Materiales para celdas de combustible en capas delgadas

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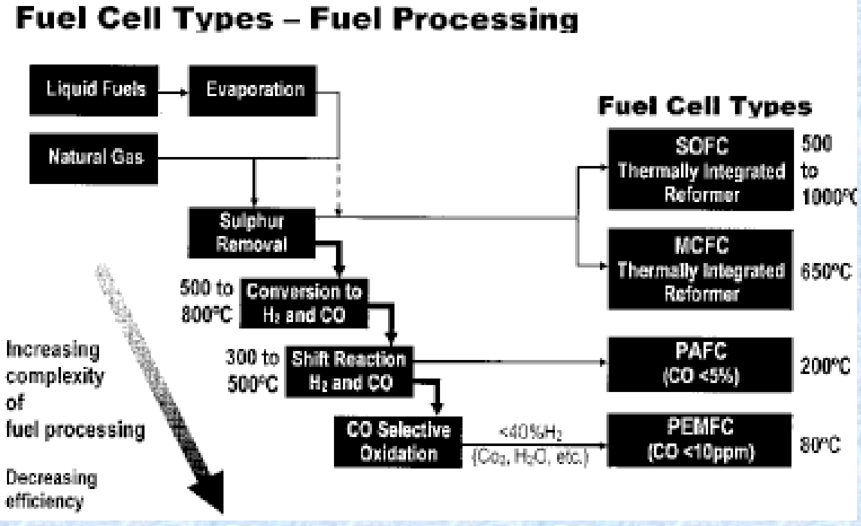
Tipos de celdas de combustible

	PEFC	PAFC	MCFC	SOFC
Electrolyte	Nafion	H_3PO_4	Na_2CO_2–Li_2CO_3	ZrO_2–Y_2O_3
Operating temperature (°C)	70–80	200	650–700	900–1000
Fuel	H_2	H_2	H_2, CO, CH_4	H_2, CO, CH_4
Expected efficiency (HHV) (%)	30–40	35–42	45–60	45–65
Power, current status (kW)	12.5[a]	100[b]	1000[c]	100[d], 15[e]
Efficiency (%)	40	40	45	43[d], 50[e]

[a] Allied signal.
[b] Fuji electric.
[c] MCFC Research Association, Japan.
[d] Siemens Westinghouse.
[e] Mitsubishi Heavy Industry and Electric Power Development, Japan (at 5 atm).

O. Yamamoto / Electrochimica Acta 45 (2000) 2423–2435



B. C. H. Steele /J. Mater. Sci. 36 (2001 1053)

Materiales para SOFC

Selected deposition processes

Method	Example
Spin coating	0.2–2 µm YSZ films on porous or dense substrates
Vacuum evaporation	25 µm YSZ films on Ni foils
Sputtering	1–3 µm YSZ films on dense or porous substrates
Colloidal deposition	10 µm YSZ on porous NiO/YSZ substrates
Plasma spraying	10 µm cathode, 220 µm electrolyte, 10 µm anode on porous metallic support
Spray pyrolysis	5–10 µm YSZ films on anode substrates
Sol–gel	YSZ films on porous LSM cathode substrates
Electrophoretic deposition	YSZ less than 10 µm on porous NiO/Ca stabilized ZrO_2 substrates
Laser deposition	0.5–0.7 µm YSZ films
Electrostatic assisted vapor deposition	5–20 µm YSZ on NiO/YSZ substrates
Metal organic chemical vapor deposition (MOCVD)	YSZ thin films on fused silica substrates
Electrochemical vapor deposition (EVD)	Dense 40 µm YSZ layers on porous substrates

Developers of SOFC in anode-supported planar cell design and corresponding fabrication and design details

Company	Country	Component	Material	Production process	Thickness	References
Sulzer Hexis	CH	Anode substrate	Ni/YSZ	Tape casting	250–500 µm	[25]
		Electrolyte	YSZ/(Ce,Y)O_2	Reactive magnetron sputtering	5/1 µm	[26]
		Cathode	$La_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8}O_3$	Screen printing	ns	[26]
ECN/InDec	NL	Anode substrate	Ni/YSZ	Tape casting	500–800 µm	[15,16,27]
		Anode	Ni/YSZ	Screen printing	3–7 µm	[27]
		Electrolyte	YSZ	Screen printing	7–10 µm	[28]
		Cathode	(La,Sr)MnO_3+YSZ	Screen printing	ns	[27]
FZJ	D	Anode substrate	Ni/YSZ	Tape casting	200–500 µm	[29]
		Anode substrate	Ni/YSZ	Warm pressing	1500 µm	[6,30]
		Anode	Ni/YSZ	Vacuum slip casting	5–15 µm	[6,30]
		Electrolyte	YSZ	Vacuum slip casting	5–30 µm	[6]
		Electrolyte	YSZ	Reactive magnetron sputtering	2–10 µm	[31]
		Cathode	(La,Sr)MnO_3+YSZ	Wet powder spraying	50 µm	[6,32]
Risø	DK	Anode substrate	Ni/YSZ	Tape casting	200–300 µm	[33]
		Electrolyte	YSZ	Wet powder spraying	10–25 µm	[34]
		Cathode	(La,Sr)MnO_3+YSZ	Screen printing	50 µm	[34]
Global Thermoelectric	CAN	Anode substrate	Ni/YSZ	Tape casting	1000 µm	[35]
		Electrolyte	YSZ	Vacuum slip casting	10 µm	[35]
		Electrolyte	YSZ	Screen printing	ns	[36]
		Cathode	(La,Sr)MnO_3	Screen printing	40 µm	[35]
Allied Signal	USA	Anode	Ni/YSZ	Tape casting and calendering	100 µm	[37,38]
		Electrolyte	YSZ	Tape calendering	5–10 µm	[37,39]
		Cathode	Doped $LaMnO_3$	Tape calendering	ns	[39]
CFCL	AUS	Anode substrate	Ni/YSZ	Tape casting	500–700 µm	[18,19,40]
		Electrolyte	YSZ	Lamination and sintering	10–30 µm	[19,40]
		Electrolyte	YSZ	Reactive magnetron sputtering	<16 µm	[41]
		Cathode	(La,Sr)MnO_3	Screen printing	ns	[19,40]
Mitsui Eng. and Shipbuilding	JP	Anode substrate	Ni/YSZ	ns	1000 µm	[23]
		Electrolyte	8YSZ	ns	30 µm	[23]
		Cathode	(La,Sr)(Mn,Cr)O_3	ns	150 µm	[23]

