

Supporting Information

Co₃O₄ Nanoparticles Embedded in Mesoporous Carbon for Supercapacitor Applications

*Sirine Zallouz^{1,2}, Bénédicte Réty^{1,2,3}, Loïc Vidal^{1,2}, Jean-Marc Le Meins^{1,2}, Camélia Matei
Ghimbeu^{1,2,3,*}*

¹ Université de Haute-Alsace, CNRS, Institut de Science des Matériaux de Mulhouse (IS2M)

UMR 7361, F-68100 Mulhouse, France

² Université de Strasbourg, F-67081 Strasbourg, France

³ Réseau sur le stockage Electrochimique de l'Energie (RS2E), FR CNRS 3459, 80039

Amiens Cedex, France

*Corresponding author.

E-mail address: camelia.ghimbeu@uha.fr (C. Matei Ghimbeu).

Tel: + 33 (0) 3 89 60 87 43

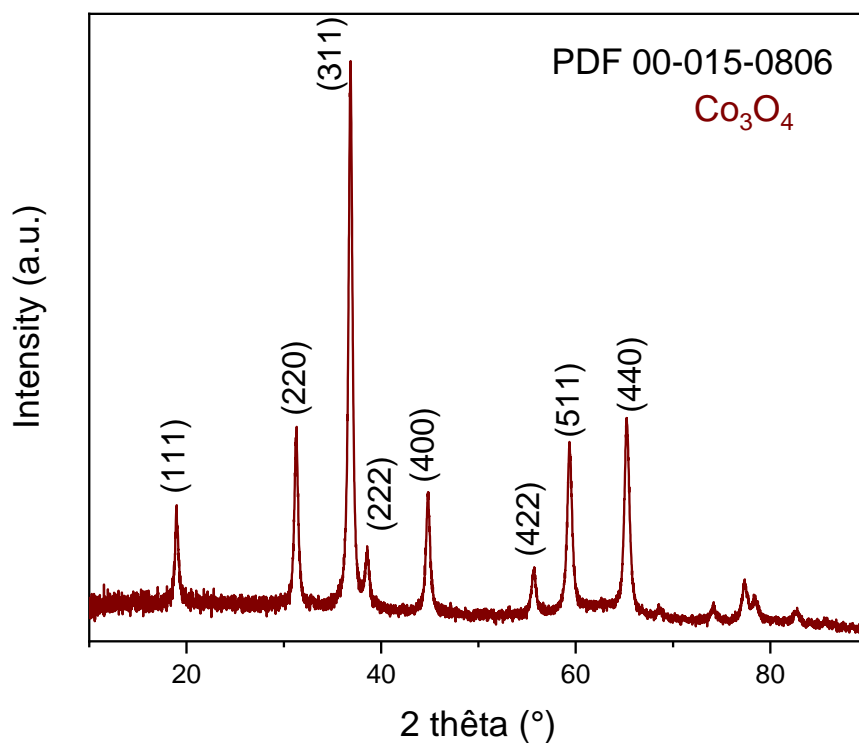


Figure S1: XRD patterns of TGA residue under air of C/Co-650 composite.

Table S1: Calculations of number of unit cells per particle before and after oxidation for a pyrolysis temperature of 750 °C.

Sample	Particles size by TEM (Å)	Lattice parameter (Å)	Number of unit cells per particle
C/Co-750	2.3	3.54470	6.488
C/Co ₃ O ₄ -750	4.3	8.08370	5.319

