Supplementary Information: Role of Graphene Oxide and Reduced Graphene Oxide in Electric Double-Layer Capacitors: A Systematic Review

Talia Tene[1], Stefano Bellucci[2,*], Marco Guevara[3], Paul Romero[4], Alberto Guapi[3], Lala Gahramanli[2,5], Salvatore Straface[6], Lorenzo S. Caputi[7,8], Cristian Vacacela Gomez[2,8*]

[1]Department of Chemistry, Universidad Técnica Particular de Loja, 110160 Loja, Ecuador
[2]INFN-Laboratori Nazionali di Frascati, Via E. Fermi 54, I-00044 Frascati, Italy
[3]Faculty of Mechanical Engineering, Escuela Superior Politécnica de Chimborazo (ESPOCH), Riobamba 060155, Ecuador
[4]FIE, Escuela Superior Politécnica de Chimborazo (ESPOCH), Riobamba 060155, Ecuador
[5]Nanoresearch Laboratory, Excellent Center, Baku State University, Baku, Azerbaijan
[6]Department of Environmental Engineering (DIAm), University of Calabria, Via P. Bucci, Cubo 42B, 87036 Rende, Italy
[7]Surface Nanoscience Group, Department of Physics, University of Calabria, 87036 Rende, Italy
[8]UNICARIBE Research Center, University of Calabria, 87036 Rende, Italy

*Correspondence: vacacela@lnf.infn.it (C.V.G); bellucci@lnf.infn.it (S.B.)

Table S1. Interventions considering the preparation method, electron, and electrolyte

Reference	Type of intervention:	Preparation Method	Electrode Fabrication	Electrolyte used
Gutierrez et al 2013 [55]	Development of a scalable prototype supercapacitor using metal oxides and graphene oxide with an ionic liquid electrolyte to combine pseudocapacitance and electric double-layer capacitance.	Modified Hummers' method for graphene oxide, ammonium evaporation for Co_3O_4 nanorods, and acid digestion for MnO_2 nanowires.	Tri-layered composite electrode including Co_3O_4 nanorods, MnO_2 nanowires, and a layer of electrophoretically deposited graphene oxide reduced to rGO.	Solutions of KOH, acetonitrile, and ionic liquid 1-Ethyl-3-methylimidazolium tetrafluoroborate (EMIm-BF4).
Lee, et al 2012 [56]	Research on supercapacitors, specifically focusing on the synergy between graphene nanosheets and the conducting polymer polyaniline.	Layer-by-layer (LbL) assembly method was used to create multilayer thin films through electrostatic interactions between negatively charged graphene oxide (GO) nanosheets and positively charged polyaniline (PANi).	The electrodes were fabricated using a combination of GO and PANi in a multilayer structure through the LbL assembly.	Sulfuric acid (H_2SO_4) was used as the electrolyte in the electrochemical testing of the supercapacitors.

Tran et al 2013 [57]	Development of new poly sodium 4-styrenesulfonate intercalated graphene oxide electrodes for supercapacitors	Controlled oxidation time in the synthesis of graphite oxide to modify the oxygen content in graphene oxide, which affects the electric double layer capacitance	Electrodes made from new composite featuring reduced oxygen content in graphene oxide	Aqueous electrolyte used in testing, specific composition not detailed in the summary
Huang et al 2014 [58]	Development of new gel electrolyte for EDLCs	Freeze-thaw/boron cross-linking method	Not specifically detailed for electrolyte preparation	Boron cross-linked graphene oxide/polyvinyl alcohol nanocomposite gel
Gao et al 2015 [59]	Development of a high-power density electric double-layer capacitor using porous multi-walled carbon nanotube microspheres as a local electrolyte micro-reservoir	Porous multi-walled carbon nanotube microspheres were prepared using a spray drying method, which helps to maintain a stable porous structure and acts as a local electrolyte micro-reservoir	The electrodes were fabricated using only MWNTMS as the active materials, achieving a robust and stable porous structure beneficial for high current density operations	KOH aqueous electrolyte was used in the tests, typical for EDLCs to provide a conducive ionic environment for charge storage
	Development of graphene/polymer hybrid thin films as	Layer-by-layer assembly based on controlled electrochemical polymerization followed by	Fabrication of electrodes from graphene and polymer	The specific type of electrolyte used was not detailed in the extracted information

Gupta et al 2015 [60]	supercapacitors, utilizing physical-chemical interfacial processes for enhanced electrochemical performance.	electrochemical reduction of graphene oxide to produce ErGO, for enhanced electronic contact through nanoscale architecture.	hybrids, using electrochemical methods to ensure high conductivity and chemical stability at the interfaces.	but typically involves aqueous solutions suitable for electrochemical applications.
Haque et al 2015 [61]	Development of nitrogen-doped graphene via thermal treatment of graphene oxide and aminoterephthalic acid for use in supercapacitors	Thermal treatment of graphene oxide with aminoterephthalic acid as a nitrogen source at 750°C under argon flow	Nitrogen-doped graphene electrodes were prepared by mixing the active material with PTFE binder and applying to gold electrodes	0.5 M H_2SO_4 used in the electrochemical tests
Ming Li et al 2015 [62]	Development of N-doped reduced graphene oxide (N-rGO) using a novel method for enhanced performance in supercapacitors	Combination of instant thermal exfoliation and covalent bond transformation from a melamine-graphene oxide mixture	Electrodes were fabricated using the developed N-rGO, showcasing improved interface characteristics for supercapacitors	Organic electrolyte 1 M tetraethylammonium tetrafluoroborate (TEABF4) in propylene carbonate (PC) was used, highlighting the improvements due to broad voltage windows

Suleman et al 2015 [63]	Development of high-rate supercapacitive electric double-layer capacitors (EDLCs) using GO and r-GO electrodes interfaced with a plastic-crystal-based gel polymer electrolyte (GPE). Development of high-rate supercapacitive electric double-layer capacitors (EDLCs) using GO and r-GO electrodes interfaced with a plastic-crystal-based gel polymer electrolyte (GPE).	Fabrication of GPE film involving lithium bis(trifluoromethanesulfonyl)imide (LiTFSI) in succinonitrile (SN) within a polyvinylidene fluoride-co-hexafluoropropylene (PVdF-HFP) matrix.	Electrodes made from GO and r-GO using specific preparation techniques to enhance the interface with GPE.	GPE comprising LiTFSI in SN entrapped in PVdF-HFP.
Tran et al 2015 [64]	Development of a one-pot synthesis method for a graphene/glucose/nickel oxide composite for use in supercapacitors	Graphite oxide was synthesized via the modified Brodie method, followed by sonication and chemical reduction using hydrazine. Glucose and nickel components were integrated during the synthesis process.	The composite materials were annealed at 500°C to form the final electrode structure.	1M H_2SO_4 used during the electrochemical testing
Youn et al. 2015 [65]	Development of high-surface-area nitrogen-doped reduced graphene oxide (N-RGO) for use in electric double-layer capacitors (EDLCs).	A two-step method involving solid-state microwave irradiation followed by heat treatment under NH_3 gas to enhance the specific surface area and introduce nitrogen doping.	N-rGO electrodes were prepared for use in EDLCs, emphasizing enhanced surface area and nitrogen doping for improved electrochemical performance.	Electrochemical tests were conducted using an organic electrolyte, specifically tetraethylammonium tetrafluoroborate in acetonitrile.

Muhammed et al 2016 [66]	Development of graphene oxide-MnO_2 nanocomposite for use in supercapacitors	Graphene oxide was synthesized via Hummer's method and MnO_2 was synthesized by a soft chemical route; these were combined to create the nanocomposite.	Fabricated from the graphene oxide-MnO_2 nanocomposite using a soft chemical route, indicating an innovative approach to combining these materials for enhanced performance.	1 M Na_2SO_4 in aqueous solution was used during electrochemical testing
Wang et al 2017 [67]	Development of a graphene-based lithium ion capacitor (LIC) with enhanced gravimetric energy and power densities	Synthesis involved creating a 3D macroporous foam from reduced graphene oxide (rGO) decorated with tin oxide nanoparticles for the anode, and thermally expanded and physically activated rGO (a-TEGO) for the cathode	Anode made from SnO_2-rGO and cathode from a-TEGO, both incorporating innovative graphene technology	1 M LiPF6 in ethylene carbonate and dimethyl carbonate (EC)
Ma et al 2019 [68]	Development and electrochemical characterization of graphene-based electrodes with different fabrication parameters for supercapacitors	Graphene oxide was reduced with sodium borohydride ($NaBH_4$) to form reduced graphene oxide (rGO), which was used as the active material on carbon fiber substrates	Electrodes made from rGO deposited on top of activated and un-activated carbon fiber substrates.	6M KOH solution

Sengottaiyan et al 2017 [69]	Development of cobalt oxide/reduced graphene oxide (Co_3O_4/rGO) composites for supercapacitors using a one-pot hydrothermal synthetic route without surfactants.	Hydrothermal synthesis without using any structure-guiding surfactants to form Co_3O_4 nanocrystals on rGO sheets.	Electrodes fabricated from Co_3O_4/rGO composites with varying ratios to study the effect of Co_3O_4 concentration on supercapacitive performance	2M KOH aqueous solution
Zhang et al 2017 [70]	Synthesis of a ternary composite of graphene oxide/carbon dots/polypyrrole (GO/CDs/PPy) for supercapacitor applications	In situ polymerization of GO/CDs with pyrrole under mild conditions to synthesize the ternary composite.	Use of GO/CDs/PPy as electrode active material, leveraging the unique properties of each component.	Not specified in the extracted information.
Hu, et al 2018 [71]	Development of a 3D hierarchical porous $V_3O_7 \cdot H_2O$ nanobelts/CNT/reduced graphene oxide composite for supercapacitors.	A one-step hydrothermal synthesis and self-assembly method was used to integrate $V_3O_7 \cdot H_2O$ nanobelts with CNT and reduced graphene oxide.	Synthesized composite was used to fabricate electrodes that were tested in supercapacitors.	5M LiCl/PVA used in electrochemical testing.

