IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 2, September 2023

Exploring the Potential of Cobalt-Based Metal Hydroxide Electrodes in Supercapacitor Technology

Sumeet[1] and Dr. Vipin Kumar[2]
Research Scholar, Department of Physics[1]
Associate Professor, Department of Physics[2]
OPJS University Churu, Rajasthan, India

Abstract: *Supercapacitors will be the most advanced, efficient energy storage technologies. It yields high specific capacitances and energy. This study illuminates supercapacitors' materials and usage by comparing their pros and cons to battery technology. Transition metal hydroxides like cobalt hydroxides have been studied for supercapacitor electrodes and energy conversion devices. Supercapacitors may use cobalt-based metal hydroxides and oxides for high-capacitance electrodes. Metal hydroxides are stable and carry electricity well. Supercapacitors employ cobalt-based metal oxides and hydroxides for electrodes. It conducts electricity well and is stronger than other oxides. Supercapacitors use cobalt hydroxides instead of nickel, copper, and aluminum. This study details the electrochemical deposition preparation, synthesis, analysis, and characterization of cobalt hydroxide thin film electrodes, as well as parameter measurements, significant features, material properties, a variety of applications, and potential supercapacitor advancements.*

Keywords: Supercapacitors

I. INTRODUCTION

Civilization may benefit from supercapacitors. Electrodes may be cobalt hydroxide. It is ideal because to its high specific capacitance, strong electrical conductivity, and pH stability. High energy density makes cobalt hydroxide supercapacitor. Cycling stability allows many charges/discharges. Expensive cobalt hydroxide supercapacitor electrodes. Research enhances cobalt hydroxide supercapacitors' stability and performance. Many devices make and test cathodic cobalt hydroxide nanoflakes. Nanoflake research uses XRD, FTIR, FE-SEM, SEM, GCD, ESD, EIP. CV and EIP measure electrode voltage-current [1]. Thin Co(OH)2 films were galvanostatically deposited on SS [2]. Alkaline cobalt hydroxide SS coating with oxygen evolution catalyst [3]. Natural porosity in homogeneous α-Co(OH)2 thin films was created and evaluated via silver deposition. High-impedance studies indicated pseudocapacitance uniformity and porousness [4].

Metal printed with a thin cobalt (Co) layer has unique patterns. SEM produced circular, vertical, and horizontal patterns [5]. High-performance electrochemical energy storage uses thin cobalt-doped nickel phosphate sheets [6, 7]. Nanoparticle foam nickel-transition metal oxide. The 230 F/g electrode specific capacitance makes it supercapacitor-like and physically robust after repeated charging cycles. Current density = 0.2 A/g [8]. MOF-Co(OH)2 electrochemical ultracapacitors store charge [9, 10]. Research found MOF/Co(OH)2-based supercapacitors more potent than carbon [11]. Graphite, aluminum, and cobalt nitrate help. Very pure 99.99% cobalt nitrate. Almost pure aluminum nitrate (Al(NO3)) boosts capacitance. The quick discharge of graphite electrodes makes them catalysts [12]. Alpha nanosheet EDX demonstrated Co3+ tetrahedral coordination in pure Co(OH)2 [13]. 2.4 times pure Co(OH), alpha-LTS has 7.1% local structural order and extensibility.Over five cycles, the Co(OH)2 electrode (27 F/g at 0.5 A/g) had fourfold higher room-temperature capacitances than commercial activated carbon anodes (7 F/g) with a charge/discharge cutoff of 3 EG reduced zinc and cobalt picolinate for ZCS disc microspheres [15]. Electrochemical mesoporous sheets may generate solid acid catalysts [16]. Industrialization, urbanization, and population increase deplete electrode materials and energy storage devices. Co-Co(OH)2 surfaces appear on spray-on Cu electrodes [17]. Its specific capacitance rose