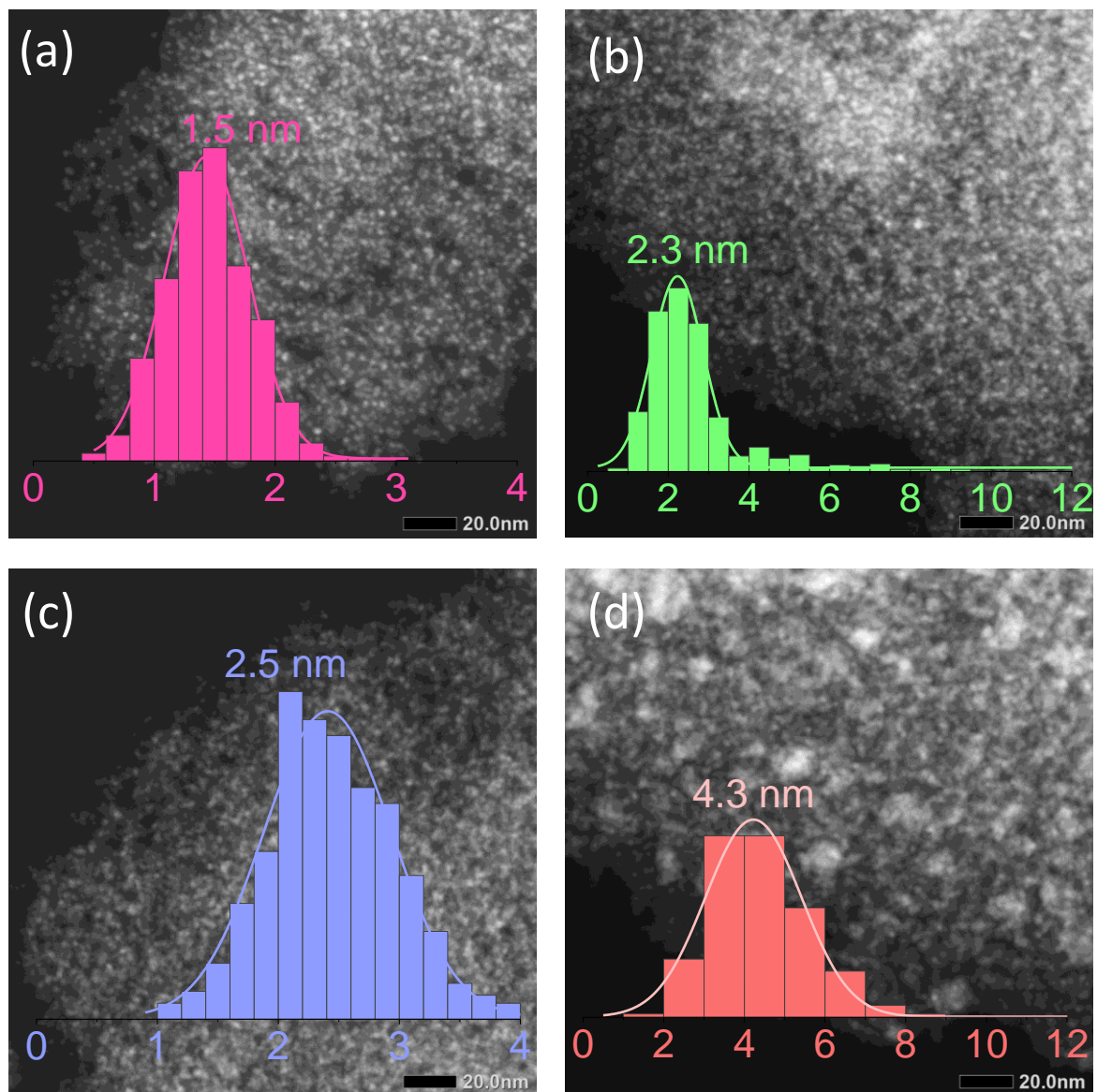


Figure S2: STEM images of Carbon/Cobalt based composites pyrolyzed at (a) 650 °C, (b) 750 °C, respectively, and the corresponding C/Co₃O₄ composites oxidized at (c) 215 °C and (d) 230 °C.

