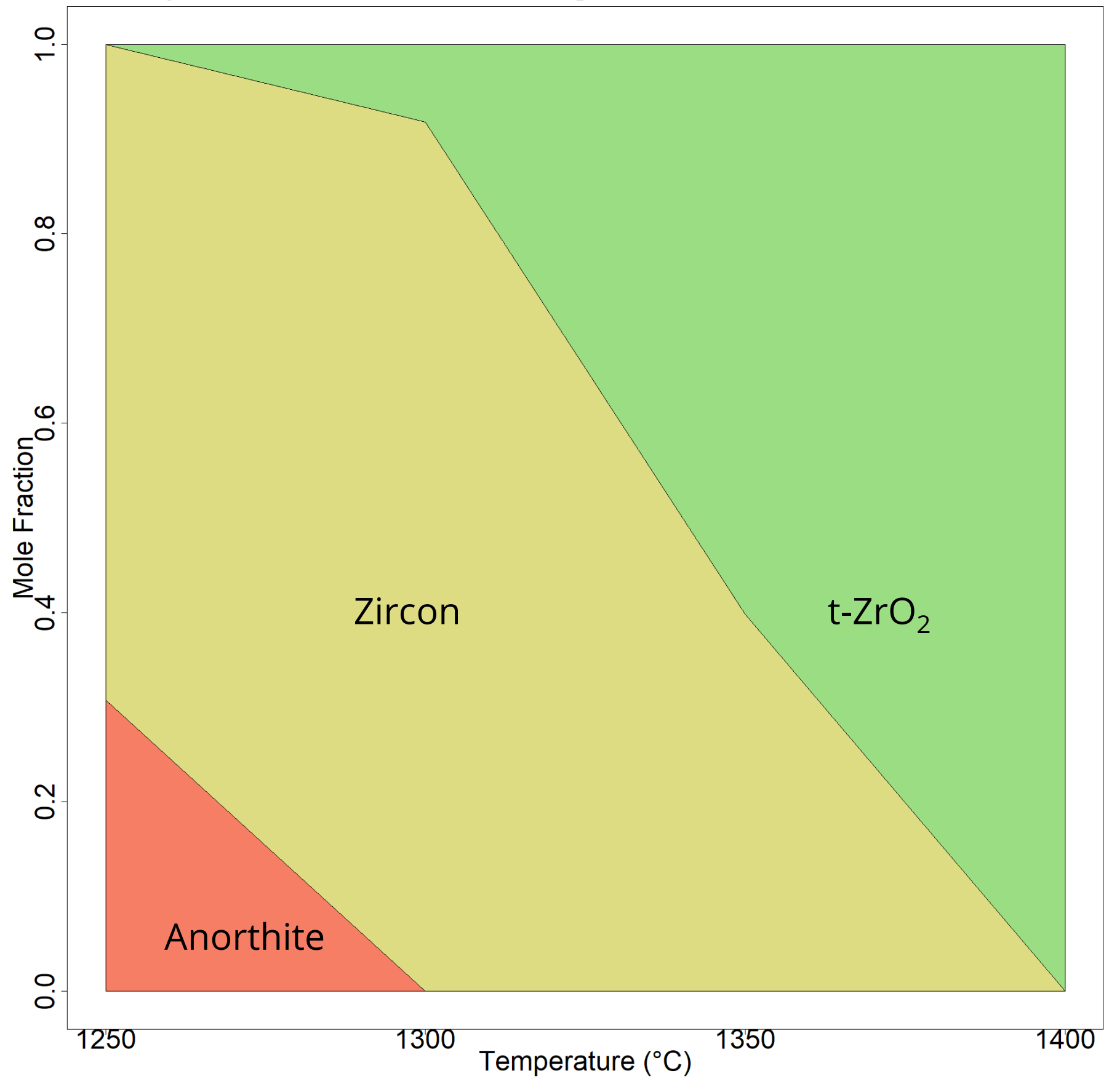


Figure 11| Solid