Interfacial resistance of new electrodes by ac impedance at OCV (Ω/cm^2)

	Materials	Electrolyte	600 °C	700 °C
Cathode	Pt-SSZ	YSZ	1.25	0.14
Cathode	Pt-Ag-SSZ	YSZ	0.67	0.083
Cathode	$(Sm_{0.6}Sr_{0.4})CoO_3$-CYO-Ag	SSZ	7.1	0.90
Cathode	$(La_{0.2}Sr_{0.2})CoO_3$-CGO-Ag	CGO	0.83	0.19
Anode	Ni-CSO	SSZ	8.9	1.16
Anode	Ni-CSO	CGO	0.25	0.10

CYO: $Ce_{0.8}Y_{0.2}O_2$, CGO: $Ce_{0.8}Gd_{0.2}O_2$, CSO: $Ce_{0.8}Sm_{0.2}O_2$.

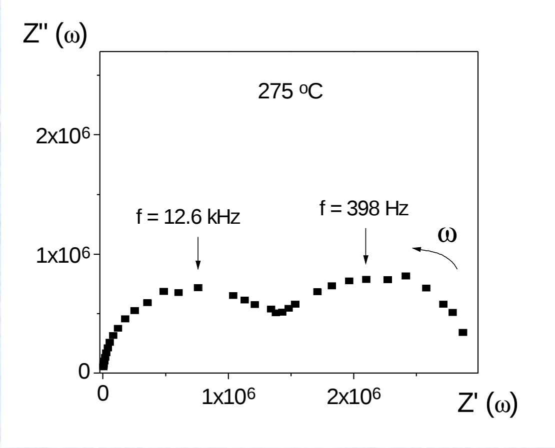
Candidate electrolyte (Ω cm^{-2})

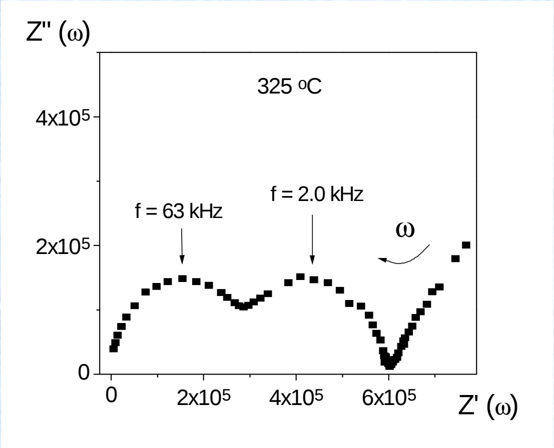
	550 °C	600 °C	700 °C	800 °C	900 °C
100 µm YSZ	–	2.2	0.77	0.31	0.15
100 µm SSZ	–	0.90	0.26	0.099	0.046
100 µm CGO	–	(0.59)	0.26	0.13	0.071
100 µm LSGM	0.71	0.37	0.15	0.074	–

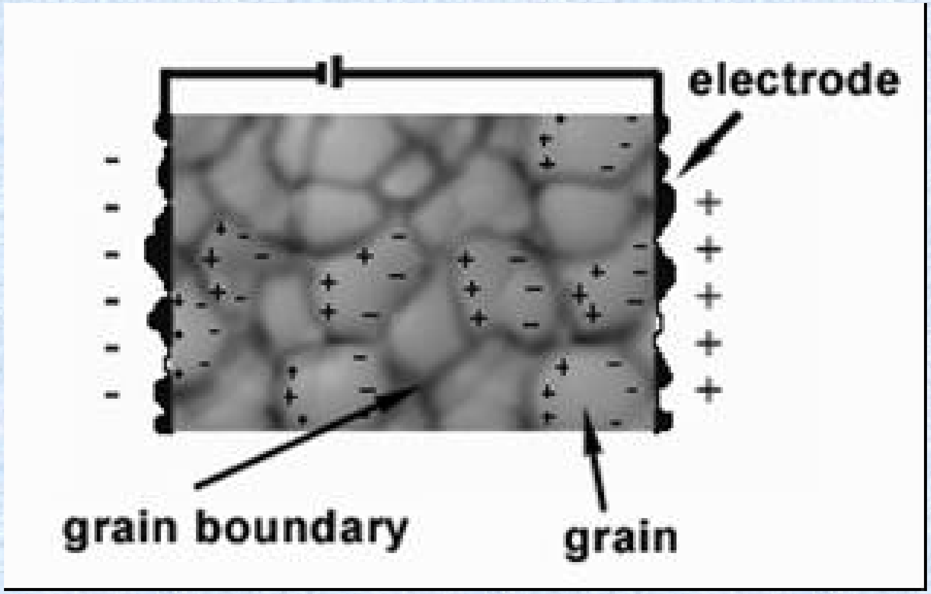
YSZ: Zr(Y)O_2, SSZ: Zr(Sc)O_2, LSGM: $La_{0.8}Sr_{0.2}Ga_{0.85}Mg_{0.15}$ [10], CGO: $Ce_{0.8}Gd_{0.2}O_2$ [9], (0.59); $Ce_{0.9}Gd_{0.1}O_2$ [9], CRO: Ce(rare earth)O_2.

