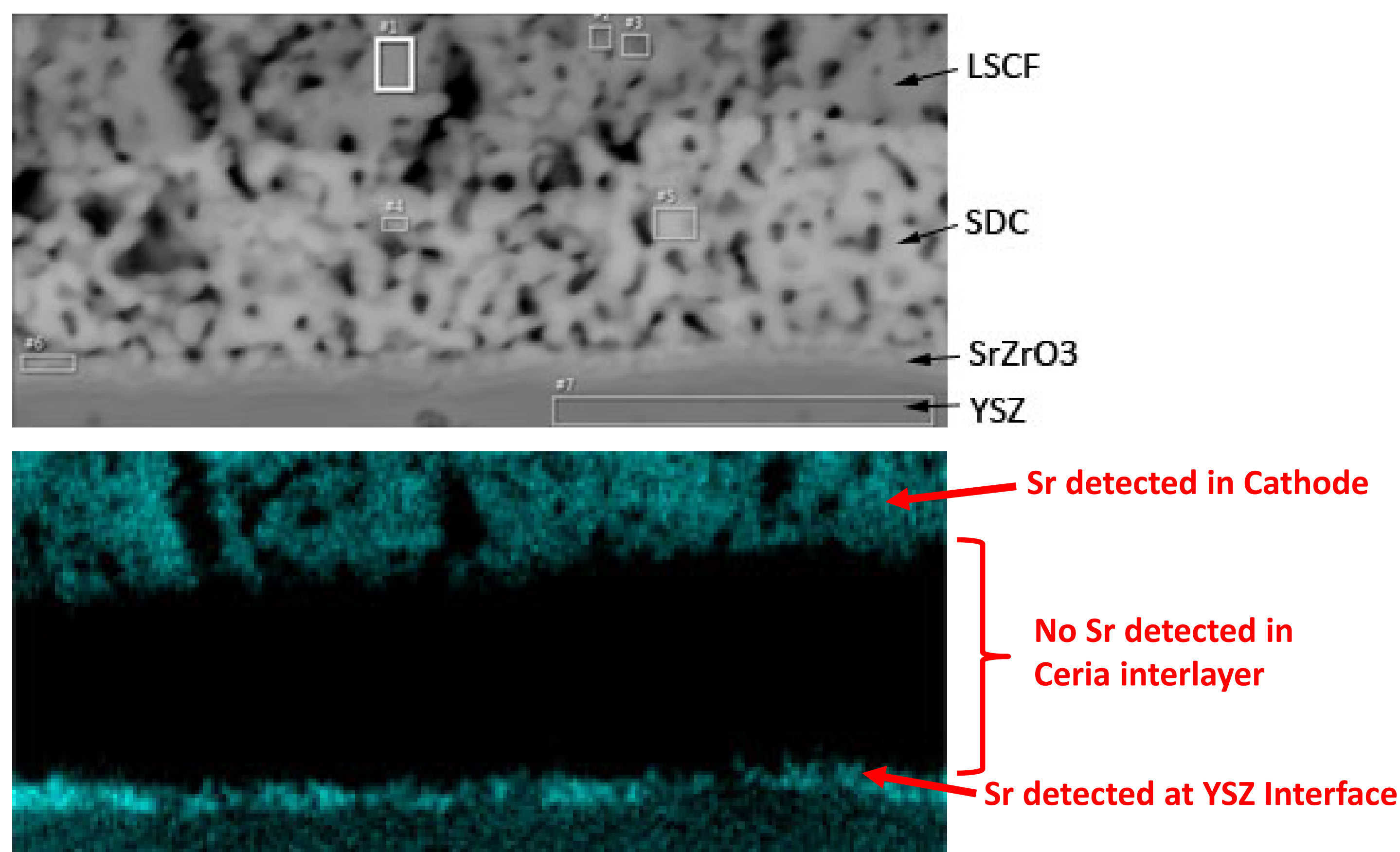


Investigating Sr Vapor Phase Evolution from LSM/YSZ and LSCF Cathodes During and After Sintering