Composition at 10.0% ZrO_2

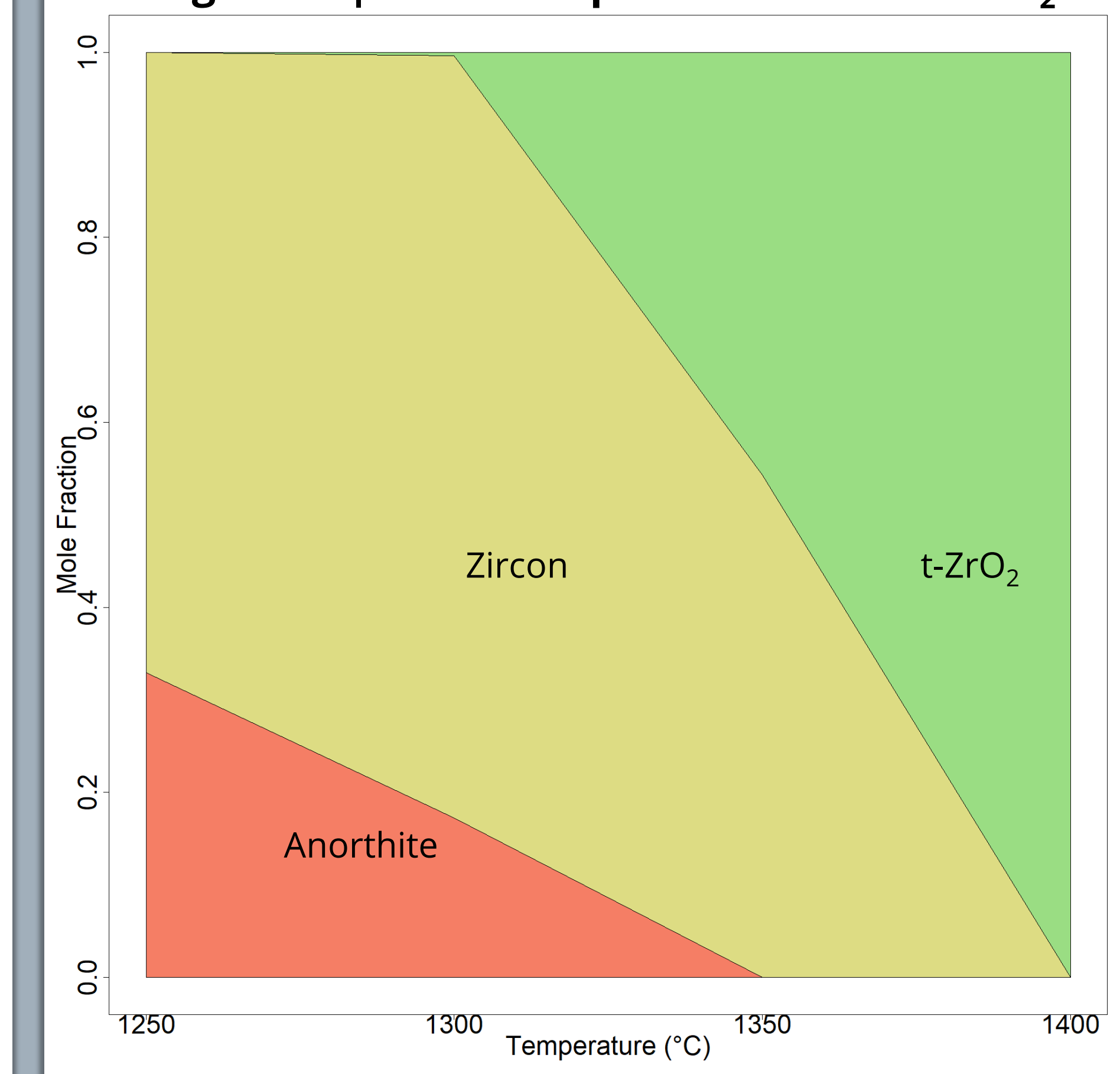
