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Supporting Information

High-precision cerium isotope analysis by thermal ionization mass spectrometry using the Ce^+ technique

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Table S1. Results of Ce isotope ratios for reference materials together with data from the literatures.

Reference	Sample	Ion species	Loading method	Ce amount (μg)	Measured ratio	Values	2SD	External precision (2RSD, ppm)
Tanaka et al.-1982[1]	JMC 304	CeO^+	Triple Re	—	$^{138}Ce/^{142}Ce$	0.0228559	0.0000011	48 (n = 15)
Shimizu et al.-1984[2]	JMC 304	CeO^+	Triple Re	5	$^{138}Ce/^{142}Ce$	0.0228559	0.0000011	48
Nakamura et al.-1984[3]	ALD Standard	CeO^+	Double Ta	0.15-2	$^{138}Ce/^{140}Ce$	0.00284178	0.00000011	39 (n = 15)
Makishima et al.-1991[4]	JMC 304	CeO^+	Double Re + H_3PO_4	1	$^{138}Ce/^{142}Ce$	0.0225685	0.0000019*	84 (n = 16)
Amakawa et al.-1996[5]	JMC 304	CeO^+	Double Re + H_3PO_4	1-5	$^{138}Ce/^{142}Ce$	0.0225694	0.0000011*	49 (n = 12)
Tanimizu et al.-2004[6]	JMC 304	CeO^+	Triple Re + H_3PO_4	1.5	$^{138}Ce/^{142}Ce$	0.0225889	0.0000013	58 (n = 21)
Hayashi et al.-2004[7]	JMC 304	CeO^+	-	—	$^{138}Ce/^{142}Ce$	0.0225771	0.0000034*	151
Tazoe et al.-2007[8]	JMC 304	CeO^+	Double Re + H_3PO_4	2	$^{138}Ce/^{142}Ce$	0.0225688	0.0000014*	62 (n = 22)
Tazoe et al.-2007[9]	JMC 304	CeO^+	Double Re + H_3PO_4	10	$^{138}Ce/^{142}Ce$	0.0225698	0.0000009*	40 (n = 5)
Willbold-2007[10]	AMES	CeO^+	Double Re	1-2	$^{138}Ce/^{136}Ce$	1.33738	0.00003	23 (n = 34)
Doucelance et al.-2014[11]	AMES	CeO^+	Double Re	1	$^{138}Ce/^{142}Ce$	0.0225747	0.0000010	44 (n = 53)
Bellot et al.-2015[12]	JMC 304	CeO^+	Double Re + H_3PO_4	1	$^{138}Ce/^{142}Ce$	0.0225706	0.0000009	40 (n = 10)
Bellot et al.-2015[12]	AMES	CeO^+	Double Re + H_3PO_4	1	$^{138}Ce/^{142}Ce$	0.0225746	0.0000011	49 (n = 15)
Willig et al.-2018[13]	AMES	CeO^+	Double Re + H_3PO_4	1-1.5	$^{138}Ce/^{136}Ce$	1.337332	—	33
Bonnand et al.-2019[14]	AMES	CeO^+	Double Re + H_3PO_4	0.75	$^{138}Ce/^{142}Ce$	0.0225743	0.0000007	31 (n = 25)
Bonnand et al.-2019[14]	LMV	CeO^+	Double Re + H_3PO_4	0.75	$^{138}Ce/^{142}Ce$	0.0225705	0.0000006	27 (n = 48)
Shimizu et al.-1992[15]	JMC 304	Ce^+	-	—	$^{138}Ce/^{142}Ce$	0.0225777	0.0000116*	517 (n = 34)
Xiao et al.-1994[16]	JMC 304	Ce^+	Single Ta	20	$^{142}Ce/^{140}Ce$	0.125228	0.000052	415 (n = 8)
Chang et al.-1995[17]	USSR Standard	Ce^+	Double Re	4	$^{140}Ce/^{142}Ce$	0.0046067	0.0000018	391 (n = 6)
Willbold-2007[10]	AMES	Ce^+	Double Re + H_3PO_4	1-3	$^{138}Ce/^{136}Ce$	1.33733	0.00045	335 (n = 24)
This study	JMC 304	Ce^+	Single Re + TaF_5	2	$^{138}Ce/^{142}Ce$	0.0225768	0.0000011	49 (n = 10)
This study	JMC 304	Ce^+	Single Re + TaF_5	2	$^{138}Ce/^{136}Ce$	1.33735	0.00007	52 (n = 10)
This study	JMC 304	Ce^+	Single Re + TaF_5	2	$^{138}Ce/^{140}Ce$	0.00284296	0.00000010	36 (n = 10)

