

Supporting Information

Thermo-mechanically robust ceramic/polymer nanocomposites modified with ionic liquid for hybrid polymer electrolyte applications

Antonio del Bosque, Bianca K. Muñoz, María Sánchez, and Alejandro Ureña*

Materials Science and Engineering Area, Escuela Superior de Ciencias Experimentales y Tecnología, Universidad Rey Juan Carlos, ESCET, C/Tulipán s/n. Móstoles, Madrid, 28933, Spain.

*Corresponding author: antonio.delbosque@urjc.es Tel: +34 914 88 46 21

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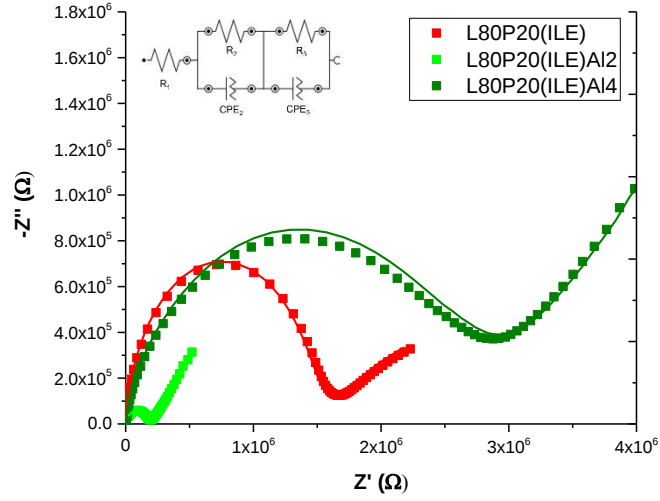


Figure S1: Nyquist plots for L80P20(ILE)

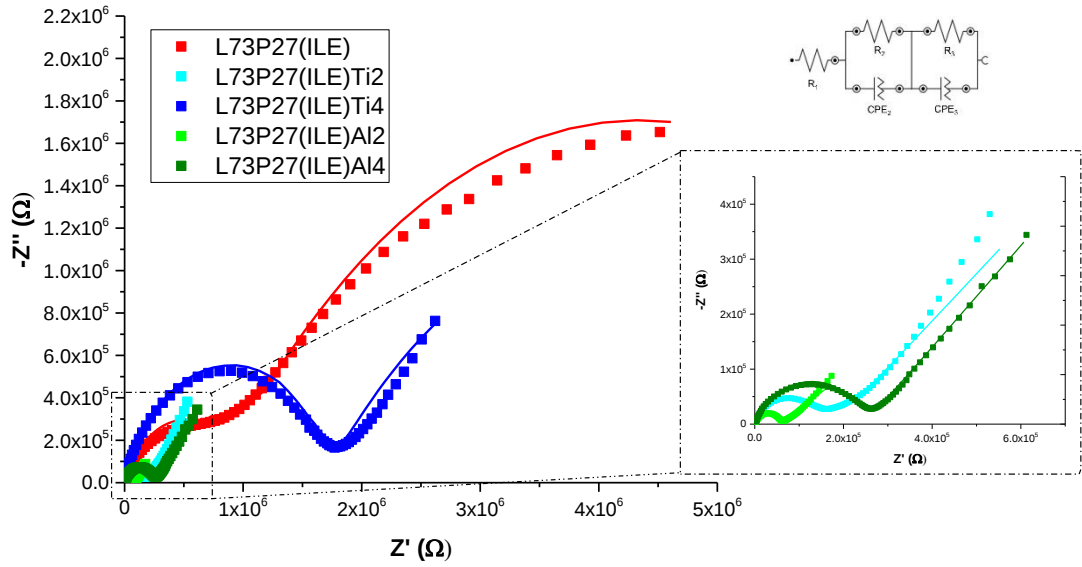


Figure S2: Nyquist plots for L73P27(ILE)