ISSN 2581-9429 IJARSCT

from 127 to 544 F/g. Energy-storage devices [18]. For investigation, scientists made Co(OH)2 films. It dissolves massive H2 and may make petrol tanks [19]. Metal oxide cobalt hydroxide is mainly oxygen and cobalt [20, 21]. Transition metal oxide 2D materials are prominent in energy and storage applications like supercapacitors and may satisfy future performance expectations [22]. Glassy carbon electrode (GCE) substrate with cobalt metal hydroxide [23]. Electrochemical capacitors store energy securely, cheaply, efficiently, and sustainably like solar, wind, and hybrid batteries [24]. High-power Li-ion backup cathodes are Co(OH)2 [25]. New energy storage employs transition metal cobalt oxides and hydroxides [26, 27]. In situ carbon microsphere/MnO2 nanosheet electrochemistry [28]. Inversion of carbon polyacrylonitrile (PAN) developed hierarchical porous carbon membranes [29]. We synthesized Mo2N and Mo2N@PANI in situ [31]. Electrodeposited vanadium nitride nanoparticles on graphene [30]. 1D and 2D networks control cobalt oxide conductivity [32–34]. The 1980s witnessed fast electronic advancements, enhancing energy storage [35, 36]. Supercapacitors have high theoretical capacitance and chemical stability [37]. Millions of theoretical and simulated capacitance measurements [38–40]. Theory maximum capacitance is 60%. Supercapacitors provide large, powerful, and long-lasting capacitances [41–43].

Increase supercapacitors' lifespan beyond 100,000 cycles. Energy density matches batteries [44–47]. Co3O4-based compounds increase LIB capacity, positive electrode safety, and environmental compatibility [48–50].

Inspiration. Fast charge and discharge times make supercapacitors excellent for high-power density applications. Their longevity and charging/discharging capabilities make them suitable for sustainable energy storage. Exploration is underway for cobalt oxide and hydroxide supercapacitor electrodes. Supercapacitors need cobalt hydroxide electrodes. Sustainable supercapacitors need cobalt hydroxide electrodes. Research cobalt hydroxide supercapacitor electrodes. Goal. Before electrochemical deposition, supercapacitors and cobalt metal-based hydroxide electrodes will be evaluated. Research supercapacitors and cobalt hydroxide. Finally, cobalt complicated facts. Research focuses on supercapacitor cobalt hydroxide performance, characterization, and categorization. Compare supercapacitors to batteries and capacitors.

II. FUTURE SCOPE OF SUPERCAPACITORS

Ultra-capacitors, or supercapacitors, might revolutionize electrical energy storage and utilization, making them of great interest in research and commercialization. Supercapacitors have several uses and may become more essential in energy storage. Overcapacitors are predicted in power grids, portable power systems, and consumer electronics. Research and development may make supercapacitors more essential in electrical energy generation, storage, and consumption.

Supercapacitors may have high power densities, specific capacitances, quick recharge times, and extended cycle lives. Metal hydroxide super- or pseudocapacitors have been intensively explored in recent decades. High specific capacitances and energy densities are sought for energy storage. Supercapacitors are in many products after years of research. SCs are desired for their performance, economy, environmental friendliness, and ease of maintenance. Portable electronics, electric cars, and other uses need pseudocapacitance energy storage. Introduction to pseudocapacitance's chemical and physical features. Cobalt hydroxide compounds are being explored as pseudocapacitive materials, despite metal oxides and zeolites being more frequent.

III. CONCLUSION

This review covers current cobalt hydroxide supercapacitors. Due to its properties, cobalt hydroxide electrodes are attractive for supercapacitors, also known as ultracapacitors. High specific capacitance stores a lot of electrical charge in a small amount of material, and its electrical conductivity and stability throughout a wide pH range are good. Costlier than other materials, cobalt hydroxide needs more R&D to improve performance and stability.

For contemporary supercapacitor materials, it is new. This growing area includes catalysis research and electrocatalytic deposition. They also briefly covered electrocapacitive materials, properties, and uses. This research analyzes energy storage device principles, techniques, preparation, and qualities. The specific capacitance of cobalt-based metal hydroxide supercapacitors supports their application. Supercapacitors swiftly store and deliver power. Energy storage using super-capacitors is possible and eco-friendly.

IV. ACKNOWLEDGMENTS

The authors appreciate and recognize the LVH Research Centre at MGV, ASCC Panchavati, Nashik (Maha-rashtra), which is affiliated with Savitribai Phule Pune University (Pune), India.

REFERENCES

[1]. N. C. Maile, R. T. Patil, S. K. Shinde et al., “Facial growth of Co(OH)2 nanoflakes on stainless steel for supercapacitors: efect of deposition potential,” Journal of Materials Science: Materials in Electronics, 2019.