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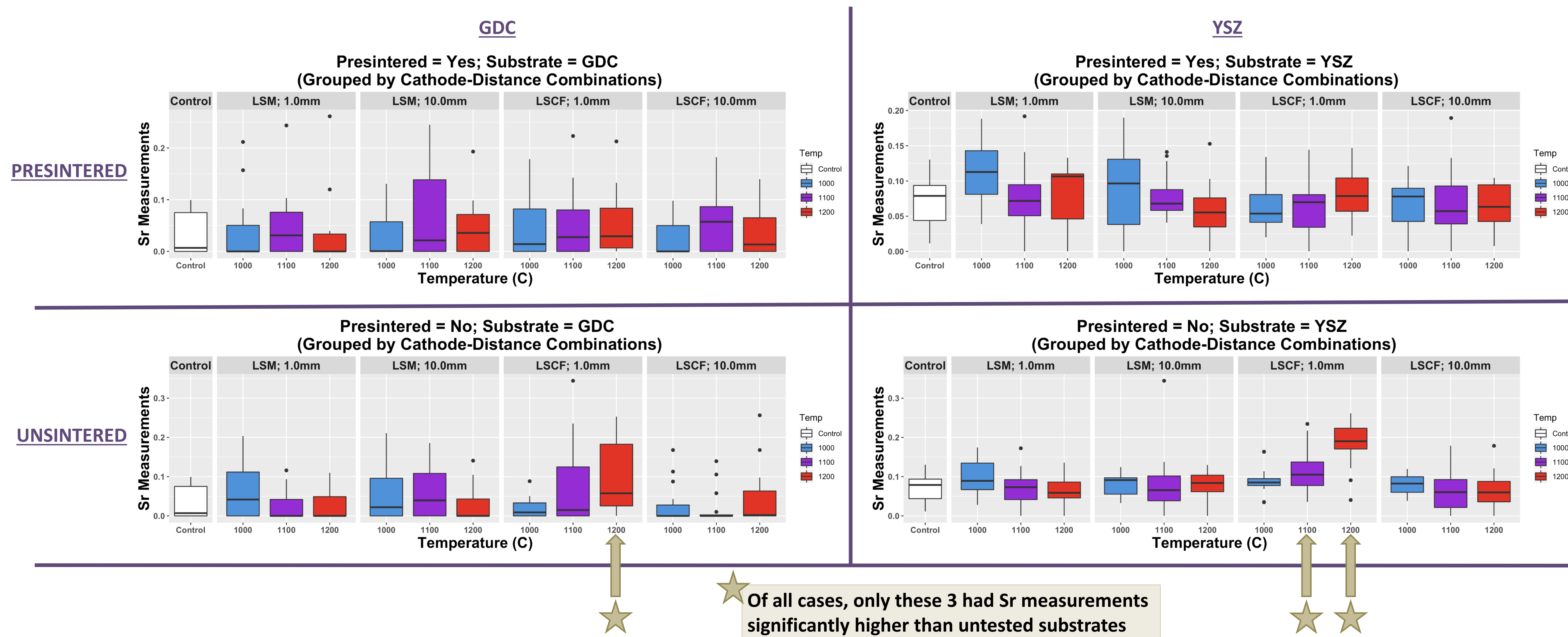