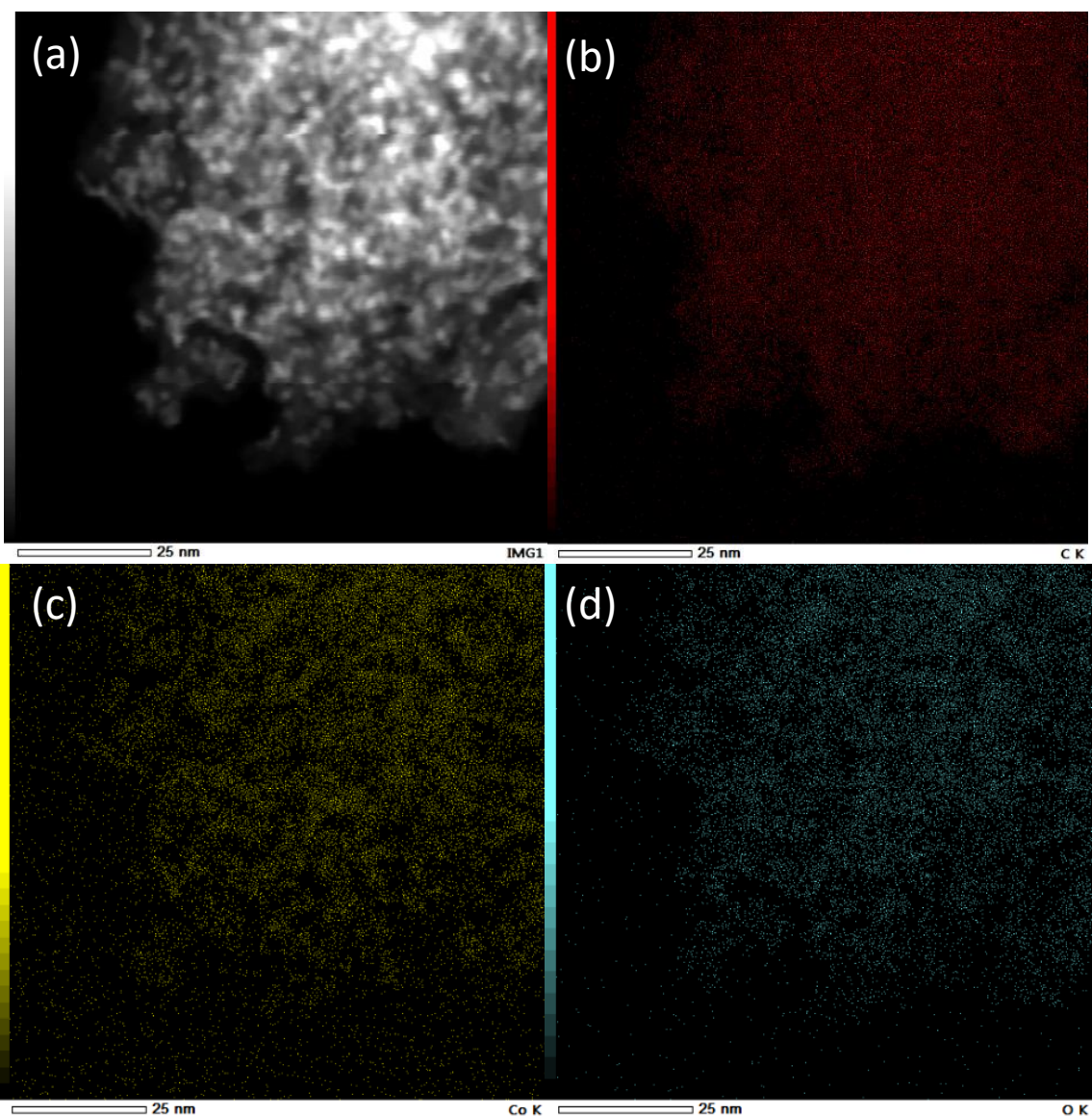


Figure S3: STEM image of (a) of C/Co₃O₄ -700 composite along with the EDX mapping showing the chemical contribution of (b) carbon (c) cobalt and (d) oxygen.

Table S2: Chemical composition derived from EDX and XPS for C/Co₃O₄-600 , C/Co₃O₄-700, C/Co₃O₄-800.