Noh et al 2019 [72]	Development and investigation of SnO_2 nanospacer-incorporated reduced graphene oxide electrodes for enhanced supercapacitor performance.	Hydrothermal synthesis method used to incorporate SnO_2 nanospacers onto rGO sheets to prevent restacking and enhance ion accessibility.	Synthesized materials were fabricated into electrodes using a mixture of active material, conductive carbon, and binder coated onto nickel foam.	Aqueous solution of 1.0 M Na_2SO_4 was used as the electrolyte in the electrochemical tests.
Li et al 2019 [73]	Development of SnO_2 nanospacer-incorporated reduced graphene oxide electrodes for improved capacitive energy storage	A novel synthesis technique involving the incorporation of SnO_2 nanospacers within the graphene oxide matrix followed by reduction	Electrodes were fabricated using a paste of the SnO_2 nanospacer-incorporated rGO composite and applied onto current collectors.	Aqueous electrolyte solution, specifics not detailed in the extracted information
Bagher et al 2020 [74]	Functionalization of highly reduced graphene oxide (rGO) with butyl methyl imidazolium ionic liquid to enhance supercapacitive features.	rGO was functionalized with butyl methyl imidazolium bromide ([BMIM]-Br) using a partial reduction process.	IFG and rGO were used to fabricate electrodes for testing in supercapacitors	Not specified in the extracted summary. Likely involved typical supercapacitor electrolytes for testing
Kil, et al 2020 [75]	Development of reduced graphene oxide (rGO) electrodes for supercapacitors using a solution-processed method with low-temperature thermal reduction	Graphene oxide (GO) was processed through spin coatings followed by a low-temperature thermal reduction at 300°C, which is lower than conventional methods.	Electrodes were fabricated using a solution process without the need for high temperatures or harmful chemicals	Poly(vinyl alcohol)/phosphoric acid (PVA/H_3PO_4) electrolyte gel was used in the supercapacitors.

Maphiri et al 2021 [76]	Development of thermally reduced graphene oxide microsupercapacitors using a mask-free AxiDraw direct writing technique	Graphene oxide films were directly written onto substrates using the AxiDraw device and thermally reduced at varying temperatures.	Microsupercapacitors fabricated with thermally reduced graphene oxide through a mask-free process, optimizing the electrode design for better performance	Not specified in the extracted summary. Likely involved typical supercapacitor electrolytes.
Lun Wu et al 2021 [77]	Development of rGO/CoSx-rGO/rGO hybrid films using a novel method involving co-assembly and sulfidation of 2D metal organic framework (MOF) nanoflakes and graphene oxide.	Co-assembly of ZIF-67 nanocubes and GO followed by sulfidation using thioacetamide to convert into CoSx and reduce GO to rGO.	Layered structure using vacuum membrane filtration and subsequent thermal treatments to achieve the rGO/CoSx-rGO/rGO hybrid film.	Electrolyte specifics are not detailed; however, general supercapacitor testing protocols applied.
Zhao et al 2021 [78]	Development of nanocarved vanadium nitride (VN) nanowires encapsulated in lamellar graphene layers for supercapacitor electrodes.	Synthesized via a freeze-casting process followed by NH_3 nitridation, which creates a hierarchical porous structure that encapsulates VN nanowires within N-doped reduced graphene oxide layers.	VN nanowires are interwoven with graphene layers, enhancing structural integrity and electrochemical performance.	1 M KOH was used in electrochemical testing, typical for supercapacitor evaluations.
Qiu et al 2015 [79]	Processing graphene oxide (GO) into microparticles by spray drying for EDLC electrode application.	GO microparticles prepared by spray drying an aqueous solution of GO, followed by thermal reduction at 225°C for 12 hours.	Mixing r-GO microparticles with an aqueous suspension of polytetrafluoroethylene (PTFE) to form a paste, which was applied to titanium foil current collectors and pressed.	1 M sulfuric acid.

			The electrodes were then soaked in 1 M sulfuric acid electrolyte.	
Ngamjumrus et al 2023 [80]	Development of a supercapacitor using hydrothermal and 3-D ball milling processes to improve the properties of reduced graphene oxide activated durian shell carbon composites.	Combination of hydrothermal processing and 3-D ball milling to treat the activated carbon derived from durian shells, then combined with reduced graphene oxide	Electrodes were fabricated using the composite material, tested under varying conditions to optimize the performance	3M KOH was used in the electrochemical tests
Qu et al 2023 [81]	Development of hybrid supercapacitor electrodes using an optimized synthetic route for $Cu_{0.33}Co_{0.67}Se_2$ nanorods on Ni foam integrated with N, S co-doped porous carbon (NSPC).	A two-step hydrothermal method was used, integrating Cu-Co-Se with rGO. N, S co-doped glucose-based porous carbon was synthesized as the anode.	Fabricated using a direct growth method on Ni foam, ensuring strong adhesion and high conductivity	Not specified in the abstract. Likely a standard supercapacitor electrolyte was used for the tests.

Table S2. Interventions considering the material and method for comparison and cyclin stability

Reference	**Comparison Materials**	**Comparison Method**	**Cyclins Stability**	**Statistical Significance**
Gutierrez et al 2013 [55]	Compared with traditional metal oxides like ruthenium dioxide, and traditional electrolytes (acids, bases, and organic solvents).	Cyclic voltammetry to compare specific capacitance, energy, and power densities.	Targeted over 100,000 life cycles	Not explicitly discussed; however, the results indicate improvements over traditional materials and methods.
Lee, et al 2012 [56]	The study involved comparisons between GO, PANi, and their combinations in various states (thermally and chemically reduced).	The study involved comparisons between GO, PANi, and their combinations in various states (thermally and chemically reduced).	Excellent cycling stability was noted, with the supercapacitor maintaining a high percentage of its initial capacity after extensive cycling tests.	The significant retention of capacitance after many cycles highlights the robustness of the electrode design.

Tran et al 2013 [57]	Previous composites of graphene oxide (GO), poly sodium 4-styrenesulfonate intercalated graphene oxide (PSSGO), and the new modified version of PSSGO with less oxygen content	Electrochemical performance evaluated using cyclic voltammetry, galvanostatic charge/discharge cycles, and impedance spectroscopy	Excellent, with capacitance retention of 94% after 3000 cycles	Capacitance retention was 94% after 3000 cycles, indicating high reliability and stability
Huang et al 2014 [58]	Compared with traditional KOH solution and GO-PVA/KOH gel	Electrochemical properties of EDLCs using different electrolytes were compared	Enhanced cycling stability reported	Improved performance metrics demonstrated through electrochemical testing
Gao et al 2015 [59]	Comparisons are likely made with other carbon-based materials, specifically regarding their structural properties and performance in EDLC applications	Likely involves comparison of electrochemical performance such as capacitance retention, power density, and rate capability using standard electrochemical techniques like cyclic voltammetry and galvanostatic charge-discharge analysis	Improved stability and high capacitance retention over numerous cycles are highlighted, with specific values likely detailed in the text	Demonstrates superior performance metrics through rigorous electrochemical testing, including enhanced cycling stability and capacitance retention

Gupta et al 2015 [60]	Comparison between graphene nanosheets (GNS) with conducting polymers polyaniline (PAni) and polypyrrole (PPy), and their reduced and oxidized states.	The electrochemical properties of the hybrid films and their components were evaluated using cyclic voltammetry and scanning electrochemical microscopy (SECM) to understand interfacial processes.	Enhanced cycling stability was highlighted, with detailed insights provided by SECM imaging on electrode reactivity and ion adsorption at interfaces.	The hybrid films outperformed many other supercapacitor configurations, showcasing superior cycling stability and charge efficiency.
Haque et al 2015 [61]	Compared nitrogen-doped graphene with pristine graphene and graphene oxide electrodes	Electrochemical performance of nitrogen-doped graphene compared against graphene oxide (GO) and pristine graphene using cyclic voltammetry, charge-discharge tests, and electrochemical impedance spectroscopy	Showed high capacity retention (>90%) after 5000 charge-discharge cycles	Significant increase in capacitance and cycling stability attributed to nitrogen doping
Ming Li et al 2015 [62]	Comparison of N-rGO with thermally reduced graphene oxide (T-rGO) and chemically reduced graphene oxide (C-rGO)	Electrochemical testing in both aqueous and organic electrolytes, using cyclic voltammetry and charge-discharge cycling	Showed excellent stability with over 71.1% capacitance retention even at high scan rates in organic electrolyte	Demonstrated statistically significant improvements in performance metrics over other reduced graphene oxides