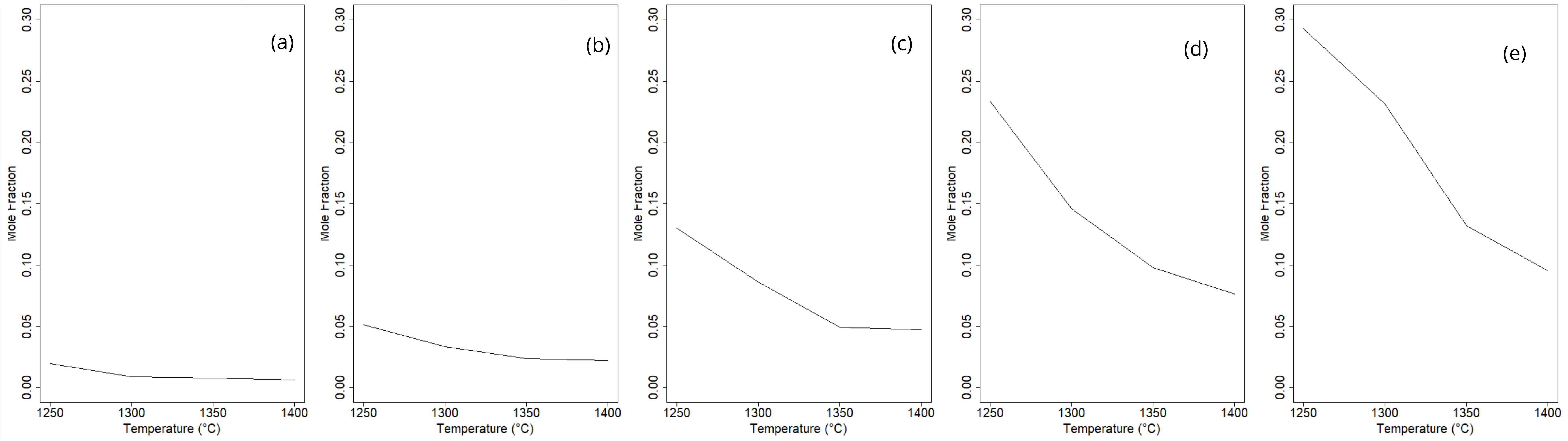