M. Dokiya / Solid State Ionics 152–153 (2002) 383–392

Espectroscopía dieléctrica







Capacitance/F	Phenomenon Responsible
10^{-12}	bulk
10^{-11}	minor, second phase
10^{-11}–10^{-8}	grain boundary
10^{-10}–10^{-9}	bulk ferroelectric
10^{-9}–10^{-7}	surface layer
10^{-7}–10^{-5}	sample–electrode interface
10^{-4}	electrochemical reactions

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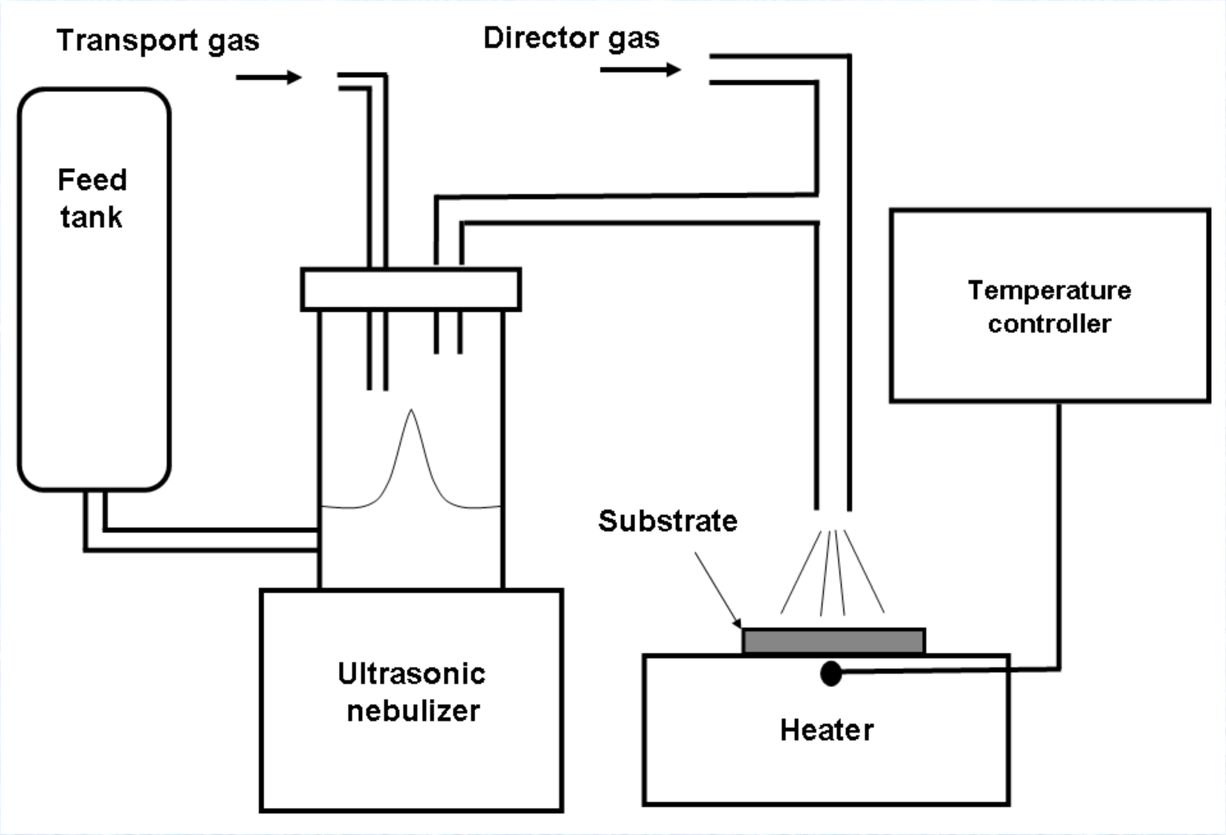
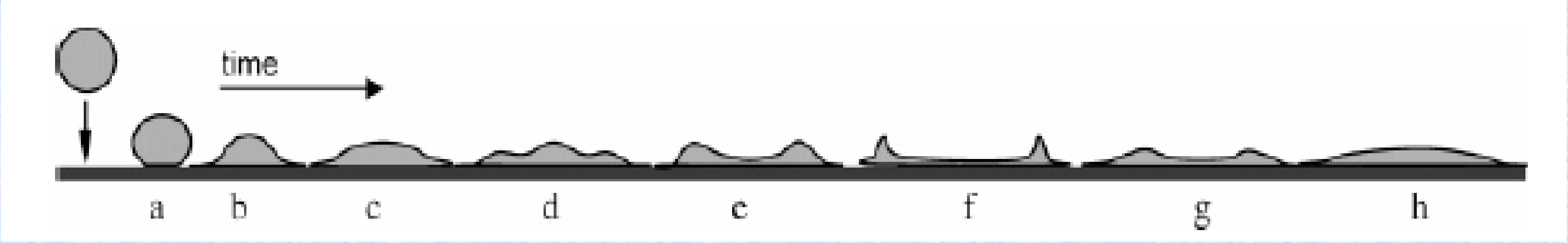
Arcos (numerados de izquierda a derecha por orden de aparición)	Capacidad (F) T_{sint}=1450 °C	Capacidad (F) T_{sint}=1500 °C	Capacidad (F) T_{sint}=1550 °C
1	(8.0 - 8.5) 10^{-12}	(7.8 - 8.1) 10^{-12}	(8.0 - 8.4) 10^{-12}
2	~ 3.6 10^{-10}	~ 2.5 10^{-10}	(4.1 - 4.4) 10^{-10}
3	(3.2 - 4.9) 10^{-6}	~2.4 10^{-6}	(5.1 - 7.3) 10^{-6}