Suleman et al 2015 [63]	Comparisons made between GO and r-GO electrodes.	Electrochemical performance is compared using electrochemical impedance spectroscopy (EIS), cyclic voltammetry (CV), and galvanostatic charge-discharge tests.	Both electrode types showed stable performance up to ~11000-13500 cycles.	Demonstrated significant improvement in high-rate capability and energy storage with the developed materials.
Tran et al 2015 [64]	Compared the ternary composite to reduced graphene oxide (RGO) and RGO/nickel oxide composites without glucose	Electrochemical testing including cyclic voltammetry, charge/discharge cycling, and impedance spectroscopy	Excellent, with over 5,000 cycles without performance degradation	Demonstrated a significant increase in capacitance and stability, attributed to the synergistic effects of glucose and nickel oxide
Youn et al. 2015 [65]	Comparison with traditional reduced graphene oxide (rGO) and other graphene-based electrode materials	Electrochemical performance was evaluated using cyclic voltammetry, galvanostatic charge-discharge cycling, and electrochemical impedance spectroscopy.	N-RGO showed excellent cycling stability with 96% capacitance retention after 100,000 cycles.	Statistically significant improvements in capacitance and cycling stability were demonstrated compared to traditional rGO.
Muhammed et al 2016 [66]	Compared GO with MnO_2 and their composite	Electrochemical performance is compared using cyclic voltammetry and galvanostatic	Enhanced stability demonstrated through cyclic voltammetry and charge-discharge testing, indicating robustness suitable for supercapacitor applications.	Significant enhancement in capacitance and electrochemical stability was noted, which supports the potential application of this nanocomposite in supercapacitors.
Wang et al 2017 [67]	Compared with standard electrical double-layer capacitors (EDLCs) and other LIC technologies	Performance metrics compared under varying conditions with traditional capacitors and other LIC configurations	70% capacity retention after 5000 cycles, showcasing excellent durability for high-performance applications	Demonstrated significant improvements over traditional capacitor technologies, especially in terms of energy and power density, and cycling stability

Ma et al 2019 [68]	Activated vs un-activated carbon fiber substrates	Electrochemical testing comparing the performance of electrodes made from activated and unactivated carbon fiber substrates.	Good stability with a high retention of capacitive properties after 600 cycles.	Enhanced performance with activated carbon fiber shows statistically significant improvement in capacitance and energy storage capacity.
Sengottaiyan et al 2017 [69]	Comparison with traditional materials for supercapacitors like fullerene, carbon nanotubes, graphene, etc., especially focusing on their electrochemical performance in supercapacitors.	Electrochemical testing including cyclic voltammetry and galvanostatic charge/discharge cycles.	Exhibited excellent stability with 96.6% capacitance retention after 2000 cycles.	Significant improvement in capacitance and cycling stability over traditional carbon-based materials.
Zhang et al 2017 [70]	Comparison with binary composites of both CDs/PPy and GO/PPy.	Electrochemical testing including cyclic voltammetry and galvanostatic charge/discharge cycles	Excellent stability with 96.6% capacitance retention after 2000 cycles.	Statistically significant improvements in capacitance and cycling stability over traditional carbon-based materials.
Hu, et al 2018 [71]	Compared to V_2O_5 nanosheets and VOx/CNT composites.	Electrochemical performance compared using cyclic voltammetry, charge-discharge cycles, and electrochemical impedance spectroscopy.	Exhibited excellent stability with 99.7% capacitance retention after 10,000 cycles.	Statistical analysis not is specified, but superior performance metrics demonstrate significant improvements.
Noh et al 2019 [72]	Comparisons made between electrodes with SnO_2 nanorod bundles, SnO_2 nanoparticles, and bare reduced graphene oxide (rGO).	Electrochemical measurements including cyclic voltammetry, galvanostatic charge-discharge, and electrochemical impedance spectroscopy were used to compare the performance.	Exhibited enhanced cycling stability, maintaining high capacitance retention over extended cycles.	Demonstrated a significant increase in performance with the incorporation of SnO_2 nanorod bundles due to improved structural characteristics and ion accessibility.
Li et al 2019 [73]	Compared with traditional reduced graphene oxide (rGO)	Electrochemical characterization including cyclic voltammetry,	Demonstrated excellent cycling stability with more than 10,000 cycles	Statistically significant improvements were observed in capacitive performance and energy density

	electrodes without SnO_2 nanospacers.	galvanostatic charge-discharge, and impedance spectroscopy.	with minimal loss in performance.	
Bagher et al 2020 [74]	Comparison between functionalized rGO (IFG) and non-functionalized rGO.	The electrochemical properties of rGO and IFG were evaluated using various techniques including cyclic voltammetry and electrochemical impedance spectroscopy.	Not specified, but IFG structure suggests potential for high stability and long cycling life.	The significant increase in capacitance and the improvement in electrochemical characteristics highlight the effectiveness of the functionalization process.
Kil, et al 2020 [75]	Comparison likely with conventional rGO preparation methods, focusing on the effects of thermal reduction temperature on the material properties.	Electrochemical performance including capacitance, energy density, and power density was compared to higher-temperature reduction methods.	Exhibited excellent cycling stability, suitable for long-term applications.	The method showed significant improvements in the structural integrity and electrochemical performance of rGO compared to traditional high-temperature reduction methods
Maphiri et al 2021 [76]	Compared the performance of microsupercapacitors at different levels of thermal reduction (TRGO-100 to TRGO-500) and configurations (number of digits per unit area).	Electrochemical performance is evaluated through cyclic voltammetry, galvanostatic charge-discharge, and electrochemical impedance spectroscopy.	Exhibited excellent stability, maintaining high performance over extensive cycles.	Demonstrated significant improvements in electrochemical properties with increased thermal reduction temperatures and optimal microsupercapacitor design.
Lun Wu et al 2021 [77]	No specific comparison materials mentioned; focus on the innovative hybrid film development.	Not explicitly mentioned; focus on the performance evaluation of the novel hybrid film itself.	Exhibited excellent stability with high capacitance retention after extended cycling	High significance in performance enhancement, retaining 92.8% capacitance after 10,000 cycles.
Zhao et al 2021 [78]	No direct comparison materials were mentioned, but the study focuses on the advanced features of the novel VN/graphene	The structural and electrochemical properties are primarily evaluated against theoretical performance metrics of similar composites.	Demonstrated long cycling life with minimal degradation, suitable for sustained industrial or commercial use	Significant improvements in capacitance and cycle life compared to typical supercapacitor materials.

	composite over traditional supercapacitor materials.			
Qiu et al 2015 [79]	Nano-sized activated carbon (DLC Super 30, Norit)	Electrochemical performance characterized with cyclic voltammetry (CV) and constant current charge/discharge measurements	The specific capacitance of the r-GO electrodes decreased initially but began to stabilize after approximately 2000 cycles, retaining most of its capacitance at high current densities.	The study demonstrated that the r-GO electrodes exhibited a specific capacitance of 75 F/g at a scan rate of 0.02 V/s, which compared well to activated carbon (72 F/g), and retained capacitance at high current densities due to the corrugated surface morphology of r-GO microparticles.
Ngamjumrus et al 2023 [80]	Comparison between different treatment durations (15 min vs 30 min of 3-D ball milling) and hydrothermal processing.	Comparison Method: Electrochemical performance was compared using cyclic voltammetry, galvanostatic charge-discharge, and electrochemical impedance spectroscopy.	High cycling stability, maintaining performance over many cycles.	Demonstrated significant enhancements in electrochemical properties through the novel processing methods.
Qu et al 2023 [81]	Not explicitly mentioned, but the study seems to focus on enhancing the performance of Cu-Co-Se-based electrodes compared to previous methods.	Electrochemical performance is evaluated in terms of energy density and specific capacity.	Demonstrated high cycling stability, which implies durability and long-term reliability for energy storage applications.	The high energy density and capacity indicate significant improvements over typical supercapacitor materials

Table S3. Performance metrics

Reference	Capacitance	Energy Density	Power Density	Efficiency:
Gutierreza et al 2013 [55]	Specific capacitance value(s) reported: 0.356 F/g, 117 F/g Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: Tri-layered electrode with reduced graphene oxide (rGO) on MnO2 nanowires and Co3O4 nanorods, traditional electrophoretic deposition (EPD) of graphene oxide and reduction on stainless steel sheets. Experimental conditions (e.g., electrolyte used, voltage window): Ionic liquid electrolyte (1-Ethyl-3-methylimidazolium tetrafluoroborate (EMIm-BF4)), KOH, acetonitrile, voltage window ±0.6 V Key findings or remarks on capacitance: The tri-layered device showed the highest specific capacitance and best symmetry within the voltage window. The specific capacitance obtained from traditional EPD of GO is within the highest reported values in the literature.	Energy density value(s) reported: Not reported Units of measurement: Not applicable Methods or materials used to achieve these values: Not applicable Experimental conditions (e.g., electrolyte used, voltage window): Not applicable Key findings or remarks on energy density: Energy density improvement is implied due to the combination of pseudocapacitance and electric double layer capacitance in the tri-layered composite electrode.	Power density value(s) reported: Not reported Units of measurement: Not applicable Methods or materials used to achieve these values: Not applicable Experimental conditions (e.g., electrolyte used, voltage window): Not applicable Key findings or remarks on power density: High power density is attributed to the device due to its design combining pseudocapacitance and electric double layer capacitance.	Efficiency value(s) reported: Not reported Units of measurement: Not applicable Methods or materials used to achieve these values: Not applicable Experimental conditions (e.g., electrolyte used, voltage window): Not applicable Key findings or remarks on efficiency: The electrode design promises high efficiency due to enhanced charge injection and stability provided by the rGO layer.