[2]. Barauskiene˙ and E. Valatka, “Synthesis, structure and capacitive properties of cobalt hydroxide films on stainless steel substrates,” Open Chemistry, vol. 12, no. 11, pp. 1206– 1211, 2014.

[3]. M. Dinamani and P. V. Kamath, “Electrocatalysis of oxygen evolution at stainless steel anodes by electro-synthesized cobalt hydroxide coatings,” Journal of Applied Electro- chemistry, vol. 30, no. 10, pp. 1157–1161, 2000.

[4]. F. Shaikh, T. D. Dongale, and R. K. Kamat, “Facile method for synthesis ofα-Co(OH)2and their supercapacitor prop- erties,” MicroElectronics International, vol. 35, no. 4, pp. 220–230, 2018.

[5]. M. S. M. Gadwal, S. D. Sartale, V. L. Mathe, and H. M. Pathan, “Substrate assisted electrochemical deposition of patterned cobalt thin films,” Electrochemistry Commu- nications, vol. 11, no. 8, pp. 1711–1713, 2009.

[6]. H. Li, Y. Gao, C. Wang, and G. Yang, “Advanced energy materials,” A Simple Electrochemical Route to Access Amorphous Mixed-Metal Hydroxides for Supercapacitor Electrode Materials, 2014.

[7]. B. Li, Y. Shi, K. Huang et al., “Cobalt-doped nickel phosphite for high performance of electrochemical energy storage,” Small, vol. 14, no. 13, Article ID 1703811, 2018.

[8]. R. R. Salunkhe, B. P. Bastakoti, C.-T. Hsu et al., “Direct growth of cobalt hydroxide rods on nickel foam and its application for energy storage,” Chemistry - A European Journal, vol. 20, no. 11, pp. 3084–3088, 2014.

[9]. B. K. Kim, S. Y. Serubbable, A. Yu, and J. Zhang, “Elec- trochemical Supercapacitors for Energy Storage and Con- version, Handbook of Clean Energy Systems,” John Wiley & Sons, 2015.

[10]. P. Vialat, C. Mousty, C. Taviot-Gueho et al., “High- performing monometallic cobalt layered double hydroxide supercapacitor with defined local structure,” Advanced Functional Materials, vol. 24, no. 30, pp. 4831–4842, 2014.

[11]. T. Deng, Y. Lu, W. Zhang et al., “Inverted design for high- performance supercapacitor via Co(OH)2-Derived highly oriented MOF electrodes,” Advanced Energy Materials, vol. 8, no. 7, Article ID 1702294, 2017.

[12]. Y. H. Chen, Z. Hu, Y. Chang et al., “Layered Al-substituted cobalt hydroxides/GO composites for electrode materials of supercapacitors,” Chinese Journal of Chemistry, vol. 29, no. 11, pp. 2257–2262, 2011.

[13]. S. Zhang and N. Pan, “Supercapacitors performance eval- uation,” Advanced Energy Materials, vol. 5, no. 6, Article ID 1401401, 2015.

[14]. Z. Gao, W. Yang, Y. Yan et al., “Synthesis and exfoliation of layered α-Co(OH)2 nanosheets and their electrochemical performance for supercapacitors,” European Journal of In- organic Chemistry, vol. 2013, no. 27, pp. 4832–4838, 2013.

[15]. X. Gao, Q. Chang, J. Hong, D. Long, G. Jin, and X. Xiao, “Zinc cobalt sulfide microspheres as a high-performance electrode material for supercapacitors,” ChemistrySelect, vol. 3, no. 48, pp. 13751–13758, 2018.

[16]. W.-J. Zhou, J. Zhang, X. Tong, D.-D. Zhao, and H.-L. Li, “Electrodeposition of ordered mesoporous cobalt hydroxide film from lyotropic liquid crystal media for electrochemical capacitors,” Journal of Materials Chemistry, RSC, 2008.

[17]. A. Yavuz, M. Yakup Hacıibrahimog˘lu, and M. Bedir, “Synthesis and characterisation of Co–Co(OH)2 composite anode material on Cu current collector for energy storage devices,” Materials Research Express, vol. 4, Article ID 045502, 2017.

[18]. W.-J. Zhou, M.-W. Xu, D.-D. Zhao, C.-L. Xu, and H. L. Li, "Electrodeposition and characterization of ordered meso- porous cobalt hydroxide films on diferent substrates for supercapacitors," Microporous and Mesoporous Materials, vol. 117, no. 1-2, pp. 55–60, 2009.