*The standard deviation (σ) is recalculated from the raw data, for the analytical precision in the literature is given by: $2\sigma_m = 2\sigma/\sqrt{n}$, where σ and n denote the standard deviation and the number of scans for a single analysis, respectively.

34

35 **Table S2.** Analytical results of Ce isotopic ratios of uranium ore samples in detail.

Sample	$^{138}Ce/^{142}Ce$	$^{138}Ce/^{136}Ce$	$^{138}Ce/^{140}Ce$	$\varepsilon(^{138}Ce/^{140}Ce)_{CHUR}$
1# UO	0.0225684	1.33695	0.00284122	-1.36
	0.0225679	1.33696	0.00284117	-1.54
	0.0225676	1.33700	0.00284125	-1.26
	0.0225687	1.33702	0.00284127	-1.19
	0.0225682	1.33698	0.00284120	-1.43
	0.0225678	1.33699	0.00284122	-1.36
Mean ± 2SD	0.0225681 ±8	1.33698 ±5	0.00284122 ±7	-1.36 ±0.25
2# UO	0.0225672	1.33695	0.00284116	-1.57
	0.0225659	1.33690	0.00284103	-2.03
	0.0225673	1.33691	0.00284092	-2.42
	0.0225681	1.33693	0.00284115	-1.61
	0.0225677	1.33701	0.00284106	-1.92
	0.0225665	1.33689	0.00284098	-2.21
Mean ± 2SD	0.0225671 ±16	1.33693 ±9	0.00284105 ±19	-1.96 ±0.67
3# UO	0.0225723	1.33723	0.00284173	+0.43
	0.0225728	1.33721	0.00284170	+0.33
	0.0225734	1.33727	0.00284181	+0.71
	0.0225725	1.33722	0.00284171	+0.36
	0.0225721	1.33721	0.00284169	+0.29
	0.0225724	1.33719	0.00284167	+0.22
Mean ± 2SD	0.0225726 ±9	1.33722 ±5	0.00284172 ±10	+0.39 ±0.35
4# UO	0.0225684	1.33691	0.00284117	-1.54
	0.0225675	1.33692	0.00284107	-1.89
	0.0225687	1.33700	0.00284125	-1.26
	0.0225672	1.33693	0.00284109	-1.82
	0.0225670	1.33695	0.00284114	-1.64
	0.0225683	1.33702	0.00284127	-1.19

Mean ± 2SD	0.0225679 ±14	1.33696 ±9	0.00284117 ±16	-1.55 ±0.56
5# UO	0.0225703	1.33706	0.00284148	-0.45
	0.0225688	1.33708	0.00284137	-0.83
	0.0225694	1.33700	0.00284135	-0.90
	0.0225702	1.33704	0.00284150	-0.38
	0.0225698	1.33706	0.00284141	-0.69
	0.0225696	1.33699	0.00284135	-0.90
Mean ± 2SD	0.0225697 ±11	1.33704 ±7	0.00284141 ±13	-0.69 ±0.46
6# UO	0.0225681	1.33713	0.00284139	-0.76
	0.0225690	1.33716	0.00284131	-1.04
	0.0225694	1.33711	0.00284137	-0.83
	0.0225682	1.33710	0.00284135	-0.90
	0.0225691	1.33707	0.00284122	-1.36
	0.0225687	1.33706	0.00284126	-1.22
Mean ± 2SD	0.0225688 ±10	1.33711 ±7	0.00284132 ±13	-1.02 ±0.46
7# UO	0.0225759	1.33732	0.00284216	+1.95
	0.0225768	1.33745	0.00284222	+2.16
	0.0225749	1.33736	0.00284201	+1.42
	0.0225753	1.33733	0.00284196	+1.24
	0.0225761	1.33741	0.00284220	+2.09
	0.0225773	1.33739	0.00284206	+1.59
Mean ± 2SD	0.0225761 ±18	1.33738 ±10	0.00284210 ±21	+1.74 ±0.74
8# UO	0.0225702	1.33698	0.00284132	-1.01
	0.0225686	1.33696	0.00284119	-1.47
	0.0225695	1.33705	0.00284139	-0.76
	0.0225710	1.33706	0.00284150	-0.38
	0.0225694	1.33701	0.00284126	-1.22
	0.0225690	1.33709	0.00284141	-0.69
Mean ± 2SD	0.0225696 ±17	1.33703 ±10	0.00284135 ±22	-0.92 ±0.77