Lee et al 2012 [56]	Specific capacitance value(s) reported: 402.5–219.4 F/g (PG10), 489.0–304.8 F/g (PG10-H), 240.1–103.5 F/g (PG10-HC), 24.6–10.9 F/g (GG10-H) Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: Hybrid electrodes of polyaniline (PANi) and graphene oxide (GO) Experimental conditions (e.g., electrolyte used, voltage window): 1.0 M H2SO4 electrolyte, three-electrode configuration with platinum wire and Ag/AgCl as counter and reference electrodes, respectively, potential range of -0.2 to 0.8 V Key findings or remarks on capacitance: The hybrid electrodes show improved capacitance due to the combination of PANi's pseudocapacitive behavior and graphene's high surface area and conductivity.	Energy density value(s) reported: 18.92 Wh/kg (PG10), 30.34 Wh/kg (PG10-H) Units of measurement: Watt-hours per kilogram (Wh/kg) Methods or materials used to achieve these values: Hybrid electrodes of polyaniline (PANi) and graphene oxide (GO) Experimental conditions (e.g., electrolyte used, voltage window): 1.0 M H2SO4 electrolyte, three-electrode configuration with platinum wire and Ag/AgCl as counter and reference electrodes, respectively, potential range of -0.2 to 0.8 V Key findings or remarks on energy density: The thermally annealed PG10-H electrode demonstrates a higher energy density due to improved electrical conductivity and close-packed structure reducing internal resistance.	Power density value(s) reported: 1.0 kW/kg Units of measurement: Kilowatts per kilogram (kW/kg) Methods or materials used to achieve these values: Hybrid electrodes of polyaniline (PANi) and graphene oxide (GO) Experimental conditions (e.g., electrolyte used, voltage window): 1.0 M H2SO4 electrolyte, three-electrode configuration with platinum wire and Ag/AgCl as counter and reference electrodes, respectively, potential range of -0.2 to 0.8 V Key findings or remarks on power density: High power density achieved due to fast charge/discharge capability and enhanced electrical properties from thermal treatment.	Efficiency value(s) reported: 90.7% retention of initial capacitance after 500 cycles (PG10-H) Units of measurement: Percentage (%) Methods or materials used to achieve these values: Hybrid electrodes of polyaniline (PANi) and graphene oxide (GO) Experimental conditions (e.g., electrolyte used, voltage window): 1.0 M H2SO4 electrolyte, three-electrode configuration with platinum wire and Ag/AgCl as counter and reference electrodes, respectively, potential range of -0.2 to 0.8 V Key findings or remarks on efficiency: The hybrid electrode PG10-H demonstrates significantly better cycling stability compared to the as-assembled PG10 electrode.

Tran et al 2013 [57]	Specific capacitance value(s) reported: 88 F/g (new composite), 109 F/g (PSSGO5) Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: Poly sodium 4-styrenesulfonate intercalated graphene oxide (PSSGO) composite, synthesized with controlled oxidation time of graphite oxide. Experimental conditions (e.g., electrolyte used, voltage window): 1.0 M H2SO4 electrolyte, current density of 0.3 A/g, potential range of -0.2 to 0.8 V Key findings or remarks on capacitance: The new PSSGO composite showed improved specific capacitance, with a retention of 94% after 3000 cycles indicating high cyclic stability and low resistance.	Energy density value(s) reported: Not reported Units of measurement: Not applicable Methods or materials used to achieve these values: Not applicable Experimental conditions (e.g., electrolyte used, voltage window): Not applicable Key findings or remarks on energy density: Improved performance suggested but specific values not provided.	Energy density value(s) reported: Not reported Units of measurement: Not applicable Methods or materials used to achieve these values: Not applicable Experimental conditions (e.g., electrolyte used, voltage window): Not applicable Key findings or remarks on energy density: Improved performance suggested but specific values not provided .	Efficiency value(s) reported: 94% retention of initial capacitance after 3000 cycles Units of measurement: Percentage (%) Methods or materials used to achieve these values: Poly sodium 4-styrenesulfonate intercalated graphene oxide (PSSGO) composite Experimental conditions (e.g., electrolyte used, voltage window): 1.0 M H2SO4 electrolyte, Galvanostatic charge/discharge measurement at 0.5 A/g Key findings or remarks on efficiency: High cyclic stability and low ESR of 35 Ω compared to 180 Ω of previous PSSGO, indicating reliable performance.
Huang et al 2014 [58]	Specific capacitance value(s) reported: 141.8 F/g Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: GO-B-PVA/KOH gel electrolyte Experimental conditions (e.g., electrolyte used, voltage window): 0.1 A/g	Energy density value(s) reported: Not specified Units of measurement: Not applicable Methods or materials used to achieve these values: Not applicable	Power density value(s) reported: Not specified Units of measurement: Not applicable Methods or materials used to achieve these values: Not applicable	Efficiency value(s) reported: Not specified Units of measurement: Not applicable Methods or materials used to achieve these values: Not applicable

	Key findings or remarks on capacitance: Specific capacitance increases up to 129.4% compared to KOH aqueous solution electrolyte; good electrochemical properties, thermal stability, and mechanical properties	Experimental conditions (e.g., electrolyte used, voltage window): Not applicable Key findings or remarks on energy density: Not mentioned	Experimental conditions (e.g., electrolyte used, voltage window): Not applicable Key findings or remarks on power density: Not mentioned	Experimental conditions (e.g., electrolyte used, voltage window): Not applicable Key findings or remarks on efficiency: Not mentioned
Gao et al 2015 [59]	Specific capacitance value(s) reported: 118 mF/cm², 136 mF/cm² Units of measurement: Millifarads per square centimeter (mF/cm²) Methods or materials used to achieve these values: Porous multi-walled carbon nanotube microspheres (MWNTMS) and rGO-MWNTMS hybrid electrodes. Experimental conditions (e.g., electrolyte used, voltage window): 6 M KOH aqueous electrolyte, current density from 0.2 A/g to 100 A/g, potential range 0-1 V. Key findings or remarks on capacitance: MWNTMS provide stable ion transport paths, maintaining high capacitance even at high current densities.	Energy density value(s) reported: 9 μWh/cm² Units of measurement: Micro-Watt-hours per square centimeter (μWh/cm²) Methods or materials used to achieve these values: rGO-MWNTMS hybrid electrodes. Experimental conditions (e.g., electrolyte used, voltage window): 6 M KOH aqueous electrolyte, discharge current of 100 A/g. Key findings or remarks on energy density: The rGO-MWNTMS EDLC shows excellent energy density at high current density, making it suitable for high power applications.	Power density value(s) reported: 1,540 mW/cm² Units of measurement: Milliwatts per square centimeter (mW/cm²) Methods or materials used to achieve these values: rGO-MWNTMS hybrid electrodes. Experimental conditions (e.g., electrolyte used, voltage window): 6 M KOH aqueous electrolyte, discharge current of 100 A/g. Key findings or remarks on power density: The rGO-MWNTMS EDLC presents high power density due to efficient ion transport paths and stable electrode structure.	Efficiency value(s) reported: 98% retention after 5,000 cycles Units of measurement: Percentage (%) Methods or materials used to achieve these values: rGO-MWNTMS hybrid electrodes. Experimental conditions (e.g., electrolyte used, voltage window): 6 M KOH aqueous electrolyte, current density of 1 A/g. Key findings or remarks on efficiency: The rGO-MWNTMS electrode exhibits excellent cyclic stability and high efficiency, retaining 98% of its initial capacitance after 5,000 charge/discharge cycles.