M. F. García-Sánchez, et. al., submited to publication

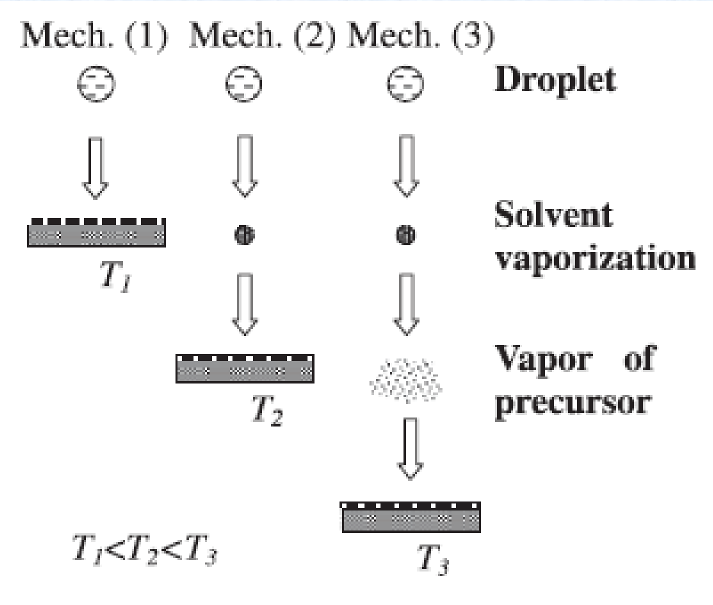
Rocío Pirolítico

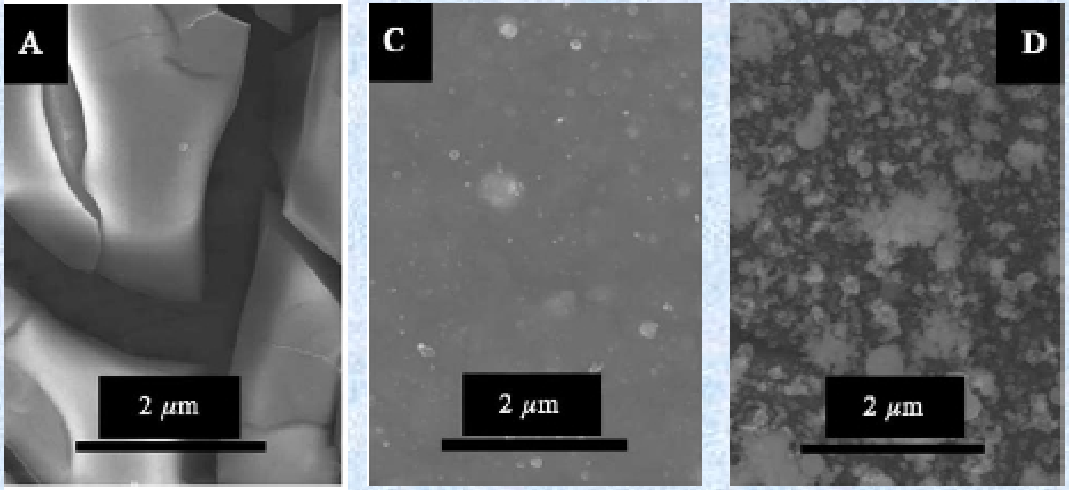


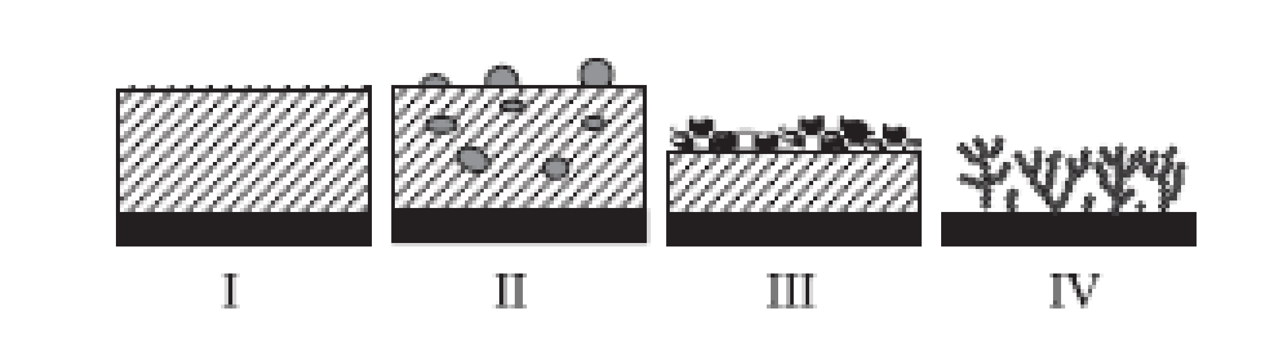
- Temperatura
- Tamaño gotas
- Velocidad Flujo
- Solvente
- Tiempo
- Distancia