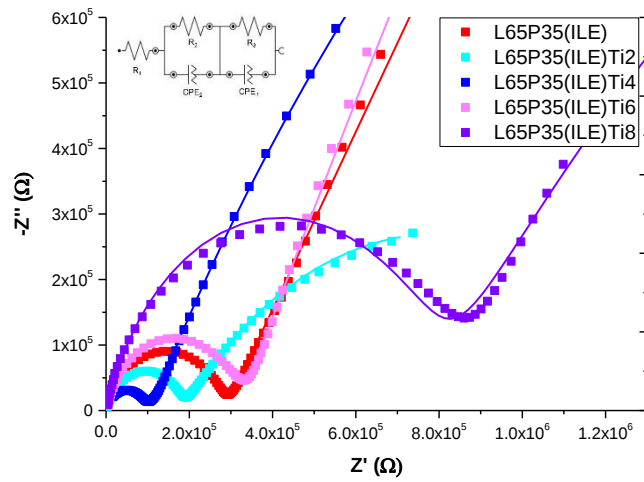


Figure S3: Nyquist plots for L65P35(ILE)Ti

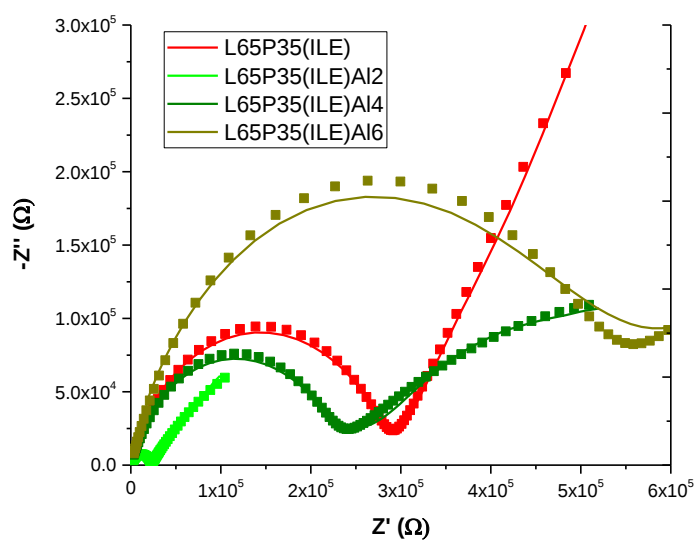


Figure S4: Nyquist plots for L65P35(ILE)Al

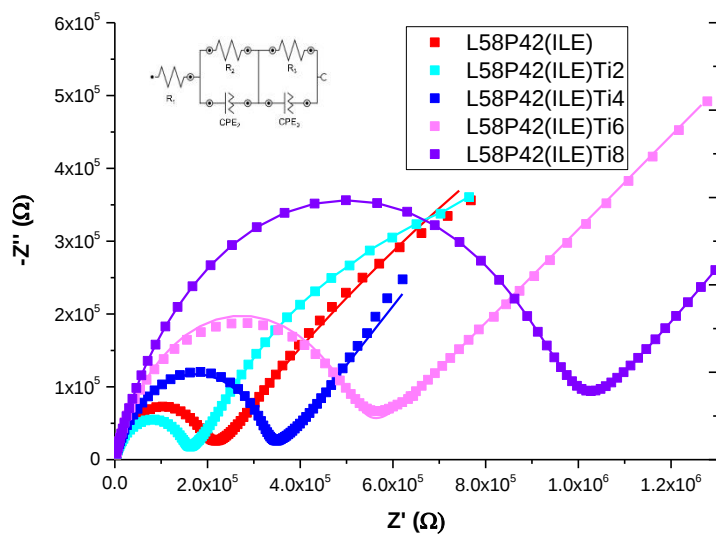