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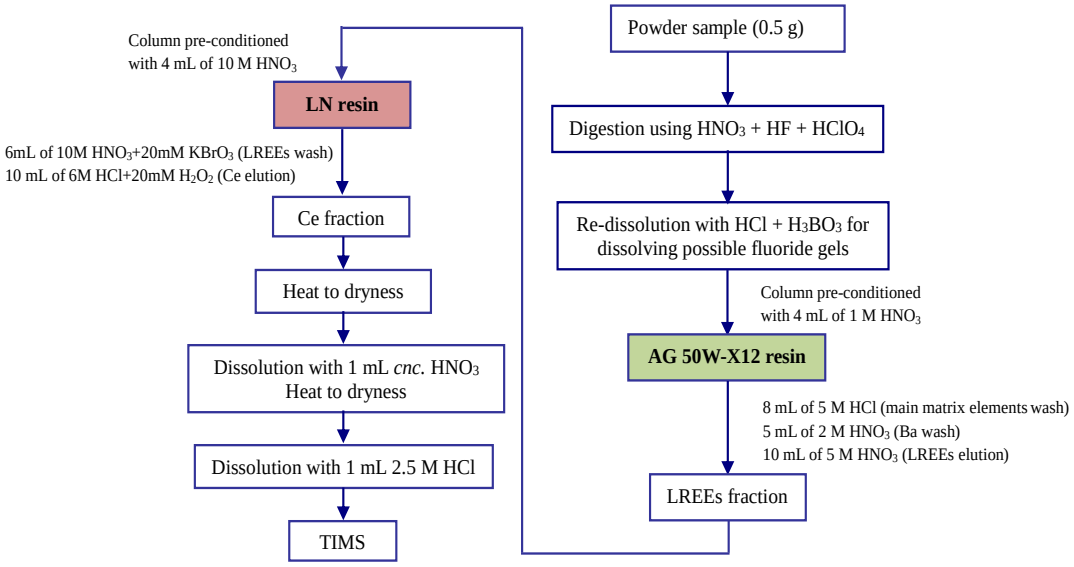

Fig. S1. Chemical procedure for the determination of Ce isotopes in powder samples.

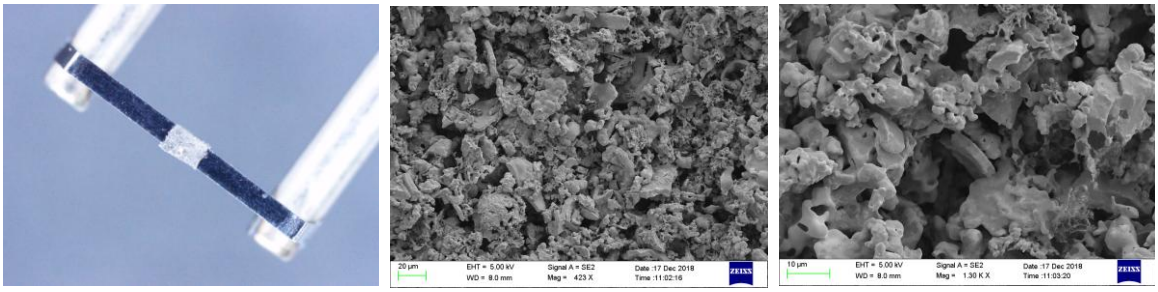

Fig. S2. Optical image and SEM images of FPIE after sintering atop a single rhenium filament. The SEM analysis was carried out using Zeiss-Supra 55, and the pores are 50-100 μm in diameter.

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