

Residual chlorine prevents full densification of 3 mol% yttria-stabilized zirconia ceramics during ultrafast high-temperature sintering (UHS)

3Y and 3YB samples for supplementary experiments were additionally pressed at lower pressure, resulting in three types of green bodies: (1) green bodies uniaxially pressed at 60 MPa (UNI 60), (2) green bodies uniaxially pressed at 60 MPa and cold isostatically pressed at 100 MPa (UNI 60 CIP 100), and (3) green bodies uniaxially pressed at 60 MPa and cold isostatically pressed at 250 MPa (UNI 60 CIP 250).

The supplementary UHS experiments were performed at different conditions than those described in the main article text. The sintering apparatus, generally built in the same manner, varied in size and shape and flowing nitrogen was used instead of argon. The graphite felt was heated in constant power mode via different DC power supply (EA-PS 9080-100, 0-80 V, 0-100 A, 3000 W, Elektro-Automatik, Germany). Like in the main text, the UHS was conducted using a two-step heating process. The felt was first heated to 85 W (about 975 °C) and held for 90 s. Temperature calibration was done by melting pure metal wires (Cu, Ni, Pt, 8 mm in length and bended to a nugget shape) placed in a graphite felt slit. The lowest power level at which each metallic wire melted was considered to represent the melting temperature of the respective metal. The power was then increased to 350 W or 500 W and held for 60 s. The power ramp was conducted at the maximum rate the power supply permits. The power supply was then turned off, allowing a fast cool down.

Photo documentation of the supplementary samples is displayed in Fig. S1. Their relative densities as a percentage of theoretical density (TD) are listed in Table S1.

Table S1 Relative densities of 3Y and 3YB. Both green body densities and densities after UHS 350 and 500 W are included.

	Relative density of 3Y (%TD)			Relative density of 3YB (%TD)		
	UNI 60	UNI 60 CIP 100	UNI 60 CIP 250	UNI 60	UNI 60 CIP 100	UNI 60 CIP 250
Green body	41.3	45.5	49.3	42.6	47.4	50.1
UHS 350 W	89.6	85.6	87.5	96.6	98.1	99.0
UHS 500 W	91.1	84.5	84.7	97.5	98.5	99.2

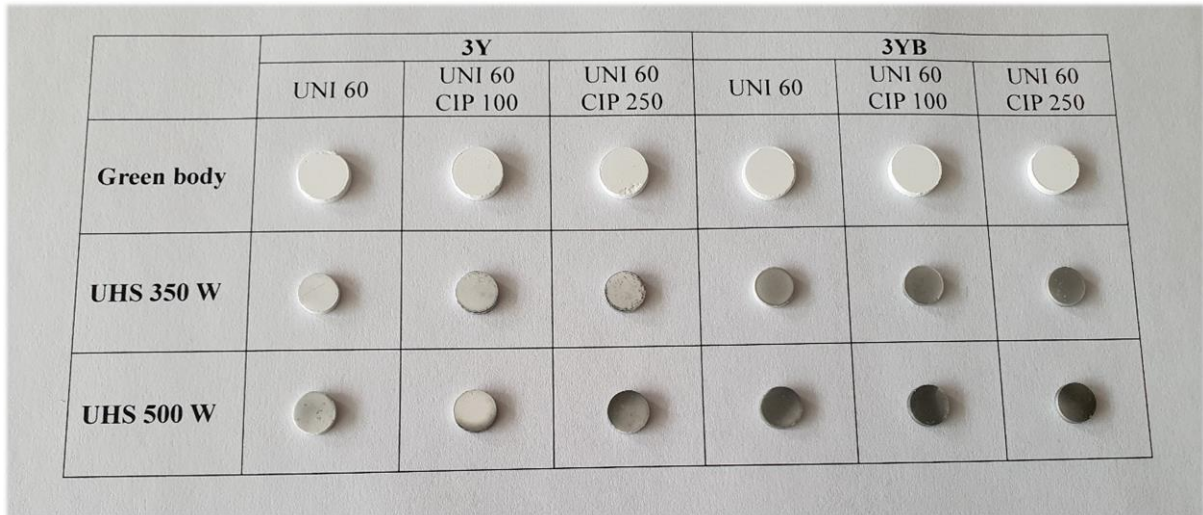


Figure S1 Photo documentation of the supplementary samples.

The UHS experiments for comparing different UHS heating rates started with a power ramp up to 62 W (800 °C) with 60 s dwell. The power was then increased to 212 W (1500 °C) and held for 60 s using the maximum heating rate the power supply permits (denoted as max heating rate), or in step-like fashion, producing either 100 °C, 50 °C, 10 °C, or 5 °C increase each minute (denoted as 100 °C/min, 50 °C/min, 10 °C/min, or 5 °C/min). The schematic depiction of these heating profiles is in Fig. S2.

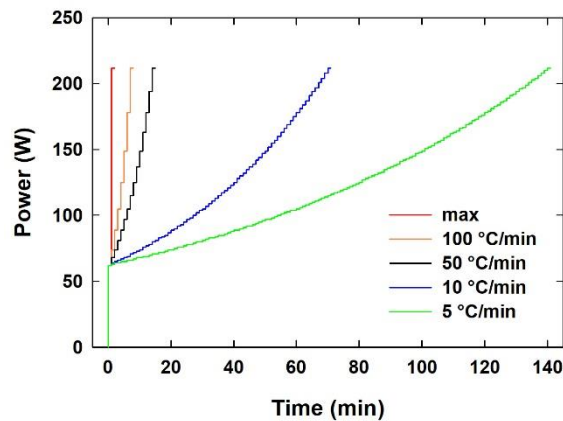


Figure S2 Schematic depiction of different UHS heating profiles.

Additionally, longer dwell time of 300 s was also tested in case of fast heating rates. The power supply was then turned off, allowing a fast cool down. The resulting final densities of samples are shown in Table S2. The data show a clear trend: samples heated at 5 °C/min reached 98.4 %TD, those heated at 100 °C/min yielded 92.8 %TD, and the maximum heating rate resulted in only 87.7 %TD. Longer dwell time did not significantly improve the final density of rapidly heated UHS samples which supports our hypothesis that fast heating traps residual chlorine, thereby restraining full densification.

Table S2 Relative densities of 3Y samples sintered at different UHS heating rates.

UHS heating rate	Dwell time (s)	Relative density of 3Y (%TD)
max	60	87.7
max	300	87.4
100 °C/min	60	92.8
100 °C/min	300	90.5
50 °C/min	60	91.4
50 °C/min	300	92.0
10 °C/min	60	97.4
5 °C/min	60	98.4