Material	EDX			XPS		
	C wt. %	O wt. %	Co wt. %	C wt. %	O wt. %	Co wt. %
C/Co ₃ O ₄ -600	52.1	9.4	38.5	70.1	18.5	11.4
C/Co ₃ O ₄ -700	70.5	6.9	22.7	63.0	18.5	18.9
C/Co ₃ O ₄ -800	78.5	7.0	15.0	60.2	16.6	23.1

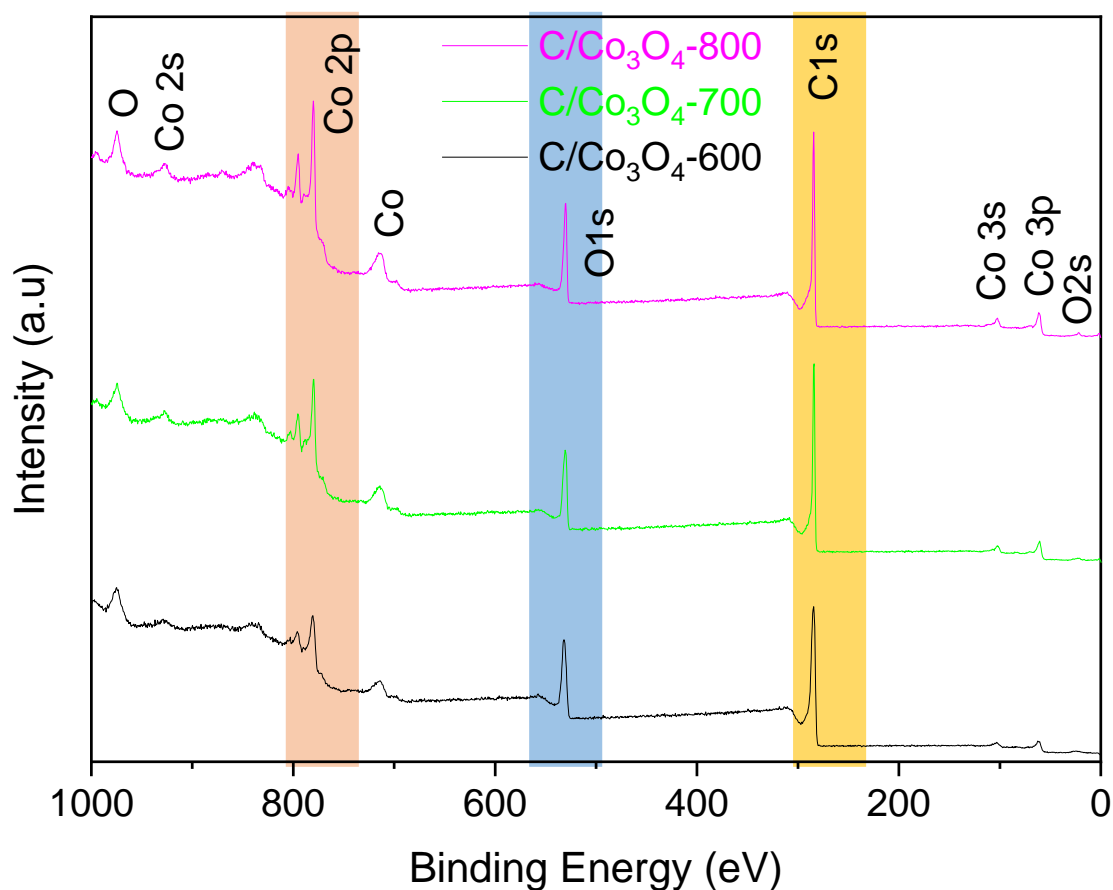


Figure S4: XPS survey spectra of C/Co₃O₄ composites pyrolyzed and oxidized at different temperatures.

Table S3: Chemical composition derived from XPS of C/Co₃O₄-600, C/Co₃O₄-700, C/Co₃O₄-800 composites materials.