Figure S5: Nyquist plots for L58P42(ILE)Ti

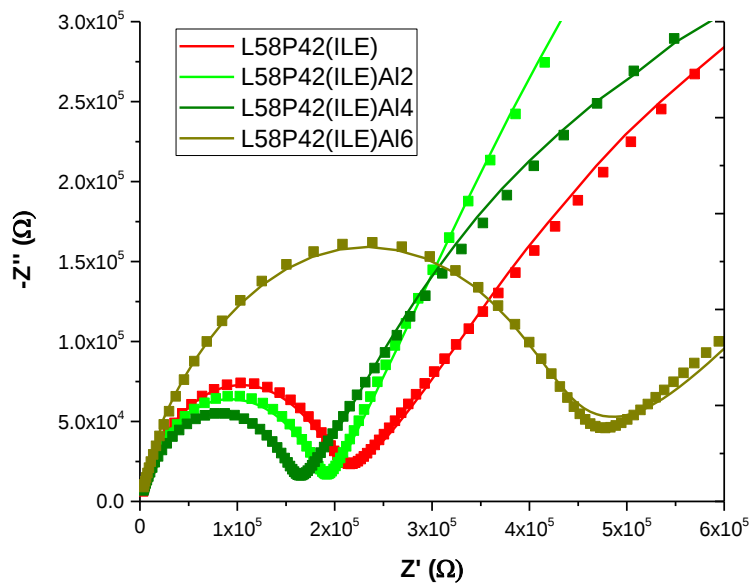


Figure S6: Nyquist plots for L58P42(ILE)Al

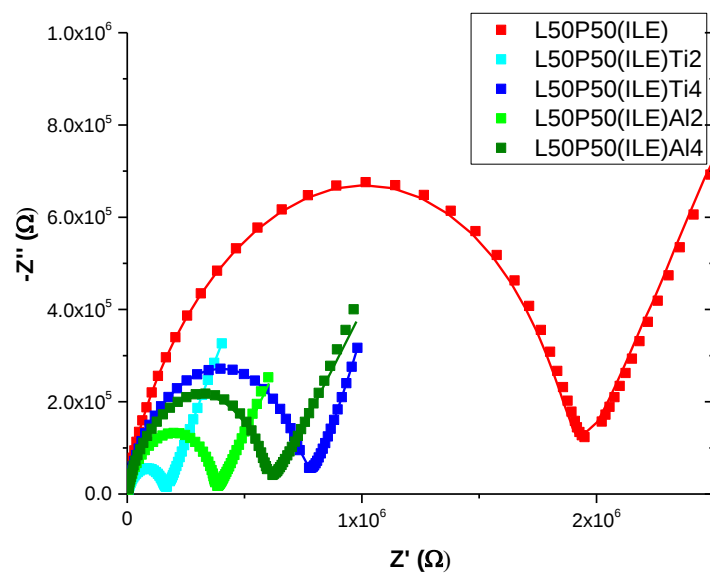


Figure S7 Nyquist plots for L50P50(ILE)