Rocío Pirolítico



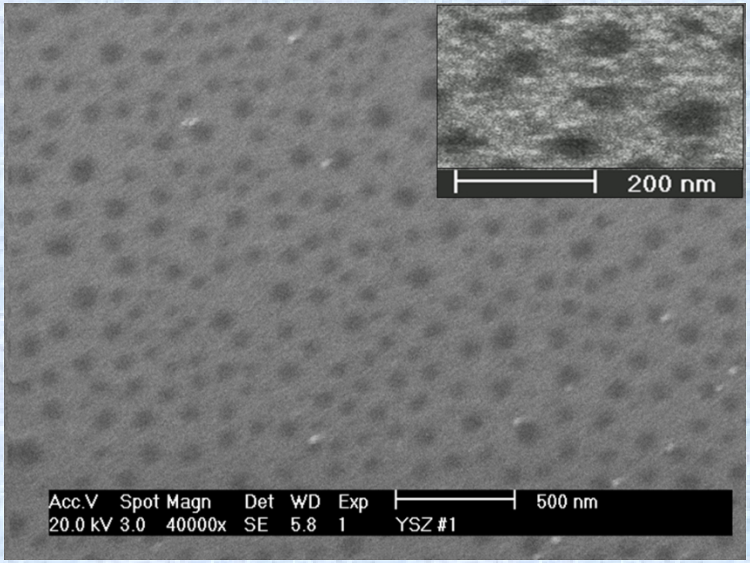




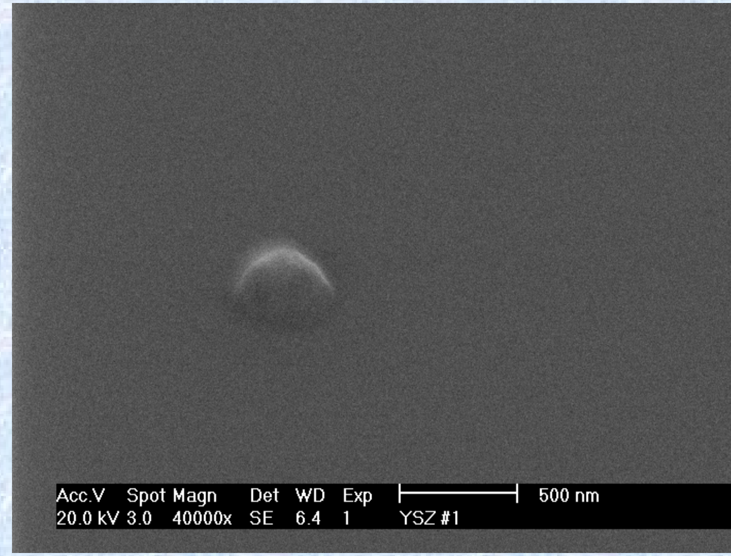
D. Perednis et al. / Thin Solid Films 474 (2005) 84–95

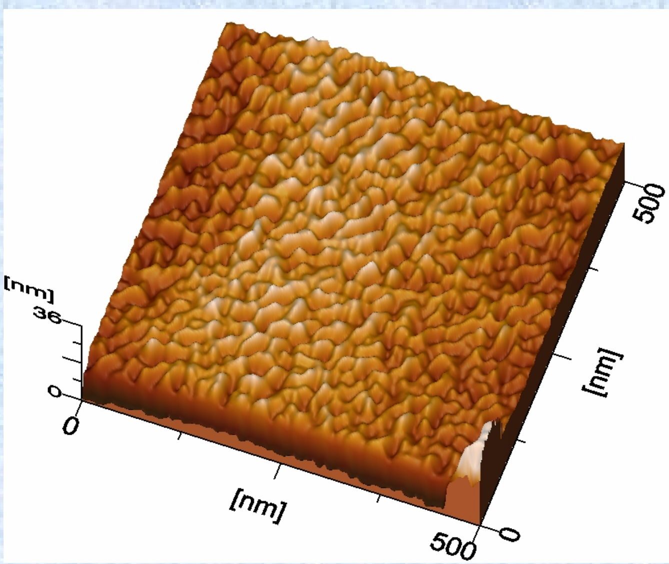
Resultados en el crecimiento de capas de YSZ