Gupta et al 2015 [60]	Specific capacitance value(s) reported: 270–350 F/g (for hybrids with ErGO), 210–300 F/g (for hybrids with GO), 10-20 F/g (for PPy and PAni), 70-80 F/g (for GO and ErGO) Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: Layer-by-layer (LbL) assembled hybrid films of PAni and PPy with GO and ErGO nanosheets. Experimental conditions (e.g., electrolyte used, voltage window): 1M KCl electrolyte, scan rate of 0.05 V/s, potential range of -0.2 to 0.8 V. Key findings or remarks on capacitance: The hybrid films exhibited significant enhancement in electrochemical performance due to the synergistic effect of high specific surface area and electrical conductivity of GNS coupled with redox transitions from PPy and PAni.	Energy density value(s) reported: Not reported Units of measurement: Not applicable Methods or materials used to achieve these values: Not applicable Experimental conditions (e.g., electrolyte used, voltage window): Not applicable Key findings or remarks on energy density: Not mentioned	Power density value(s) reported: Not explicitly mentioned in the provided text. Units of measurement: NOT APPLICABLE Methods or materials used to achieve these values: NOT APPLICABLE Experimental conditions (e.g., electrolyte used, voltage window): NOT APPLICABLE Key findings or remarks on power density: NOT APPLICABLE	Efficiency value(s) reported: Not explicitly mentioned in the provided text. Units of measurement: NOT APPLICABLE Methods or materials used to achieve these values: NOT APPLICABLE Experimental conditions (e.g., electrolyte used, voltage window): NOT APPLICABLE Key findings or remarks on efficiency: NOT APPLICABLE
Haque et al 2015 [61]	Specific capacitance value(s) reported: 210 F/g (at 1 A/g), 226 F/g (from CV) Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: Nitrogen doping of graphene via thermal treatment of graphene oxide with aminoterephthalic acid Experimental conditions (e.g., electrolyte used, voltage window): 0.5 M H2SO4 electrolyte, current density of 1 A/g, scan rate of 100 mV/s Key findings or remarks on capacitance: The N-doped graphene electrode showed	Energy density value(s) reported: Not explicitly mentioned in the provided text. Units of measurement: NOT APPLICABLE Methods or materials used to achieve these values: NOT APPLICABLE Experimental conditions (e.g., electrolyte used, voltage window): NOT APPLICABLE	Power density value(s) reported: Not explicitly mentioned in the provided text. Units of measurement: NOT APPLICABLE Methods or materials used to achieve these values: NOT APPLICABLE Experimental conditions (e.g., electrolyte used, voltage window): NOT APPLICABLE	Efficiency value(s) reported: >90% capacity retention after 5000 cycles Units of measurement: Percentage (%) Methods or materials used to achieve these values: N-doped graphene electrode in EDLC Experimental conditions (e.g., electrolyte used, voltage window): 0.5 M H2SO4 electrolyte, current density of 1 A/g

	significant enhancement in capacitance compared to undoped graphene and graphene oxide, demonstrating a specific capacitance of 210 F/g at a current density of 1 A/g and 226 F/g from cyclic voltammetry.	Key findings or remarks on energy density: NOT APPLICABLE	Key findings or remarks on power density: NOT APPLICABLE	Key findings or remarks on efficiency: The N-doped graphene electrode demonstrated excellent cyclic stability with capacity retention of over 90% after 5000 cycles, indicating high efficiency and stability for supercapacitor applications.
Ming Li et al 2015 [62]	Specific capacitance value(s) reported: 234.3 F/g (in 0.5 M H2SO4), 187.8 F/g (in 1 M TEABF4/PC) Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: Nitrogen-doped reduced graphene oxide (N-rGO) Experimental conditions (e.g., electrolyte used, voltage window): Aqueous electrolyte (0.5 M H2SO4), Organic electrolyte (1 M TEABF4 in propylene carbonate) Key findings or remarks on capacitance: N-rGO exhibits excellent capacitive performances due to its high surface area, unique crumpled structure, and nitrogen-doped configurations which enhance conductivity and surface wettability.	Energy density value(s) reported: 25.1 Wh/kg Units of measurement: Watt-hours per kilogram (Wh/kg) Methods or materials used to achieve these values: N-rGO in 1 M TEABF4/PC electrolyte Experimental conditions (e.g., electrolyte used, voltage window): Organic electrolyte (1 M TEABF4 in propylene carbonate), voltage window up to 2 V Key findings or remarks on energy density: Using organic electrolyte effectively enlarges the cell voltage, constructing a high-performance EDLC with superior specific energy.	Power density value(s) reported: 10 kW/kg Units of measurement: Kilowatts per kilogram (kW/kg) Methods or materials used to achieve these values: N-rGO in 1 M TEABF4/PC electrolyte Experimental conditions (e.g., electrolyte used, voltage window): Organic electrolyte (1 M TEABF4 in propylene carbonate), voltage window up to 2 V Key findings or remarks on power density: The unique properties of N-rGO, including its crumpled structure and nitrogen-doped configurations, contribute to high power density.	Efficiency value(s) reported: 97.9% capacitance retention after 730 cycles Units of measurement: Percentage (%) Methods or materials used to achieve these values: N-rGO-based symmetric supercapacitor Experimental conditions (e.g., electrolyte used, voltage window): 1 M TEABF4/PC electrolyte, voltage window up to 2 V Key findings or remarks on efficiency: The N-rGO cell possesses excellent charge-discharge stability with minimal capacitance decay, indicating promising potential for application in supercapacitors with organic electrolytes.

Suleman et al 2015 [63]	Specific capacitance value(s) reported: 66 F/g (GO), 60 F/g (r-GO) Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: GO and r-GO electrodes interfaced with plastic-crystal-based flexible gel polymer electrolyte Experimental conditions (e.g., electrolyte used, voltage window): Gel polymer electrolyte (GPE) comprising lithium bis(trifluoromethanesulfonyl)imide (LiTFSI) in succinonitrile (SN) entrapped in poly(vinylidene fluoride-co-hexafluoropropylene) (PVdF-HFP), voltage window from -2.6 to +2.4 V Key findings or remarks on capacitance: GO electrodes showed higher specific capacitance due to additional pseudocapacitance from residual oxygen functionalities.	Energy density value(s) reported: 18 Wh/kg (GO), 15.6 Wh/kg (r-GO) Units of measurement: Watt-hours per kilogram (Wh/kg) Methods or materials used to achieve these values: Same methods and materials as above. Experimental conditions (e.g., electrolyte used, voltage window): Same as above. Key findings or remarks on energy density: Higher energy density in GO electrodes due to the pseudocapacitance effect.	Power density value(s) reported: 33.3 kW/kg (GO), 54.9 kW/kg (r-GO) Units of measurement: Kilowatts per kilogram (kW/kg) Methods or materials used to achieve these values: Same methods and materials as above. Experimental conditions (e.g., electrolyte used, voltage window): Same as above. Key findings or remarks on power density: r-GO electrodes exhibited higher power density due to better rate performance and faster charge/discharge capability.	Efficiency value(s) reported: Stable up to 11000-13500 charge-discharge cycles Units of measurement: Number of cycles Methods or materials used to achieve these values: Same methods and materials as above. Experimental conditions (e.g., electrolyte used, voltage window): Same as above. Key findings or remarks on efficiency: r-GO electrodes demonstrated better cyclic stability and lower initial fading compared to GO electrodes.
Tran et al 2015 [64]	Specific capacitance value(s) reported: Up to five times higher than that of reduced GO, about 300 F/g Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: Reduced graphene oxide (RGO) functionalized with glucose and nickel oxide Experimental conditions (e.g., electrolyte used, voltage window): Aqueous electrolyte, 1M H2SO4, voltage window 0-0.8 V Key findings or remarks on capacitance: The addition of glucose and nickel oxide resulted	Energy density value(s) reported: Not explicitly mentioned in the provided text. Units of measurement: NOT APPLICABLE Methods or materials used to achieve these values: NOT APPLICABLE Experimental conditions (e.g., electrolyte used,	Power density value(s) reported: Not explicitly mentioned in the provided text. Units of measurement: NOT APPLICABLE Methods or materials used to achieve these values: NOT APPLICABLE Experimental conditions (e.g., electrolyte used,	Efficiency value(s) reported: Maintains the same specific capacitance up to 5000 cycles Units of measurement: Number of cycles Methods or materials used to achieve these values: Reduced graphene oxide (RGO) functionalized with glucose and nickel oxide Experimental conditions (e.g., electrolyte used, voltage

	in a significant increase in specific capacitance due to the synergistic effects and enhanced surface area from the microspores formed by glucose.	voltage window): NOT APPLICABLE Key findings or remarks on energy density: NOT APPLICABLE	voltage window): NOT APPLICABLE Key findings or remarks on power density: NOT APPLICABLE	window): Aqueous electrolyte, 1M H2SO4, voltage window 0-0.8 V Key findings or remarks on efficiency: The ternary composite exhibited excellent cyclic stability, retaining its specific capacitance over 5000 cycles.
Youn. et al 2015 [65]	The specific capacitance of N-RGO was 291 F/g at a current density of 1 A/g.	Energy density was calculated based on specific capacitance and potential window.	Power density and rate capability were highlighted; specific values can be calculated from discharge profiles and current densities.	Demonstrated high efficiency in charge storage and power delivery due to its high conductivity and surface area.
Muhammed et al. 2016 [66]	Specific capacitance value(s) reported: 291 F/g (at 1 A/g), 261 F/g (at 50 A/g) Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: Nitrogen-doped reduced graphene oxide (N-RGO) synthesized by solid-state microwave irradiation and heat treatment under NH3 gas. Experimental conditions (e.g., electrolyte used, voltage window): 1M TEABF4 in acetonitrile (ACN), voltage window 0-3.0 V Key findings or remarks on capacitance: N-RGO showed high specific capacitance due to high surface area, high electrical conductivity,	Energy density value(s) reported: 91.0 Wh/kg Units of measurement: Watt-hours per kilogram (Wh/kg) Methods or materials used to achieve these values: N-RGO in 1M TEABF4/ACN electrolyte Experimental conditions (e.g., electrolyte used, voltage window): 1M TEABF4 in acetonitrile (ACN), voltage window 0-3.0 V	Power density value(s) reported: 75.0 kW/kg Units of measurement: Kilowatts per kilogram (kW/kg) Methods or materials used to achieve these values: N-RGO in 1M TEABF4/ACN electrolyte Experimental conditions (e.g., electrolyte used, voltage window): 1M TEABF4 in acetonitrile (ACN), voltage window 0-3.0 V	Efficiency value(s) reported: 96% capacitance retention after 100,000 cycles Units of measurement: Percentage (%) Methods or materials used to achieve these values: N-RGO in a two-electrode unit cell Experimental conditions (e.g., electrolyte used, voltage window): 1M TEABF4 in acetonitrile (ACN), voltage window 0-3.0 V Key findings or remarks on efficiency: The N-RGO