Figure 12| Solid Composition of Equilibrium Solution (a)1.0% ZrO_2 (b) 2.5% ZrO_2 (c) 5.0% ZrO_2 (d) 8.0% ZrO_2 (e) 10.0% ZrO_2



- Coating toughness is also of great consideration as the coating is also subject to physical stresses. As the quantity of t'-ZrO_2 decreases, the fracture toughness of the material will decrease, leading to premature failure of the coating [3].
- Delamination toughness cannot be directly obtained although an indicator on how vulnerable a coating will be to delamination can be qualitatively determined by the quantity of t-ZrO_2 present [3].

- Higher proportion of Zirconia in the TBC yields better results at higher temperatures but toughness of the coating decreases as
- Future work can be done, utilizing other systems such as the Gadolinia-Zirconia system to compare performance to the YSZ system[1,4]
- Attempts were done to analyze more complex melts although oxygen activity and Iron multi-valency affected the model more than anticipated [5].

Methodology

Figure 5| Phase Compositions of $C_{24}A_{17}S_{59}$ at Different Temperatures

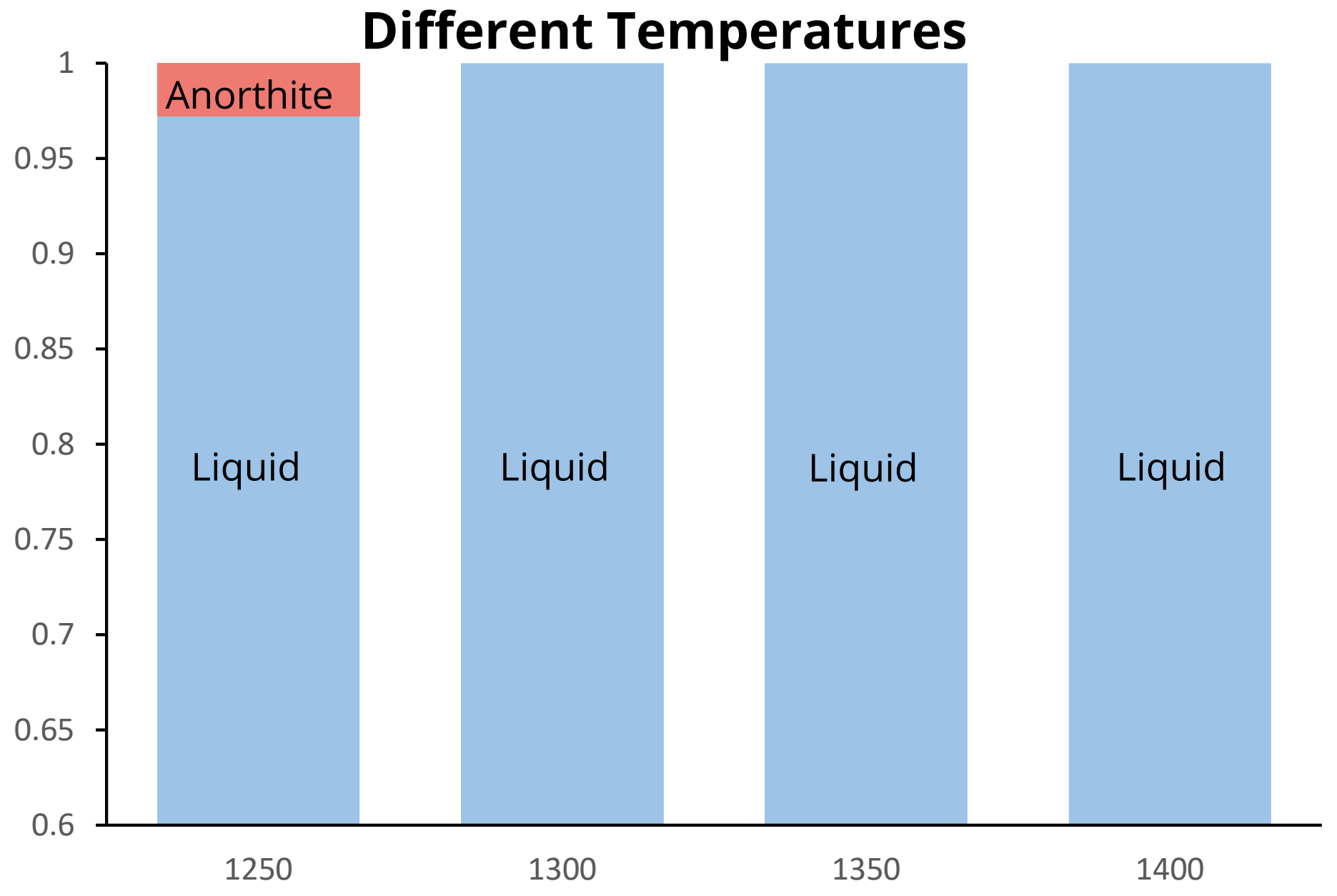
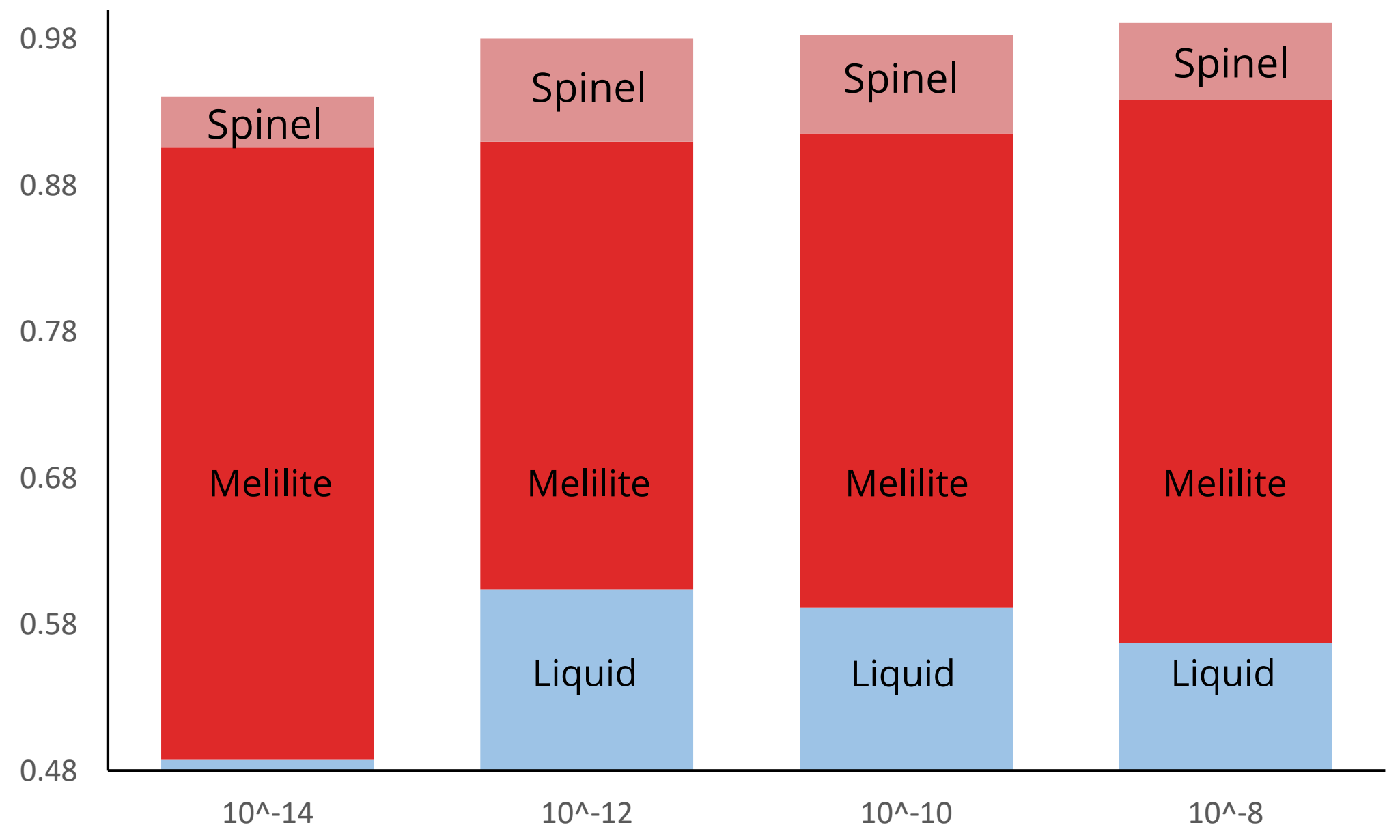


Figure 6| Melt Products with $C_{32}M_{12}A_{20}F_4S_{32}$ at 1300C



- Equilibrium data for the systems shown here were generated using the Calculation of Phase Diagrams (CALPHAD) methodology through ThermoCalc.
- Database used was TCOX 7, a metal oxide solution simulator. CALPHAD utilizes multiple different chemical and physical properties such as crystallography and available free energy.
- Figure 5 shows melt composition if 100% pure. Changes to phases developed was observed upon addition of TBC. Desired phases include reactive crystallization products which have a geometry favourable to impede melt progress.
- Figure 6 demonstrates ThermoCalc's oxygen activity limits with a more complex system. A CAS system was selected with 10^{-14} oxygen activity to ensure solution convergence.

Acknowledgements

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