Material	C (at %)	O (at %)	Co (at %)	C sp ² (at %)	<u>O</u> -C (at %)	<u>O</u> -Co (at %)	C sp ² / <u>O</u> -C (at %)
C/Co ₃ O ₄ -600	81.18	16.13	2.68	69.43	4.70	2.09	14.8
C/Co ₃ O ₄ -700	78.29	16.94	4.77	59.39	3.79	3.32	15.6
C/Co ₃ O ₄ -800	77.79	16.11	6.09	60.83	2.96	4.46	20.0

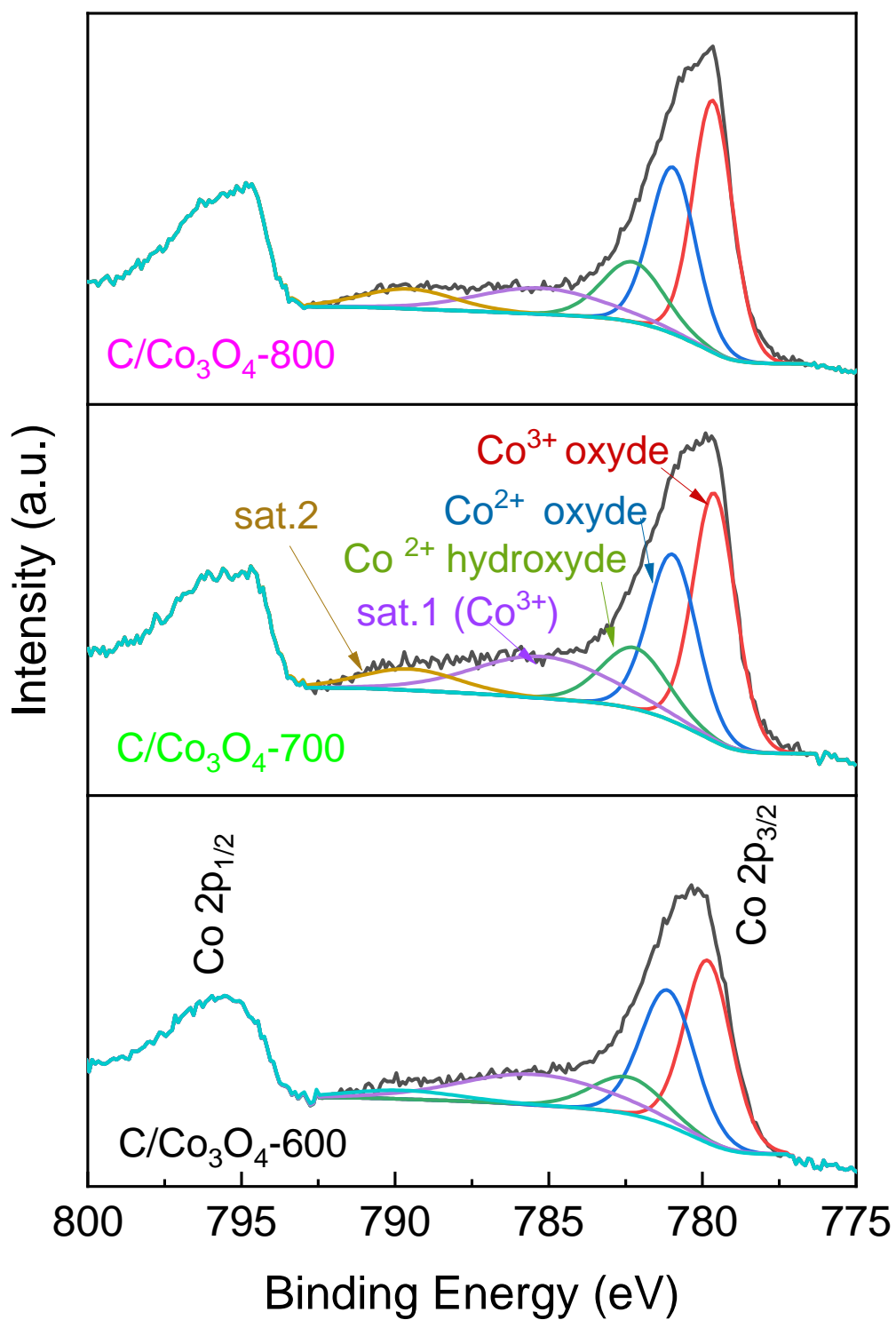