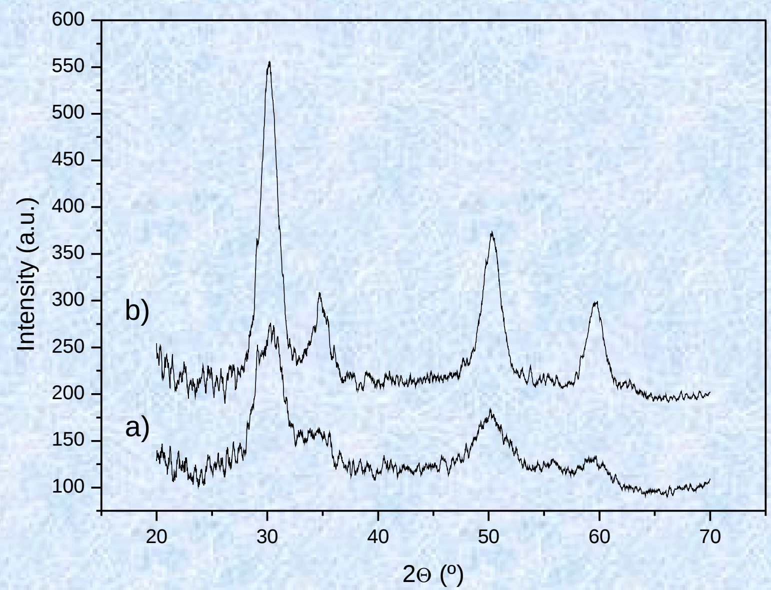
T=400 ºC, t= 10min



T=400 ºC, t= 25 min







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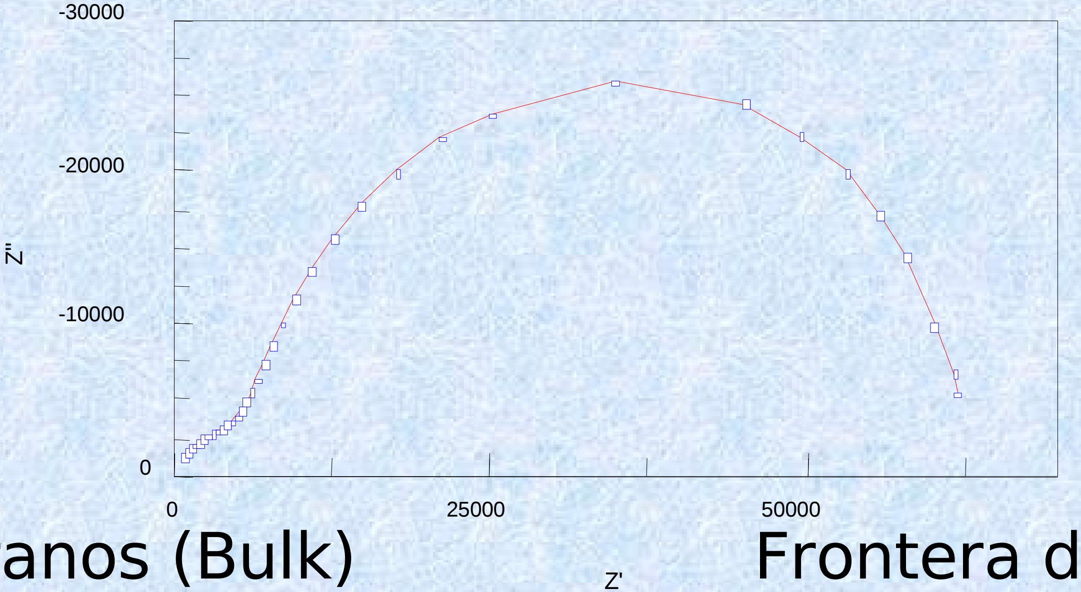
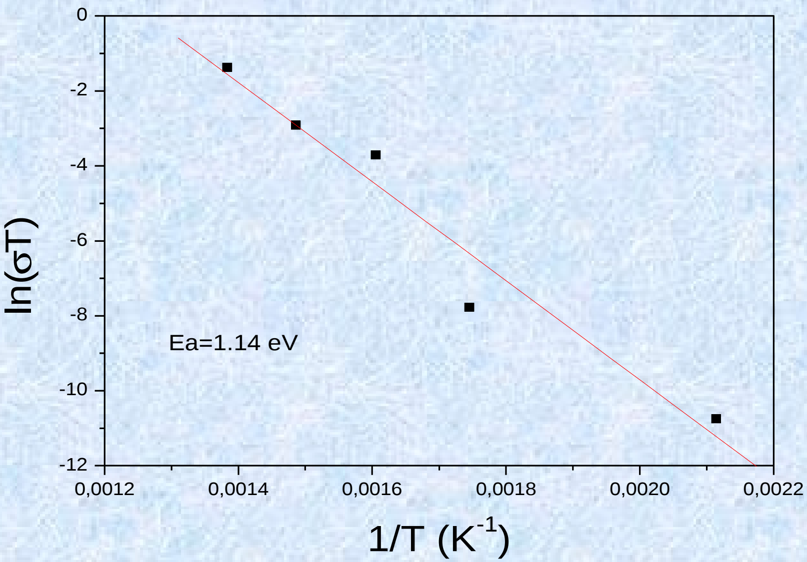
Resultados en el crecimiento de capas de YSZ

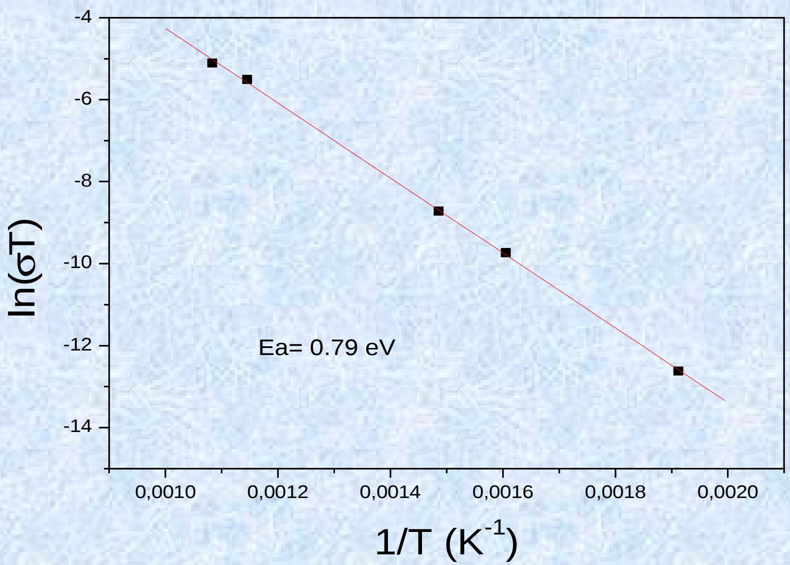
Muestra crecida a 425 ºC por 10 min



Granos (Bulk)