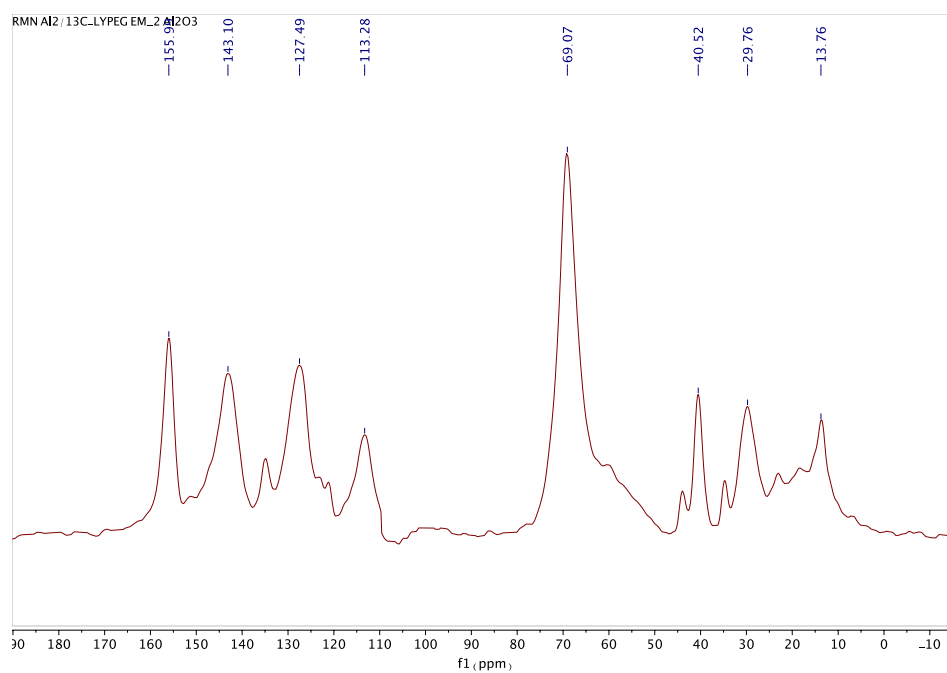


Figure S8: ^{13}C CP-MAS NMR for sample L65P35(ILE)Al2

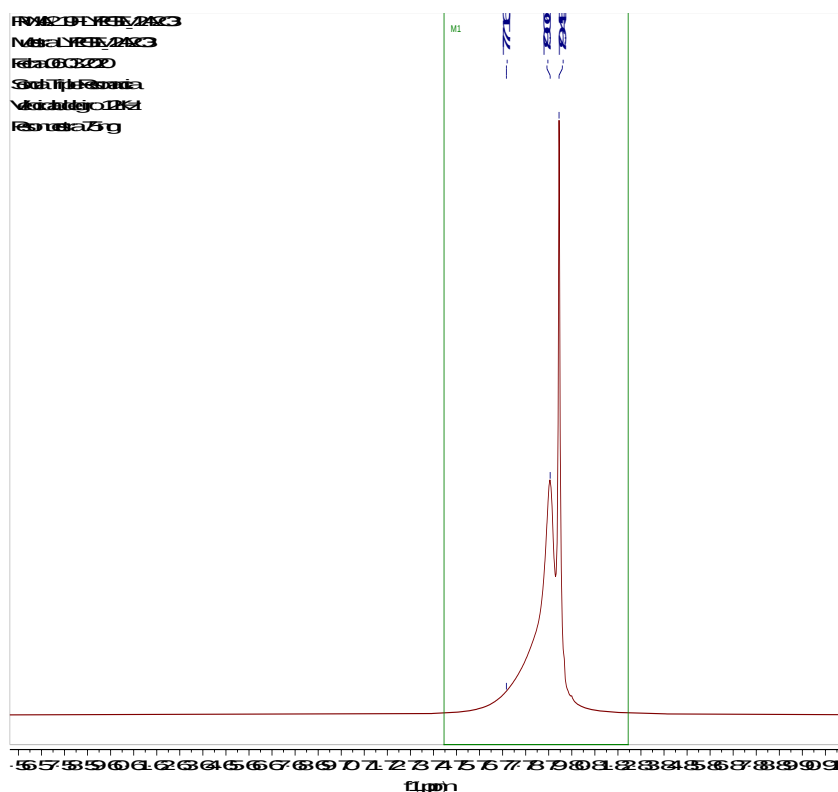


Figure S9: ^{19}F CP-MAS NMR for sample L65P35(ILE)A12

Table S1: Equivalent circuit parameters for L80P20(ILE)