Figure S5: XPS High resolution deconvoluted spectra of Co 2p peaks in C/Co₃O₄-600, C/Co₃O₄-700 and C/Co₃O₄-800 composites.

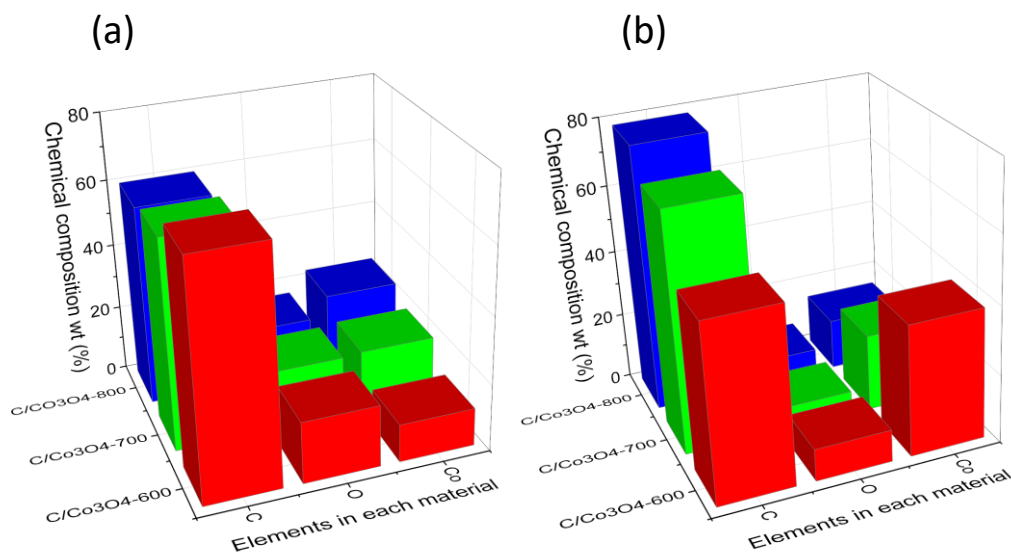


Figure S6: Chemical composition wt. (%) by (a) XPS and (b) EDX of C, O and Co for C/Co₃O₄-600 , C/Co₃O₄-700, C/Co₃O₄-800