	and nitrogen doping, indicating very good rate capability and cycling stability.	Key findings or remarks on energy density: High energy density attributed to the extensive recovery of the p-conjugated structure and low oxygen content in N-RGO.	Key findings or remarks on power density: The high power density achieved is due to the enhanced electrical conductivity and surface area of N-RGO.	electrode demonstrated excellent cycling stability, attributed to its high surface area, high electrical conductivity, and low oxygen content.
Wang et al 2017 [67]	Specific capacitance value(s) reported: Not explicitly mentioned in the provided text. Units of measurement: NOT APPLICABLE Methods or materials used to achieve these values: Anode based on reduced graphene oxide (rGO) decorated with nanosized SnO2, Cathode based on activated thermally expanded reduced graphene oxide (a-TEGO). Experimental conditions (e.g., electrolyte used, voltage window): 1M LiPF6 in EC , potential window of 0.002 - 2 V vs. Li/Li+. Key findings or remarks on capacitance: Not explicitly mentioned in the provided text.	Energy density value(s) reported: Up to 200 Wh/kg. Units of measurement: Watt-hours per kilogram (Wh/kg) Methods or materials used to achieve these values: Full hybrid cell with SnO2-rGO as anode and a-TEGO as cathode. Experimental conditions (e.g., electrolyte used, voltage window): 1M LiPF6 in EC . Key findings or remarks on energy density: Achieved a 10-fold increase in energy density compared to EDLC counterpart.	Power density value(s) reported: 10 kW/kg Units of measurement: Kilowatts per kilogram (kW/kg) Methods or materials used to achieve these values: Full hybrid cell with SnO2-rGO as anode and a-TEGO as cathode. Experimental conditions (e.g., electrolyte used, voltage window): 1M LiPF6 in EC . Key findings or remarks on power density: Achieved double the energy in the high power region.	Efficiency value(s) reported: 70% capacity retention after 5000 cycles. Units of measurement: Percentage (%) Methods or materials used to achieve these values: Full hybrid cell with SnO2-rGO as anode and a-TEGO as cathode. Experimental conditions (e.g., electrolyte used, voltage window): 1M LiPF6 in EC . Key findings or remarks on efficiency: Demonstrated long cycle life and good capacity retention.

Ma et al 2019 [68]	Specific capacitance value(s) reported: Not clearly visible, need to extract from better quality text Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: Carbon fiber electrodes enhanced with graphene oxide Experimental conditions (e.g., electrolyte used, voltage window): Not clearly visible, need to extract from better quality text Key findings or remarks on capacitance: Not clearly visible, need to extract from better quality text	Energy density value(s) reported: Not clearly visible, need to extract from better quality text Units of measurement: Watt-hours per kilogram (Wh/kg) Methods or materials used to achieve these values: Not clearly visible, need to extract from better quality text Experimental conditions (e.g., electrolyte used, voltage window): Not clearly visible, need to extract from better quality text Key findings or remarks on energy density: Not clearly visible, need to extract from better quality text	Power density value(s) reported: Not clearly visible, need to extract from better quality text Units of measurement: Kilowatts per kilogram (kW/kg) Methods or materials used to achieve these values: Not clearly visible, need to extract from better quality text Experimental conditions (e.g., electrolyte used, voltage window): Not clearly visible, need to extract from better quality text Key findings or remarks on power density: Not clearly visible, need to extract from better quality text	Efficiency value(s) reported: Not clearly visible, need to extract from better quality text Units of measurement: Percentage (%) Methods or materials used to achieve these values: Not clearly visible, need to extract from better quality text Experimental conditions (e.g., electrolyte used, voltage window): Not clearly visible, need to extract from better quality text Key findings or remarks on efficiency: Not clearly visible, need to extract from better quality text
Sengottaiyan et al 2017 [69]	Specific capacitance value(s) reported: 487 F/g Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: Cobalt oxide (Co3O4) nanocrystals embedded in reduced graphene oxide (RGO) sheet fabricated using one-pot hydrothermal synthetic route. Experimental conditions (e.g., electrolyte used, voltage window): Aqueous KOH electrolyte (2 M), scan rate of 5 mV/s	Energy density value(s) reported: Not explicitly mentioned in the extracted text Units of measurement: NOT APPLICABLE Methods or materials used to achieve these values: NOT APPLICABLE Experimental conditions (e.g., electrolyte used,	Power density value(s) reported: Not explicitly mentioned in the extracted text Units of measurement: NOT APPLICABLE Methods or materials used to achieve these values: NOT APPLICABLE Experimental conditions (e.g., electrolyte used,	Efficiency value(s) reported: 96.6% capacitance retention after 2000 cycles Units of measurement: Percentage (%) Methods or materials used to achieve these values: Cobalt oxide (Co3O4) nanocrystals embedded in reduced graphene oxide (RGO) sheet

	Key findings or remarks on capacitance: The Co3O4/RGO composite material exhibits high specific capacitance with outstanding cyclic stability, sustaining 96.6% of capacitance after 2000 cycles.	voltage window): NOT APPLICABLE Key findings or remarks on energy density: NOT APPLICABLE	voltage window): NOT APPLICABLE Key findings or remarks on power density: NOT APPLICABLE	Experimental conditions (e.g., electrolyte used, voltage window): Aqueous KOH electrolyte (2 M) Key findings or remarks on efficiency: The composite material demonstrated excellent cyclic stability with 96.6% capacitance retention after 2000 cycles.
Zhang et al 2017 [70]	Specific capacitance value(s) reported: 576 F/g Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: Ternary composite of graphene oxide/carbon dots/polypyrrole (GO/CDs/PPy) Experimental conditions (e.g., electrolyte used, voltage window): 1 mol/L LiCl aqueous solution, current density of 0.5 A/g Key findings or remarks on capacitance: The ternary composite shows higher specific capacitance compared to binary composites due to the enhanced electron transportation and increased dielectric constant provided by carbon dots.	Energy density value(s) reported: 30.1 Wh/kg Units of measurement: Watt-hours per kilogram (Wh/kg) Methods or materials used to achieve these values: Symmetric supercapacitor fabricated with GO/CDs/PPy electrodes Experimental conditions (e.g., electrolyte used, voltage window): 1 mol/L LiCl aqueous solution Key findings or remarks on energy density: The ternary composite achieves high energy density, making it superior to many other graphene-based and polypyrrole-based materials.	Power density value(s) reported: 250 W/kg Units of measurement: Watts per kilogram (W/kg) Methods or materials used to achieve these values: Symmetric supercapacitor fabricated with GO/CDs/PPy electrodes Experimental conditions (e.g., electrolyte used, voltage window): 1 mol/L LiCl aqueous solution Key findings or remarks on power density: The ternary composite maintains high power density while preserving 79.5% of its energy density at 5000 W/kg.	Efficiency value(s) reported: 92.9% capacitance retention after 5000 cycles Units of measurement: Percentage (%) Methods or materials used to achieve these values: Symmetric supercapacitor fabricated with GO/CDs/PPy electrodes Experimental conditions (e.g., electrolyte used, voltage window): 1 mol/L LiCl aqueous solution Key findings or remarks on efficiency: The ternary composite exhibits excellent cycle stability and high coulombic efficiency, making it a promising material for long-term supercapacitor applications.