MOTIVATION – TYPICAL SEM-EDS Sr MAPS OF SINTERED LSCF CATHODES

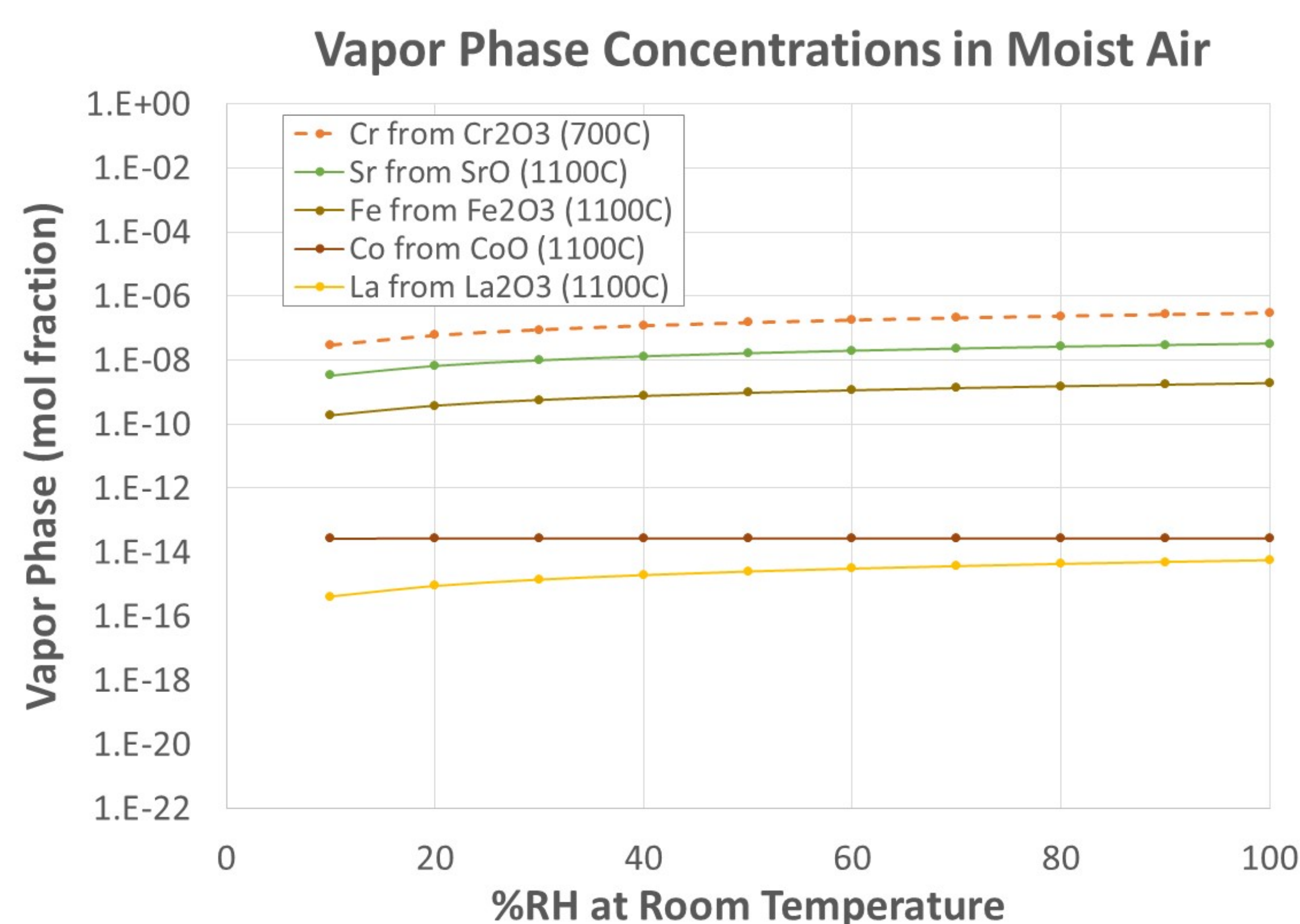


During sintering, Sr from LSCF cathode diffuses to YSZ interface and reacts to form Sr-zirconate. Sr concentration gradient characteristic of solid phase diffusion that would be expected across the ceria interlayer is absent. Could vapor phase transport play a role?