Passive element	Parameter	L80P20(ILE)		L80P20(ILE)A12		L80P20(ILE)A14	
		Value	Desv. (%)	Value	Desv. (%)	Value	Desv. (%)
R ₁	R (Ω)	-8695	-9.55	-9609	-11.65	-993.75	-44.82
R ₂	R (Ω)	$1.80 \cdot 10^7$	1.13	$2.00 \cdot 10^5$	1.19	$2.80 \cdot 10^6$	2.01
Q ₂	Y0 (Mho.s ⁿ)	$3.28 \cdot 10^{-9}$	8.21	$2.78 \cdot 10^{-9}$	8.21	$7.13 \cdot 10^{-10}$	8.87
	n	0.66	1.19	0.66	1.19	0.74	0.95
R ₃	R (Ω)	$8.00 \cdot 10^8$	4.10	$9.00 \cdot 10^7$	6.90	$8.00 \cdot 10^6$	1.20
Q ₃	Y0 (Mho.s ⁿ)	$4.12 \cdot 10^{-6}$	2.59	$2.82 \cdot 10^{-6}$	2.59	$4.12 \cdot 10^{-7}$	8.96
	n	0.46	2.60	0.46	2.60	0.57	7.21
	χ^2	0.012		0.014		1.193	

Table S2: Equivalent circuit parameters for L73P27(ILE)Ti

Passive element	Parameter	L73P27(ILE)		L73P27(ILE)Ti2		L73P27(ILE)Ti4	
		Value	Desv. (%)	Value	Desv. (%)	Value	Desv. (%)
R ₁	R (Ω)	-1571.1	-20.94	-26275	-17.79	-308.81	-70.224
R ₂	R (Ω)	$8.50 \cdot 10^5$	0.98	$1.80 \cdot 10^5$	5.71	$1.70 \cdot 10^6$	0.32
Q ₂	Y0 (Mho.s ⁿ)	$3.62 \cdot 10^{-9}$	9.48	$2.14 \cdot 10^{-8}$	25.43	$1.10 \cdot 10^{-9}$	5.168
	n	0.69	1.13	0.49	5.25	0.76	0.57
R ₃	R (Ω)	$7.00 \cdot 10^6$	56.01	$6.00 \cdot 10^8$	2.75	$5.00 \cdot 10^{-6}$	3.01
Q ₃	Y0 (Mho.s ⁿ)	$1.66 \cdot 10^{-7}$	4.76	$2.54 \cdot 10^{-6}$	7.42	$9.13 \cdot 10^{-7}$	6.07
	n	0.57	2.59	0.45	8.75	0.54	5.205
	χ^2	0.524		0.130		0.205	

Table S3: Equivalent circuit parameters for L73P27(ILE)Al

Passive element	Parameter	L73P27(ILE)Al2		L73P27(ILE)Al4	
		Value	Desv. (%)	Value	Desv. (%)
R ₁	R (Ω)	90.5	-5.8	-685.05	-31.64
R ₂	R (Ω)	59867	1.457	2.50E+05	1.76
Q ₂	Y0 (Mho.s ⁿ)	2.48·10 ⁻⁹	9.449	2.93·10 ⁻⁹	8.343
	n	0.71	1.034	0.69	0.974
R ₃	R (Ω)	6.51·10 ⁷	4.08	6.85·10 ⁸	2.87
Q ₃	Y0 (Mho.s ⁿ)	8.91·10 ⁻⁶	5.06	2.56·10 ⁻⁶	6.379
	n	0.36	4.79	0.47	6.434
	χ ²	0.044		0.119	

Table S4: Equivalent circuit parameters for L65P35(ILE)Ti

Passive element	Parameter	L65P35(ILE)		L65P35(ILE)Ti2		L65P35(ILE)Ti4	
		Value	Desv. (%)	Value	Desv. (%)	Value	Desv. (%)
R ₁	R (Ω)	135.84	136.86	107.25	93.20	115	8.3
R ₂	R (Ω)	2.87·10 ⁵	0.73	1.73·10 ⁵	0.66	1.13·10 ⁵	1.36
Q ₂	Y0 (Mho.s ⁿ)	1.07·10 ⁻⁹	5.26	1.39·10 ⁻⁹	4.10	5.80·10 ⁻⁹	9.28
	n	0.73	0.55	0.73	0.43	0.62	1.48
R ₃	R (Ω)	3.75·10 ⁶	3.89	1.23·10 ⁶	4.95	5.99·10 ⁶	8.04
Q ₃	Y0 (Mho.s ⁿ)	1.16·10 ⁻⁶	2.18	1.33·10 ⁻⁶	2.21	9.4810 ⁻⁷	1.05
	n	0.59	1.83	0.52	1.58	0.64	0.68
	χ ²	0.040		0.017		0.014	