Frontera de granos



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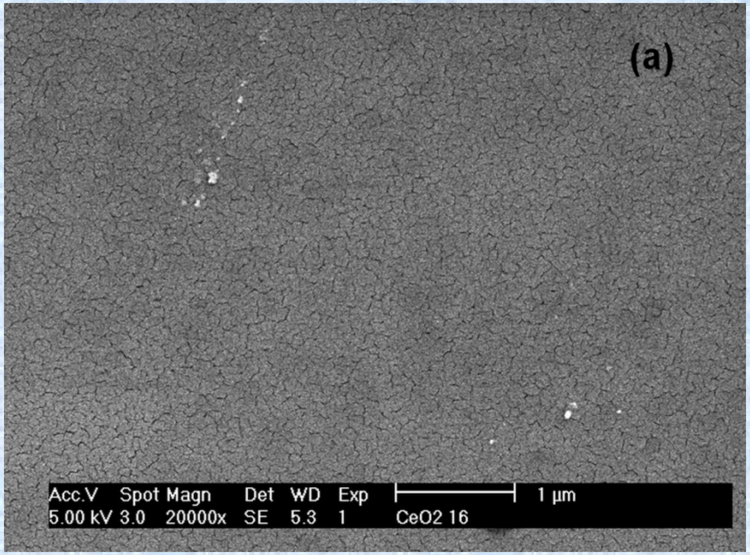
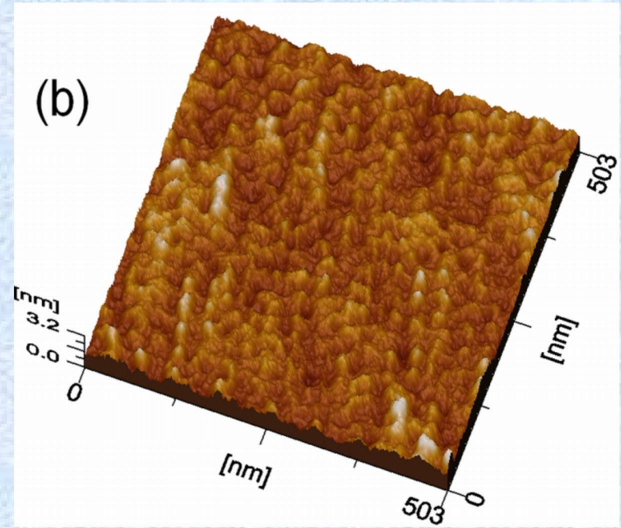
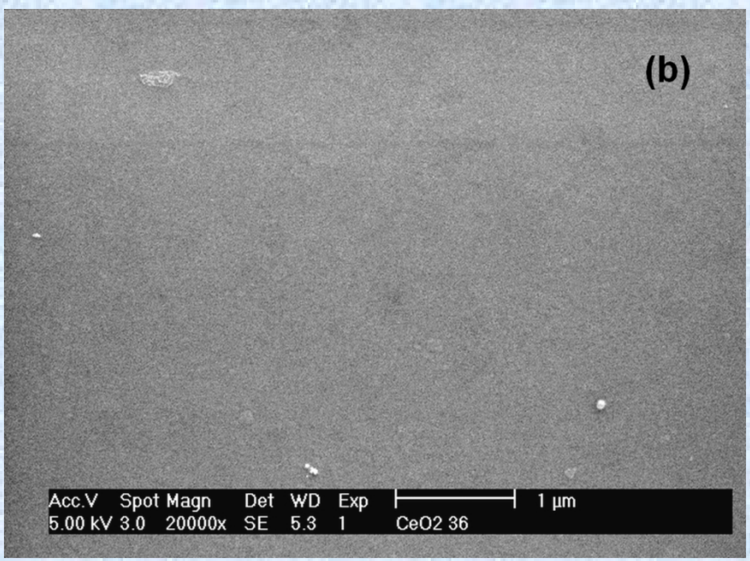
Resultados en el crecimiento de capas de CeO