COMPARING TESTED SUBSTRATES TO UNTESTED SUBSTRATES



THERMODYNAMIC CALCULATIONS SUPPORT Sr VAPOR TRANSPORT



Sr volatility at 1100°C is within an order of magnitude of the level of Cr that poisons SOFC cathodes at 700°C and is the highest amongst LSCF components.

WILCOX-MANN-WHITNEY TEST TO EVALUATE STATISTICAL SIGNIFICANCE

The Wilcoxon-Mann-Whitney test is a non-parametric method used when the statistical distribution can not be assumed. In this case, it was used to test the probability that the null hypothesis is true (i.e., that the Sr measurements from the tested samples came from the same distribution as the measurements from untested samples). This probability is known as the p-value. Low p-values indicate a significant difference between the measured values, with $p < 0.100$ indicating weak significance and $p < 0.025$ indicating strong significance.

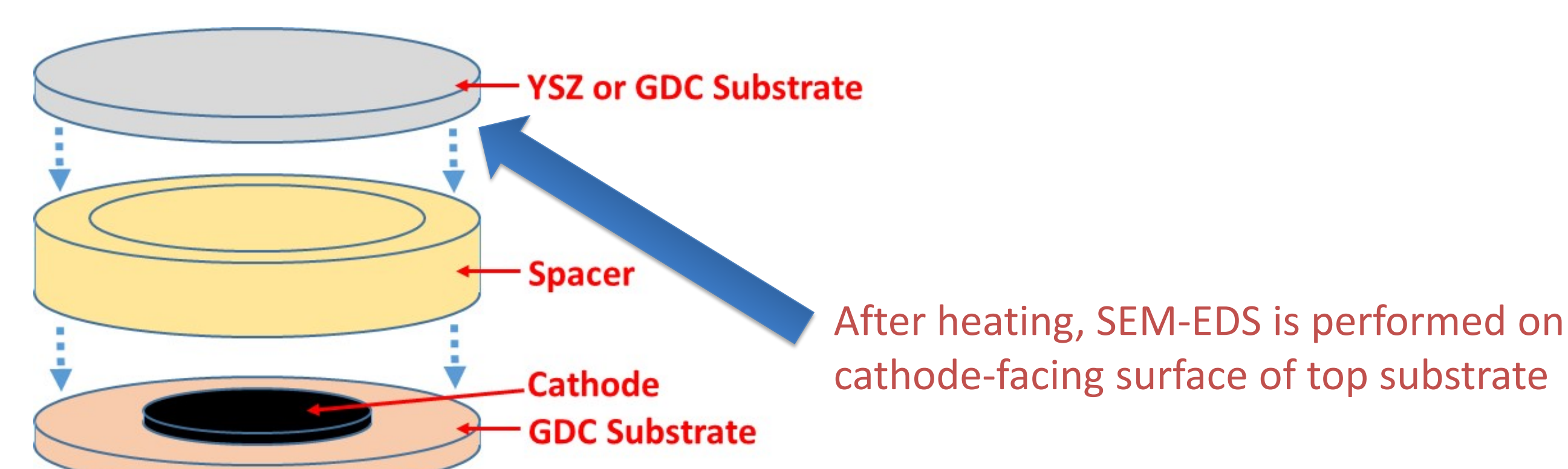
Preliminary analysis determined that the time variable could be disregarded to reduce the number of cases and effectively increase the number of measurements per case.