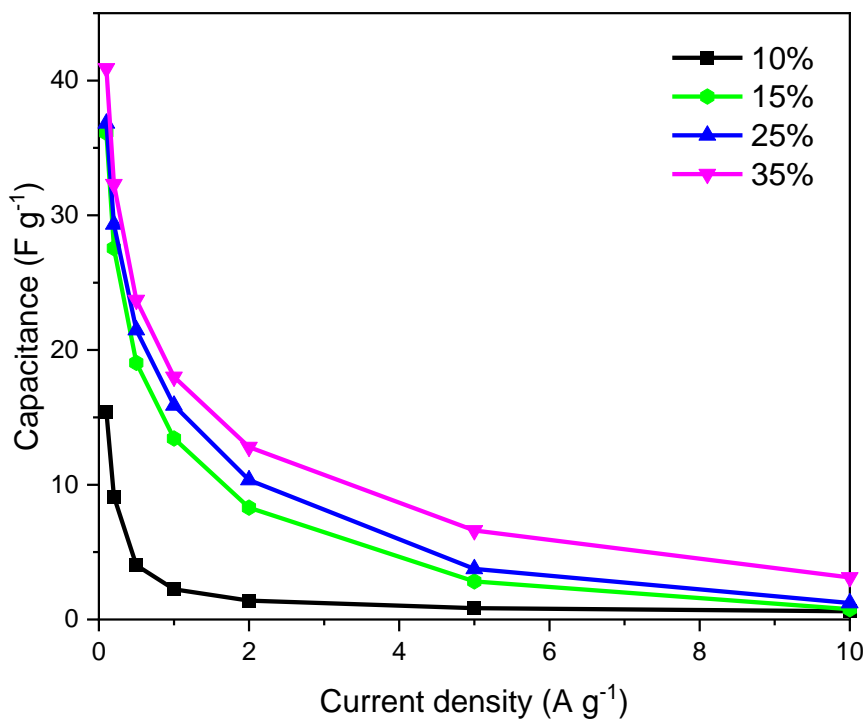


Figure S7: Capacitance vs current density of C-Co₃O₄-600 with different amounts of carbon black.

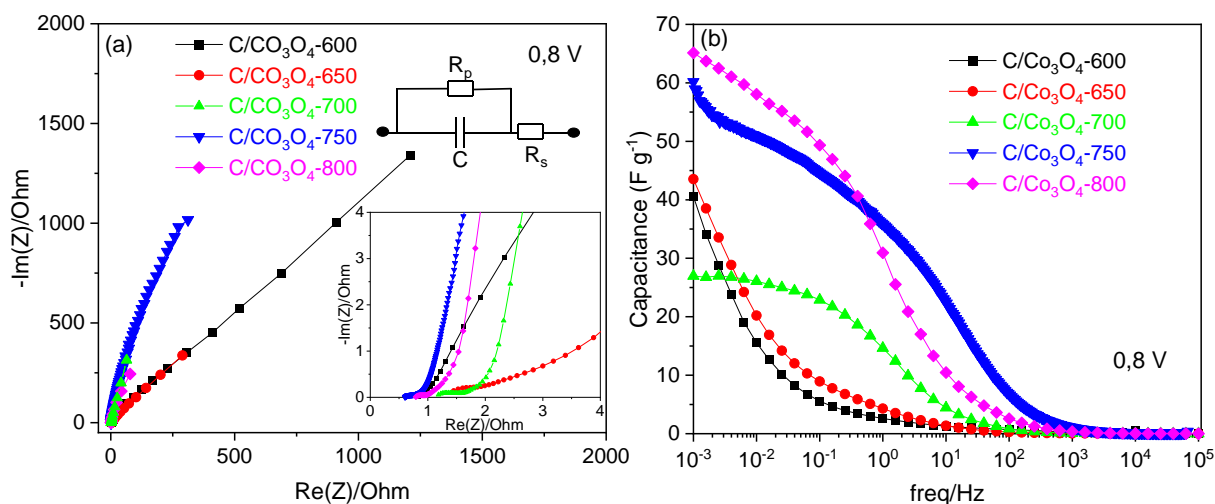


Figure S8: Electrochemical impedance spectroscopy recorded at 0.8 V for symmetric cells, Nyquist Plot at 0.8 V (inset: equivalent circuit diagram) (a), specific capacitance vs. frequency of C/Co₃O₄-T symmetric capacitors at 0.8 V (b)