Passive element	Parameter	L65P35(ILE)Ti6		L65P35(ILE)Ti8	
		Value	Desv. (%)	Value	Desv. (%)
R ₁	R (Ω)	432.41	31.31	-685.05	-31.64
R ₂	R (Ω)	3.20·10 ⁵	0.59	2.50·10 ⁵	1.76
Q ₂	Y0 (Mho.s ⁿ)	6.53·10 ⁻¹⁰	4.28	2.93·10 ⁻⁹	8.34
	n	0.77	0.42	0.69	0.97
R ₃	R (Ω)	2.90·10 ⁸	1.99	6.85·10 ⁸	2.87
Q ₃	Y0 (Mho.s ⁿ)	2.52·10 ⁻⁷	0.74	2.56·10 ⁻⁶	6.37
	n	0.66	0.45	0.47	6.43
	χ ²	0.030		0.080	

Table S5: Equivalent circuit parameters for L65P35(ILE)A1

Passive element	Parameter	L65P35(ILE)A12		L65P35(ILE)A14		L65P35(ILE)A16	
		Value	Desv. (%)	Value	Desv. (%)	Value	Desv. (%)
R ₁	R (Ω)	58	2.61	-388.86	-61.19	-512.19	-67.05
R ₂	R (Ω)	$2.28 \cdot 10^4$	0.98	$2.20 \cdot 10^5$	1.90	$5.05 \cdot 10^5$	2.18
Q ₂	Y0 (Mho.s ⁿ)	$1.69 \cdot 10^{-9}$	11.52	$1.25 \cdot 10^{-9}$	7.51	$5.35 \cdot 10^{-10}$	8.56
	n	0.76	1.16	0.74	0.90	0.79513	0.99
R ₃	R (Ω)	$4.12 \cdot 10^5$	11.80	$7.37 \cdot 10^5$	17.24	$4.81 \cdot 10^6$	19.30
Q ₃	Y0 (Mho.s ⁿ)	$1.02 \cdot 10^{-5}$	2.22	$2.41 \cdot 10^{-6}$	6.76	$5.79 \cdot 10^{-7}$	5.16
	n	0.51	1.55	0.38	6.83	0.43	4.62
	χ^2	0.030		0.035		0.067	

Table S6: Equivalent circuit parameters for L58P42(ILE)Ti

Passive element	Parameter	L58P42(ILE)		L58P42(ILE)Ti2		L58P42(ILE)Ti4	
		Value	Desv. (%)	Value	Desv. (%)	Value	Desv. (%)
R ₁	R (Ω)	536.91	19.16	240	24.67	-1307.3	-54.53
R ₂	R (Ω)	$2.01 \cdot 10^5$	0.85	$1.5 \cdot 10^5$	0.90	$5.10 \cdot 10^5$	2.23
Q ₂	Y0 (Mho.s ⁿ)	$6.96 \cdot 10^{-10}$	4.64	$8.86 \cdot 10^{-10}$	2.97	$3.90 \cdot 10^{-10}$	10.49
	n	0.78	0.47	0.69	0.36	0.81	1.21
R ₃	R (Ω)	$4.44 \cdot 10^6$	24.26	$4.6 \cdot 10^6$	6.47	$4.67 \cdot 10^6$	3.88
Q ₃	Y0 (Mho.s ⁿ)	$1.65 \cdot 10^{-6}$	2.64	$2.02 \cdot 10^{-6}$	4.83	$1.32 \cdot 10^{-6}$	7.13
	n	0.44	2.22	0.50	2.64	0.36	7.78
	χ^2	0.021		0.031		0.073	