[19]. T. Deng, W. Zhang, O. Arcelus et al., "Atomic-level energy storage mechanism of cobalt hydroxide electrode for pseu- docapacitors," Nature Communications, vol. 8, no. 1, Article ID 15194, 2017.

[20]. S. Rovetta, M. P. Browne, A. Harvey, I. J. Godwin, J. N. Coleman, and M. E. G. Lyons, "Cobalt hydroxide nanoflakes and their application as supercapacitors and oxygen evolution catalysts," Nanotechnology, vol. 28, no. 37, Article ID 375401, 2017.

[21]. M. Aghazadeh, I. Karimzadeh, A. Ahmadi, and M. R. Ganjali, "Electrochemical grown cobalt hydroxide three-dimensional nanostructures on Ni foam as high performance super- capacitor electrode material," Journal of Materials Science: Materials in Electronics, vol. 29, no. 17, pp. 14567–14573, 2018.

[22]. Y. Fan, L. Fan, S. Meng, Y. Guo, and Y. Liu, "Preparation of cobalt hydroxide film modified electrode and its analytical application," Journal of Analytical Chemistry, vol. 67, no. 4, pp. 370–377, 2012.

[23]. Y. Yang, T. Yuan, P. Zhu et al., "Cobalt hydroxide-based compressible electrode material for asymmetrical all-solid supercapacitor," Railway System Controls, 2013.

[24]. D. T. Dam, X. Wang, and J. M. Lee, "Fabrication of a mesoporous Co(OH)2/ITO nanowire composite electrode and its application in supercapacitors," RSC Advances, vol. 2, no. 28, pp. 10512–10518, 2012.

[25]. Gulino, P. Dapporto, P. Rossi, and I. Fragala, "A novel self-generating liquid MOCVD precursor for Co3O4 thin films," Chemistry of Materials, vol. 15, no. 20, pp. 3748–3752, 2003.

[26]. J. S. Choi and C. H. Yo, "Nonstoichiometric compositions of cobaltous oxide," Inorganic Chemistry, vol. 13, no. 7, pp. 1720–1724, 1974.

[27]. X. Zhang, F. Ran, H. Fan et al., "A dandelion-like carbon microsphere/MnO2 nanosheets composite for super- capacitors," Journal of Energy Chemistry, vol. 23, no. 1, pp. 82–90, 2014.

[28]. H. Fan, "A hierarchical porous carbon membrane from polyacrylonitrile/polyvinylpyrrolidone blending mem- branes: preparation, characterization and electrochemical capacitive performance," Journal of Energy Chemistry, vol. 23, no. 6, pp. 684–693, 2014.

[29]. T. He, Z. Wang, X. Li et al., "Intercalation structure of va- nadium nitride nanoparticles growing on graphene surface toward high negative active material for supercapacitor utilization," Journal of Alloys and Compounds, vol. 781, pp. 1054–1058, 2019.

[30]. T. He, W. Zhang, P. Manasa, and F. Ran, "Quantum dots of molybdenum nitride embedded in continuously distributed polyaniline as novel electrode material for supercapacitor," Journal of Alloys and Compounds, vol. 812, Article ID 152138, 2020.

[31]. X. Wang, W. Tian, T. Zhai, C. Zhi, Y. Bando, and D. Golberg, "Cobalt(II, III) oxide hollow structures: fabrication, prop- erties, and applications," Journal of Materials Chemistry, vol. 22, no. 44, pp. 23310–23326, 2012.

[32]. W. L. Smith and A. D. Hobson, "The structure of cobalt oxide, Co3O4," Acta Crystallographica Section B Structural Crystallography and Crystal Chemistry, vol. 29, no. 2, pp. 362-363, 1973.

[33]. Q. He and E. J. Cairns, "Review—recent progress in elec- trocatalysts for oxygen reduction suitable for alkaline anion exchange membrane fuel cells," Journal of the Electro- chemical Society, vol. 162, no. 14, pp. F1504–F1539, 2015.

[34]. J. Lee, B. Jeong, and J. D. Ocon, "Oxygen electrocatalysis in chemical energy conversion and storage technologies," Current Applied Physics, vol. 13, no. 2, pp. 309–321, 2013.