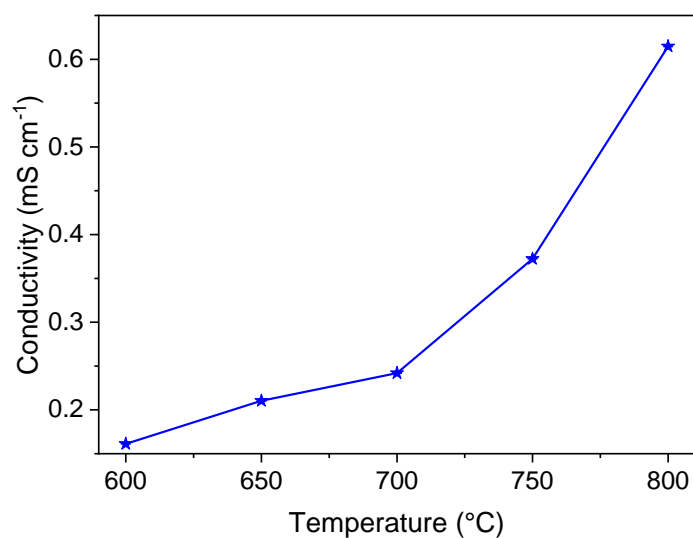


Figure S9: Conductivity of the C/Co₃O₄ composites using Electrochemical Impedance Spectroscopy.

The conductivity (σ) was calculated using the following formula.

$$\sigma = \frac{L}{R * A}$$

Where: L is the thickness of the self-standing electrode (cm), R is the resistance given by EIS (Ω) and A is the surface of the self-standing electrode (cm²). The result is given in mS cm⁻¹. It is important to highlight that the resistance R measured by EIS has been done in several places and several values were collected. The average has been used here. Hence the values may slightly differ from one spot in the material to another.

Table S4: Comparison of different carbon/Co₃O₄ materials performance in two-electrode configuration for supercapacitors

Material	Mass loading	Type of device	Negative electrode material	Electrolyte	Specific capacitance	Maximum energy and power density	Capacitance retention	Ref
Co ₃ O ₄ / Graphene aerogel	-	Asymmetric	Graphene aerogel	LiOH-PVA gel	193.1 F g ⁻¹ at 1 A g ⁻¹	68.1 Wh kg ⁻¹ , 982.9 W kg ⁻¹	81.5%, 5000 cycles	¹
Co ₃ O ₄ / reduced graphene oxide	-	Asymmetric	Activated carbon	6 M KOH	114.1 F g ⁻¹ at 0.375 A g ⁻¹	35 Wh kg ⁻¹ , 100 W kg ⁻¹	95%, 1000 cycles	²
Co ₃ O ₄ / 3D porous carbon	1.99 mg cm ⁻²	Asymmetric	Activated carbon	3 M KOH	60.7 F g ⁻¹ at 1 A g ⁻¹	21.1 Wh kg ⁻¹ , 790 W kg ⁻¹	83%, 2000 cycles	³
Co ₃ O ₄ / Graphene	3 mg cm ⁻²	Asymmetric	Porous carbon	6 M KOH	130 F g ⁻¹ at 0.455 A g ⁻¹	40 Wh kg ⁻¹ , 340 W kg ⁻¹	98%, 2000 cycles	⁴
Co ₃ O ₄ / carbon nanofibers	-	Symmetric	-	6 M KOH	299 F g ⁻¹ at 1 A g ⁻¹	-	74%, 2000 cycles	⁵
Co ₃ O ₄ / Bio-inspired Carbon	-	Symmetric	-	PVA-KOH gel	28.38 F g ⁻¹ at 0.1 A g ⁻¹	17 Wh kg ⁻¹ , 184 W kg ⁻¹	87%, 10000 cycles	⁶
Co ₃ O ₄ / Graphene	50 μg cm ⁻²	Symmetric	-	PVA-KOH gel	300 F g ⁻¹ at 5 A g ⁻¹	27 Wh kg ⁻¹ , 2000 W kg ⁻¹	86%, 20000 cycles	⁷
Co ₃ O ₄ / reduced grapheme oxide	0.8 mg cm ⁻²	Symmetric	-	2 M KOH	458 F g ⁻¹ at 0.5 A g ⁻¹	47.2 Wh kg ⁻¹ , 200.6 W kg ⁻¹	95.6%, 1000 cycles	⁸
Co ₃ O ₄ / Carbon	19 - 25 mg cm ⁻²	Symmetric	-	2 M KOH	54 F g ⁻¹ at 0.1 A g ⁻¹	1.66 Wh kg ⁻¹ , 1223 W kg ⁻¹	82%, 10000 cycles	This work

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