Hu et al 2018 [71]	Specific capacitance value(s) reported: 657 F/g Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: V3O7·H2O nanobelts/CNT/reduced graphene oxide composite Experimental conditions (e.g., electrolyte used, voltage window): 5 M LiCl/PVA electrolyte, current density of 1 A/g Key findings or remarks on capacitance: The ternary composite shows high specific capacitance due to the synergistic effect between pseudocapacitors and electric double-layer capacitors.	Energy density value(s) reported: 34.3 Wh/kg Units of measurement: Watt-hours per kilogram (Wh/kg) Methods or materials used to achieve these values: V3O7·H2O nanobelts/CNT/reduced graphene oxide composite Experimental conditions (e.g., electrolyte used, voltage window): 5 M LiCl/PVA electrolyte Key findings or remarks on energy density: The composite delivers high energy density, significantly higher than many other vanadium oxide-based materials.	Power density value(s) reported: 3000 W/kg Units of measurement: Watts per kilogram (W/kg) Methods or materials used to achieve these values: V3O7·H2O nanobelts/CNT/reduced graphene oxide composite Experimental conditions (e.g., electrolyte used, voltage window): 5 M LiCl/PVA electrolyte Key findings or remarks on power density: The ternary composite maintains high power density while preserving high energy density, demonstrating fast charge/discharge capability.	Efficiency value(s) reported: 99.7% capacitance retention after 10,000 cycles Units of measurement: Percentage (%) Methods or materials used to achieve these values: V3O7·H2O nanobelts/CNT/reduced graphene oxide composite Experimental conditions (e.g., electrolyte used, voltage window): 5 M LiCl/PVA electrolyte Key findings or remarks on efficiency: The composite exhibits excellent cycle stability and high coulombic efficiency, making it a promising material for long-term supercapacitor applications.
Noh, et al 2019 [72]	Specific capacitance value(s) reported: 138.4 F/g for RGO-SnO_2-NR, 78.4 F/g for RGO-SnO_2-NP, 70.0 F/g for bare RGO Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: Hydrothermal synthesis, SnO_2 nanorod bundles on reduced graphene oxide (RGO) sheets Experimental conditions (e.g., electrolyte used, voltage window): 1.0 M Na_2SO_4 electrolyte, 0.0-1.0 V vs. SCE	Energy density value(s) reported: 4.17 Wh/kg for RGO-SnO_2-NR Units of measurement: Watt-hours per kilogram (Wh/kg) Methods or materials used to achieve these values: Galvanostatic charge/discharge measurement	Power density value(s) reported: 123.0 W/kg for RGO-SnO_2-NR Units of measurement: Watts per kilogram (W/kg) Methods or materials used to achieve these values: Ragone plot analysis from galvanostatic charge/discharge measurements	Efficiency value(s) reported: Not reported Units of measurement: NOT APPLICABLE Methods or materials used to achieve these values: NOT APPLICABLE Experimental conditions (e.g., electrolyte used, voltage window): NOT APPLICABLE

	Key findings or remarks on capacitance: RGO-SnO_2-NR showed higher capacitance and rate capability compared to RGO-SnO_2-NP and bare RGO due to the effective role of SnO_2 nanorod bundles as spacers to prevent restacking and enhance ion transfer.	Experimental conditions (e.g., electrolyte used, voltage window): 1.0 M Na_2SO_4 electrolyte, 0.0-1.0 V vs. SCE Key findings or remarks on energy density: The RGO-SnO_2-NR electrode demonstrated higher energy density compared to other configurations, attributed to improved ion transfer behavior.	Experimental conditions (e.g., electrolyte used, voltage window): 1.0 M Na_2SO_4 electrolyte, 0.0-1.0 V vs. SCE Key findings or remarks on power density: RGO-SnO_2-NR exhibited high power density due to the enhanced charge storage and ion transfer facilitated by the SnO_2 nanorods.	Key findings or remarks on efficiency: The study focused on capacitance, energy density, and power density, and did not explicitly report efficiency values.
Li et al 2019 [73]	Specific capacitance value(s) reported: 6.12 F/g Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: Pencil-drawn electrodes using AgNPs/rGO composite on copy paper Experimental conditions (e.g., electrolyte used, voltage window): 1 M H_2SO_4 solution, voltage window of 0-0.8 V Key findings or remarks on capacitance: The pencil-drawn electrodes exhibited good capacitance retention and ideal capacitive behavior.	Energy density value(s) reported: 0.48 Wh/kg Units of measurement: Watt-hours per kilogram (Wh/kg) Methods or materials used to achieve these values: Symmetric supercapacitor with Li-doped chitosan/starch gel electrolyte Experimental conditions (e.g., electrolyte used, voltage window): 1 M H_2SO_4 solution Key findings or remarks on energy density: The energy density was competitive considering the simplicity	Power density value(s) reported: 371 W/kg Units of measurement: Watts per kilogram (W/kg) Methods or materials used to achieve these values: Symmetric supercapacitor with Li-doped chitosan/starch gel electrolyte Experimental conditions (e.g., electrolyte used, voltage window): 1 M H_2SO_4 solution Key findings or remarks on power density: The power density was comparable to conventional supercapacitors, demonstrating the	Efficiency value(s) reported: 99% capacitance retention after 2400 cycles Units of measurement: Percentage (%) Methods or materials used to achieve these values: Symmetric supercapacitor with Li-doped chitosan/starch gel electrolyte Experimental conditions (e.g., electrolyte used, voltage window): 1 M H_2SO_4 solution Key findings or remarks on efficiency: The device exhibited excellent cycling stability and high coulombic efficiency, making it suitable for flexible and foldable electronic devices.

		and biodegradability of the materials used.	effectiveness of the pencil-drawn electrodes.	
Bagher et al 2020 [74]	Specific capacitance value(s) reported: 436.7 F/g for IFG, 262.5 F/g for RGO Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: Reduced graphene oxide (RGO) and ionic liquid-functionalized graphene (IFG) Experimental conditions (e.g., electrolyte used, voltage window): 1 M H_2SO_4 electrolyte, potential window of 0.0 to 1.0 V vs. SCE Key findings or remarks on capacitance: IFG showed higher specific capacitance due to its novel three-dimensional (3D) structure, which increases the accessible surface area and enhances ion transfer.	Energy density value(s) reported: Not reported in the extracted text Units of measurement: NOT APPLICABLE Methods or materials used to achieve these values: NOT APPLICABLE Experimental conditions (e.g., electrolyte used, voltage window): NOT APPLICABLE Key findings or remarks on energy density: NOT APPLICABLE	Power density value(s) reported: Not reported in the extracted text Units of measurement: NOT APPLICABLE Methods or materials used to achieve these values: NOT APPLICABLE Experimental conditions (e.g., electrolyte used, voltage window): NOT APPLICABLE Key findings or remarks on power density: NOT APPLICABLE	Efficiency value(s) reported: Not reported in the extracted text Units of measurement: NOT APPLICABLE Methods or materials used to achieve these values: NOT APPLICABLE Experimental conditions (e.g., electrolyte used, voltage window): NOT APPLICABLE Key findings or remarks on efficiency: The study focused more on capacitance and structural characteristics and did not explicitly report efficiency values.

Kil et al 2020 [75]	Specific capacitance value(s) reported: Not explicitly mentioned for a single electrode. Units of measurement: F/g Methods or materials used to achieve these values: Nanosized SnO_2 decorated reduced graphene oxide as the negative electrode, activated thermally expanded reduced graphene oxide as the positive electrode. Experimental conditions (e.g., electrolyte used, voltage window): 1 M $LiPF_6$ in EC and 1.5 M Et_4NBF_4/ACN electrolytes, voltage window not specified. Key findings or remarks on capacitance: The LIC system showed high specific energy density and power density, highlighting the material's performance advantages.	Energy density value(s) reported: 186 Wh/kg at 142 W/kg, 100 Wh/kg at 10 kW/kg. Units of measurement: Wh/kg Methods or materials used to achieve these values: Hybrid supercapacitor with graphene-based electrodes. Experimental conditions (e.g., electrolyte used, voltage window): 1 M $LiPF_6$ in EC and 1.5 M Et_4NBF_4/ACN electrolytes. Key findings or remarks on energy density: The energy density of 186 Wh/kg is among the best reported for hybrid supercapacitors, and the system shows a 10-fold increase in stored energy density compared to EDLCs.	Power density value(s) reported: 10 kW/kg Units of measurement: kW/kg Methods or materials used to achieve these values: Hybrid supercapacitor with graphene-based electrodes. Experimental conditions (e.g., electrolyte used, voltage window): 1 M $LiPF_6$ in EC and 1.5 M Et_4NBF_4/ACN electrolytes. Key findings or remarks on power density: The LIC system surpassed the challenging 10 kW/kg barrier, indicating greatly improved high power capabilities over its EDLC counterpart.	Efficiency value(s) reported: 70% capacity retention after 5000 cycles Units of measurement: Percentage (%) Methods or materials used to achieve these values: Hybrid supercapacitor with graphene-based electrodes. Experimental conditions (e.g., electrolyte used, voltage window): 1 M $LiPF_6$ in EC and 1.5 M Et_4NBF_4/ACN electrolytes. Key findings or remarks on efficiency: High efficiency and stability demonstrated with 70% capacity retention after 5000 cycles, making it suitable for real applications.

Maphiri, et al 2021 [76]	Specific capacitance value(s) reported: The highest areal capacitance of 0.5421 mF/cm² at 10 mV/s for TRGO-200. Units of measurement: mF/cm² Methods or materials used to achieve these values: Thermally reduced graphene oxide films prepared using atmospheric pressure chemical vapor deposition (AP-CVD) and a mask-free AxiDraw sketching apparatus. Experimental conditions (e.g., electrolyte used, voltage window): Cyclic voltammetry (CV) potential window of 0–0.8 V at various scan rates (5–1000 mV/s), and the use of PVA-H_3PO_4 gel electrolyte. Key findings or remarks on capacitance: TRGO-500 showed a better retention and shape of capacitance; the areal capacitance improved significantly as the number of digits per unit area increased up to 14 cm².	Energy density value(s) reported: Volumetric energy density of 14.61 mWh/cm³ for TRGO-500. Units of measurement: mWh/cm³ Methods or materials used to achieve these values: Thermally reduced graphene oxide films prepared using AP-CVD and a mask-free AxiDraw sketching apparatus. Experimental conditions (e.g., electrolyte used, voltage window): Volumetric energy density was measured at a current density of 0.0083 μA/cm². Key findings or remarks on energy density: The TRGO-500 showed comparable energy densities to other advanced microsupercapacitors prepared using more complex and sophisticated methods.	Power density value(s) reported: Volumetric power density of 142.67 mW/cm³ for TRGO-500. Units of measurement: mW/cm³ Methods or materials used to achieve these values: Thermally reduced graphene oxide films prepared using AP-CVD and a mask-free AxiDraw sketching apparatus. Experimental conditions (e.g., electrolyte used, voltage window): Measured at a current density of 1.66 μA/cm². Key findings or remarks on power density: The TRGO-500 demonstrated excellent power density, maintaining good capacitive behavior at minimal internal resistance even at higher current densities.	Efficiency value(s) reported: Capacitance retention and coulombic efficiency of 95% and 100%, respectively, at a current density of 0.83 μA/cm² for 4000 cycles. Units of measurement: Percentage (%) Methods or materials used to achieve these values: Thermally reduced graphene oxide films prepared using AP-CVD and a mask-free AxiDraw sketching apparatus. Experimental conditions (e.g., electrolyte used, voltage window): Efficiency measurements were conducted over multiple charge-discharge cycles. Key findings or remarks on efficiency: The TRGO-500 microsupercapacitors exhibited excellent long-term stability and efficiency, with minimal loss in performance over 4000 cycles.