Passive element	Parameter	L58P42(ILE)Ti6		L58P42(ILE)Ti8	
		Value	Desv. (%)	Value	Desv. (%)
R ₁	R (Ω)	-1307.3	-54.53	-1218.9	-56.66
R ₂	R (Ω)	$5.10 \cdot 10^5$	2.23	$9.60 \cdot 10^5$	2.62
Q ₂	Y0 (Mho.s ⁿ)	$3.90 \cdot 10^{-10}$	10.49	$4.77 \cdot 10^{-10}$	11.07
	n	0.81	1.21	0.79	1.36
R ₃	R (Ω)	$4.67 \cdot 10^6$	3.88	$1.20 \cdot 10^9$	-1.08
Q ₃	Y0 (Mho.s ⁿ)	$1.32 \cdot 10^{-6}$	7.13	$9.97 \cdot 10^{-7}$	10.16
	n	0.36	7.78	0.41	11.94
	χ^2	0.073		0.136	

Table S7: Equivalent circuit parameters for L58P42(ILE)Al

Passive element	Parameter	L58P42(ILE)Al2		L58P42(ILE)Al4		L58P42(ILE)Al6	
		Value	Desv. (%)	Value	Desv. (%)	Value	Desv. (%)
R ₁	R (Ω)	528.97	25.73	160	19.32	-455.45	-75.43
R ₂	R (Ω)	1.88·10 ⁵	0.54	1.59·10 ⁵	0.56	4.38·10 ⁵	1.59
Q ₂	Y ₀ (Mho.s ⁿ)	6.58·10 ⁻¹⁰	4.65	8.86·10 ⁻¹⁰	4.24	5.11·10 ⁻¹⁰	6.66
	n	0.77	0.46	0.76	0.43	0.78	0.77
R ₃	R (Ω)	4.54·10 ⁶	7.75	1.80·10 ⁶	5.24	1.96·10 ⁶	22.42
Q ₃	Y ₀ (Mho.s ⁿ)	8.86·10 ⁻⁷	1.46	1.29·10 ⁻⁶	1.71	1.40·10 ⁻⁶	5.93
	n	0.59	0.98	0.53	1.18	0.39	6.12
	χ ²	0.021		0.015		0.033	

Table S8: Equivalent circuit parameters for L50P50(ILE)

Passive element	Parameter	L50P50(ILE)Ti2		L50P50(ILE)Ti4	
		Value	Desv. (%)	Value	Desv. (%)
R ₁	R (Ω)	113.15	2.82	113.15	-12.50
R ₂	R (Ω)	1.13·10 ⁵	0.89	3.80·10 ⁵	1.58
Q ₂	Y ₀ (Mho.s ⁿ)	2.84·10 ⁻¹⁰	0.59	6.35·10 ⁻¹⁰	6.66
	n	0.62	0.45	0.73	0.82
R ₃	R (Ω)	3.20·10 ¹²	7.25	9.90·10 ⁸	19.38
Q ₃	Y ₀ (Mho.s ⁿ)	9.11·10 ⁻⁷	2.90	1.63·10 ⁻⁶	6.25
	n	0.50	1.89	0.52	4.26
	χ ²	0.058		0.175	

Passive element	Parameter	L50P50(ILE)Al2		L50P50(ILE)Al4	
		Value	Desv. (%)	Value	Desv. (%)
R ₁	R (Ω)	-130.02	-113.39	-112.16	-181.24
R ₂	R (Ω)	3.81·10 ⁵	0.57	6.06·10 ⁵	0.81
Q ₂	Y ₀ (Mho.s ⁿ)	5.72·10 ⁻¹⁰	3.83	4.32·10 ⁻¹⁰	4.43
	n	0.77	0.39	0.78	0.45
R ₃	R (Ω)	1.10·10 ¹²	13.10	1.10·10 ¹²	9.34E+6
Q ₃	Y ₀ (Mho.s ⁿ)	3.89·10 ⁻⁶	4.40	1.51·10 ⁻⁶	4.36
	n	0.52	4.77	0.50	4.49
	χ ²	0.023		0.036	