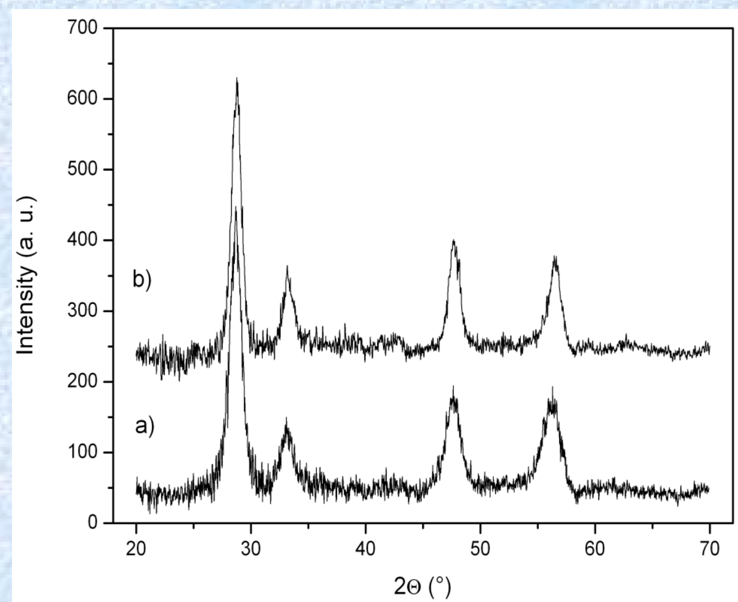
T=400 ºC, t= 10min

T=425ºC, t= 10min









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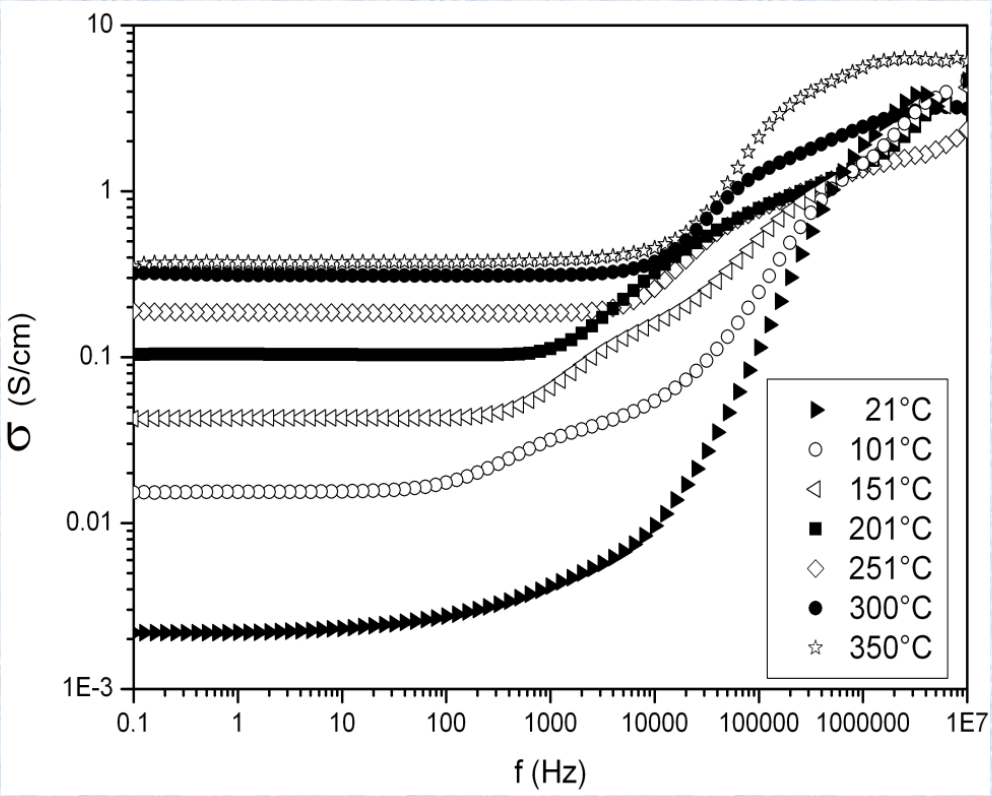
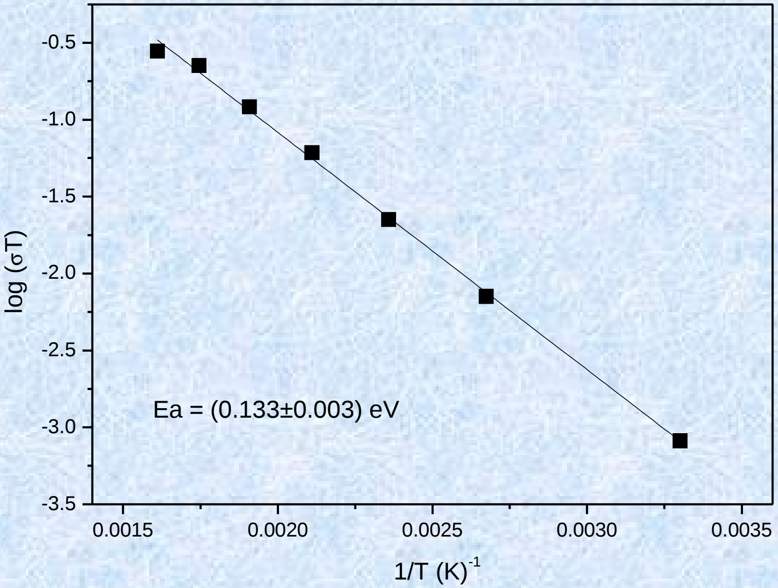
Resultados en el crecimiento de capas de CeO





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Conclusiones

- Optimizando las condiciones de crecimiento pueden obtenerse capas densas y homogéneas de conductores iónicos con tamaño de grano nanométricos.
- La reducción del tamaño de grano tiene una implicación importante en la conductividad total del material.

Trabajos futuros

- Comprobar la importancia del tamaño de grano en las propiedades eléctricas.
- Utilizar otros dopantes tanto en ceria como en zirconia.
- Estudiar sistemas multicapas nanoestructurados.
- Crecer por la misma técnica al menos uno de los electrodos.
- Hacer una celda de combustible en capas delgadas utilizando los materiales antes preparados y estudiar su comportamiento en condiciones de trabajo.