Lun Wu et al 2021 [77]	Specific capacitance value(s) reported: 375 F/g Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: rGO/CoSx-rGO/rGO hybrid film Experimental conditions (e.g., electrolyte used, voltage window): Aqueous electrolyte, 0-1 V Key findings or remarks on capacitance: The hybrid film showed a high specific capacitance of 375 F/g, which is attributed to the synergistic effect of the composite materials.	Energy density value(s) reported: 31.68 Wh/kg Units of measurement: Watt-hours per kilogram (Wh/kg) Methods or materials used to achieve these values: rGO/CoSx-rGO/rGO hybrid film Experimental conditions (e.g., electrolyte used, voltage window): Not specified Key findings or remarks on energy density: The energy density reached 31.68 Wh/kg, showcasing the potential of the hybrid film for high-energy applications.	Power density value(s) reported: 6750 W/kg Units of measurement: Watts per kilogram (W/kg) Methods or materials used to achieve these values: rGO/CoSx-rGO/rGO hybrid film Experimental conditions (e.g., electrolyte used, voltage window): Not specified Key findings or remarks on power density: The hybrid film achieved a power density of 6750 W/kg, indicating excellent performance in power applications.	Efficiency value(s) reported: 96.6% Units of measurement: Percentage (%) Methods or materials used to achieve these values: rGO/CoSx-rGO/rGO hybrid film Experimental conditions (e.g., electrolyte used, voltage window): Not specified Key findings or remarks on efficiency: The film showed high efficiency and stability with a retention of 96.6% after 2000 cycles.
Zhao et al 2021 [78]	Specific capacitance value(s) reported: 222 F/g at 0.5 A/g, 65 F/g at 10 A/g Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: Nanocarved VN nanowires encapsulated in N-doped reduced graphene oxide layers (VNNWs@rGO) Experimental conditions (e.g., electrolyte used, voltage window): 1 M KOH, potential window of -0.9 to 0.1 V Key findings or remarks on capacitance: The improved electrochemical performance is associated with the unique structural design,	Energy density value(s) reported: Not specified Units of measurement: NOT APPLICABLE Methods or materials used to achieve these values: NOT APPLICABLE Experimental conditions (e.g., electrolyte used, voltage window): NOT APPLICABLE	Power density value(s) reported: Not specified Units of measurement: NOT APPLICABLE Methods or materials used to achieve these values: NOT APPLICABLE Experimental conditions (e.g., electrolyte used, voltage window): NOT APPLICABLE	Efficiency value(s) reported: Not specified Units of measurement: NOT APPLICABLE Methods or materials used to achieve these values: NOT APPLICABLE Experimental conditions (e.g., electrolyte used, voltage window): NOT APPLICABLE Key findings or remarks on efficiency: NOT APPLICABLE

	enhanced electric conductivity, and chemical stability.	Key findings or remarks on energy density: NOT APPLICABLE	Key findings or remarks on power density: NOT APPLICABLE	
Qiu et al 2015 [79]	Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: Spray drying of graphene oxide followed by thermal reduction Experimental conditions (e.g., electrolyte used, voltage window): Voltage scan rates in the range of 0.02 to 0.5 V/s; cyclic voltammetry (CV) measurement Key findings or remarks on capacitance: The r-GO microparticles exhibited specific capacitance values comparable to those of nano-sized activated carbon, attributed to the corrugated surface morphology of r-GO microparticles.	Energy density value(s) reported: 3.52 Wh/kg (highest) Units of measurement: Watt-hours per kilogram (Wh/kg) Methods or materials used to achieve these values: r-GO electrodes in full-cell experimental EDLCs Experimental conditions (e.g., electrolyte used, voltage window): Galvanostatic charge/discharge measurement from 0 V to 0.6 V window Key findings or remarks on energy density: The energy density was achieved at a power density of 0.09 kW/kg.	Power density value(s) reported: 0.44 kW/kg (highest) Units of measurement: Kilowatts per kilogram (kW/kg) Methods or materials used to achieve these values: r-GO electrodes in full-cell experimental EDLCs Experimental conditions (e.g., electrolyte used, voltage window): Galvanostatic charge/discharge measurement from 0 V to 0.6 V window Key findings or remarks on power density: The highest power density was obtained at an energy density of 2.26 Wh/kg.	Efficiency value(s) reported: Not reported Units of measurement: NOT APPLICABLE Methods or materials used to achieve these values: NOT APPLICABLE Experimental conditions (e.g., electrolyte used, voltage window): NOT APPLICABLE Key findings or remarks on efficiency: NOT APPLICABLE

Ngamjumrus, et al 2023 [80]	Specific capacitance value(s) reported: 545.78 F/g (highest), 65.585 F/g (coin cell) Units of measurement: Farads per gram (F/g) Methods or materials used to achieve these values: rGO/AC–HDC–3D15M sample Experimental conditions (e.g., electrolyte used, voltage window): 3M KOH electrolyte, potential window between -1.0 V and 0.0 V, current density from 0.5 A/g to 30 A/g Key findings or remarks on capacitance: rGO/AC–HDC–3D15M electrode displayed high specific capacitance and good performance for charge carriers in EDLCs.	Energy density value(s) reported: 60.834 Wh/kg (highest), 5.123 Wh/kg (coin cell) Units of measurement: Watt-hours per kilogram (Wh/kg) Methods or materials used to achieve these values: rGO/AC–HDC–3D15M sample Experimental conditions (e.g., electrolyte used, voltage window): 3M KOH electrolyte, potential window between -1.0 V and 0.0 V Key findings or remarks on energy density: Enhanced electrochemical performance for the fabrication of an EDLC supercapacitor device.	Power density value(s) reported: 260.834 W/kg (highest), 47.286 W/kg (coin cell) Units of measurement: Watts per kilogram (W/kg) Methods or materials used to achieve these values: rGO/AC–HDC–3D15M sample Experimental conditions (e.g., electrolyte used, voltage window): 3M KOH electrolyte, potential window between -1.0 V and 0.0 V Key findings or remarks on power density: rGO/AC–HDC–3D15M electrode displayed high power density and fast ionic and electronic migration during charging and discharging.	Efficiency value(s) reported: Not specified Units of measurement: Not applicable Methods or materials used to achieve these values: Not specified Experimental conditions (e.g., electrolyte used, voltage window): Not specified Key findings or remarks on efficiency: Not specified
Qu et al 2023 [81]	Specific capacitance value(s) reported: ~458 mAh/g at 1 A/g Units of measurement: mAh/g Methods or materials used to achieve these values: Reduced graphene oxide-decorated Cu0.33Co0.67Se2 nanorods on Ni foam integrated with N, S co-doped porous carbon Experimental conditions (e.g., electrolyte used, voltage window): PVA/KOH as the electrolyte	Energy density value(s) reported: ~41.5 Wh/kg Units of measurement: Wh/kg Methods or materials used to achieve these values: Cu0.33Co0.67Se2/rGO composite Experimental conditions (e.g., electrolyte used,	Power density value(s) reported: ~801.5 W/kg Units of measurement: W/kg Methods or materials used to achieve these values: Cu0.33Co0.67Se2/rGO composite Experimental conditions (e.g., electrolyte used,	Efficiency value(s) reported: Not specified Units of measurement: NOT APPLICABLE Methods or materials used to achieve these values: NOT APPLICABLE Experimental conditions (e.g., electrolyte used, voltage window): NOT APPLICABLE

	Key findings or remarks on capacitance: The composite electrode displayed high specific capacity due to the optimized structure and synergistic effects of the materials used.	voltage window): PVA/KOH electrolyte, voltage window of ~1.6 V Key findings or remarks on energy density: The assembled hybrid supercapacitor exhibited a high energy density due to the combined electric double-layer capacitive and pseudocapacitive behavior.	voltage window): PVA/KOH electrolyte, voltage window of ~1.6 V Key findings or remarks on power density: The hybrid supercapacitor exhibited a high power density, reflecting its ability for fast energy delivery and storage .	Key findings or remarks on efficiency: NOT APPLICABLE