[35]. C. R. Raj, A. Samanta, S. H. Noh, S. Mondal, T. Okajima, and T. Ohsaka, "Emerging new generation electrocatalysts for the oxygen reduction reaction," Journal of Materials Chemistry, vol. 4, no. 29, pp. 11156–11178, 2016.

[36]. M. Tahir, L. Pan, F. Idrees, X. Zhang, L. Wang, and J. J. Zou, "Oxygen evolution reaction for energy conversion and storage: a comprehensive review," Nano Energy, vol. 37, pp. 136–157, 2017.

[37]. Y. Jiao, Y. Zheng, M. Jaroniec, and S. Z. Qiao, "Design of electrocatalysts for oxygen and hydrogen-involving energy conversion reactions," Chemical Society Reviews, vol. 44, no. 8, pp. 2060–2086, 2015.

[38]. N.-T. Suen, S.-F. Hung, Q. Quan, N. Zhang, Y.-J. Xu, and H. M. Chen, "Electrocatalysis for the oxygen evolution re- action: recent development and future perspectives," Chemical Society Reviews, vol. 46, no. 2, pp. 337–365, 2017.

[39]. T. Reier, H. N. Nong, D. Teschner, R. Schlo¨gl, and P. Strasser, "Electrocatalytic oxygen evolution reaction in acidic envi- ronments – reaction mechanisms and catalysts," Advanced Energy Materials, vol. 7, no. 1, Article ID 1601275, 2017.

[40]. L. Lin, J. Liu, T. Liu et al., "Growth-controlled NiCo2S4 nanosheet arrays with self-decorated nanoneedles for high- performance pseudocapacitors," Journal of Materials Chemistry, vol. 3, no. 34, pp. 17652–17658, 2015.

[41]. Y. P. Zhu, C. Guo, Y. Zheng, and S.-Z. Qiao, "Surface and interface engineering of noble-metal-free electrocatalysts for efficient energy conversion processes," Accounts of Chemical Research, vol. 50, no. 4, pp. 915–923, 2017.

[42]. L. Zhang, J. Xiao, H. Wang, and M. Shao, "Carbon-based electrocatalysts for hydrogen and oxygen evolution re- actions," ACS Catalysis, vol. 7, no. 11, pp. 7855–7865, 2017.

[43]. M. Shao, Q. Chang, J. P. Dodelet, and R. Chenitz, "Recent advances in electrocatalysts for oxygen reduction reaction," Chemistry Review, vol. 116, no. 6, pp. 3594–3657, 2016.

[44]. G. Wu and P. Zelenay, "Nanostructured nonprecious metal catalysts for oxygen reduction reaction," Accounts of Chemical Research, vol. 46, no. 8, pp. 1878–1889, 2013.

[45]. C. Zhu and S. Dong, "Recent progress in graphene-based nanomaterials as advanced electrocatalysts towards oxygen reduction reaction," Nanoscale, vol. 5, pp. 1753–1767, 2013.

[46]. P. Poizot, S. Laruelle, S. Grugeon, L. DuPont, and J.-M. Tarascon, "Nanosized transition-metal oxides as negative-electrode materials for lithium-ion batteries," Na- ture, vol. 407, no. 6803, pp. 496–499, 2000.

[47]. D. Larcher, G. Sudant, J. Leriche, Y. Chabre, and J. Tarascon, "The electrochemical reduction of Co3O4 in a lithium cell," J Electrochem Soc, vol. 149, pp. A234–A241, 2002.

[48]. R. B. Rakhi, W. Chen, D. Cha, and H. N. Alshareef, "Substrate-dependent self-organization of mesoporous co- balt oxide nanowires with remarkable pseudocapacitance," Nano Letters, vol. 12, no. 5, pp. 2559–2567, 2012.

[49]. Z.-L. Wang, D. Xu, J.-J. Xu, and X.-B. Zhang, "Oxygen electrocatalysts in metal-air batteries: from aqueous to non- aqueous electrolytes," Chemical Society Reviews, vol. 43, no. 22, pp. 7746–7786, 2014.

[50]. H. J. Qiu, L. Liu, Y. P. Mu, H. J. Zhang, and Y. Wang, "Designed synthesis of cobalt-oxide-based nanomaterials for superior electrochemical energy storage devices," Nano Research, vol. 8, no. 2, pp. 321–339, 2015.