Presintered	Substrate	Cathode	Dist (mm)	Temp (C)	p_values
Yes	GDC	LSCF	1.0	1000	0.6755
Yes	GDC	LSCF	1.0	1100	0.7232
Yes	GDC	LSCF	1.0	1200	0.3647
Yes	GDC	LSCF	10.0	1000	0.5160
Yes	GDC	LSCF	10.0	1100	0.5407
Yes	GDC	LSCF	10.0	1200	0.7267
Yes	GDC	LSM/YSZ	1.0	1000	0.5495
Yes	GDC	LSM/YSZ	1.0	1100	0.6336
Yes	GDC	LSM/YSZ	1.0	1200	0.6081
Yes	GDC	LSM/YSZ	10.0	1000	0.9783
Yes	GDC	LSM/YSZ	10.0	1100	0.3957
Yes	GDC	LSM/YSZ	10.0	1200	0.7749
Yes	YSZ	LSCF	1.0	1000	0.6529
Yes	YSZ	LSCF	1.0	1100	0.6529
Yes	YSZ	LSCF	1.0	1200	0.8810
Yes	YSZ	LSCF	10.0	1000	0.8782
Yes	YSZ	LSCF	10.0	1100	0.6026
Yes	YSZ	LSCF	10.0	1200	0.6529
Yes	YSZ	LSM/YSZ	1.0	1000	0.1153
Yes	YSZ	LSM/YSZ	1.0	1100	0.9284
Yes	YSZ	LSM/YSZ	1.0	1200	0.6968
Yes	YSZ	LSM/YSZ	10.0	1000	0.5606
Yes	YSZ	LSM/YSZ	10.0	1100	0.9284
Yes	YSZ	LSM/YSZ	10.0	1200	0.4167
No	GDC	LSCF	1.0	1000	0.7232
No	GDC	LSCF	1.0	1100	0.5841
No	GDC	LSCF	1.0	1200	0.0882
No	GDC	LSCF	10.0	1000	0.5495
No	GDC	LSCF	10.0	1100	0.2901
No	GDC	LSCF	10.0	1200	0.9743
No	GDC	LSM/YSZ	1.0	1000	0.4209
No	GDC	LSM/YSZ	1.0	1100	0.8153
No	GDC	LSM/YSZ	1.0	1200	0.8153
No	GDC	LSM/YSZ	10.0	1000	0.5090
No	GDC	LSM/YSZ	10.0	1100	0.4648
No	GDC	LSM/YSZ	10.0	1200	0.6472
No	YSZ	LSCF	1.0	1000	0.3742
No	YSZ	LSCF	1.0	1100	0.0808
No	YSZ	LSCF	1.0	1200	0.0004
No	YSZ	LSCF	10.0	1000	0.6968
No	YSZ	LSCF	10.0	1100	0.6457
No	YSZ	LSCF	10.0	1200	0.6460
No	YSZ	LSM/YSZ	1.0	1000	0.3196
No	YSZ	LSM/YSZ	1.0	1100	0.7828
No	YSZ	LSM/YSZ	1.0	1200	0.7417
No	YSZ	LSM/YSZ	10.0	1000	0.6101
No	YSZ	LSM/YSZ	10.0	1100	0.6905
No	YSZ	LSM/YSZ	10.0	1200	0.6968

SUMMARY

- Significant Sr vapor phase transport was measured when:
 - The cathode was not sintered prior to testing
 - The cathode composition was LSCF
 - The distance of the substrate from the cathode was shorter (1 mm)
 - The temperature was higher (1100 or 1200°C)
- Sr was more likely to deposit on YSZ than on GDC
 - At 1100°C, Sr on YSZ was weakly significant ($p=0.0808$)
 - At 1200°C, Sr on YSZ was very strongly significant ($p=0.0004$)
 - Sr on GDC was only weakly significant at 1200°C ($p=0.0882$) (slightly less significant than on YSZ at 1100°C)
- No Sr vapor phase transport occurred with:
 - Pre-sintered cathodes
 - LSM/YSZ cathodes
 - Longer (10 mm) separation between substrate and cathode
 - Lower temperature (1000°C)

EXPERIMENTAL METHODOLOGY



Variables	Settings
Cathode State	Sintered; Unsintered
Cathode Composition	LSM/YSZ; LSCF
Substrate (Sr Sink) Composition	GDC; YSZ
Spacer Thickness	1 mm; 10 mm
Test Temperature	1000°C; 1100°C; 1200°C
Time at Temperature	0.5 h; 2 h

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