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Synthesis and Characterisation of Nano-Cobalt Carbonate: A Potential Catalyst for Waste Management

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Abstract

Every now and then, novel strategies have evolved to tackle the issues of plastic waste, incorporating incineration, landfill disposal, mechanical recycling, housing construction with plastic bottles, and feedstock recycling. With regards to developing ecological concerns and reducing petroleum product preserves, theinvestigation of maintainable energy sources is the principle. It has been surveyed and analyzed that the scope ofenergy recovery processes pointed toward transforming waste plastics into feasible fuel choices. Various studies have indicated utilization of catalysts enhances the yield of the by-product in an energy-efficient way. This catalytic process could be further enhanced by increasing the efficiency of the catalyst. Thus, for themanagement process of non-biodegradable waste into various types of by-products, we have synthesized aNano-metal carbonatecatalyst. Nano-cobalt carbonate was synthesized using a hydrothermal process. The $CoCO_3$nanoparticles were characterized using the FTIR, XRD, and SEM analysis which confirmed the development of the nanoparticles with high yield, having high crystallinity and regular spherical geometry.This exploration addresses a spearheading work to tackle the plastic waste emergency whilecreating significant side effects through reactant pyrolysis utilizing Nano-metal carbonate impetuses.

Keyword: Nano-metal carbonate, Catalyst, Hydrothermal Synthesis, FTIR analysis

1. Introduction

Non-biodegradablepolymeric waste pyrolysis for energy recovery researches the usage of pyrolysisas a strategy for changing non-biodegradable polymeric waste into energy investments. Theresearcher addresses the developing worry of plastic waste removal and its ecological effect. Theydig into the capability of pyrolysis, a warm disintegration process, to separate complex polymersinto important items like gases, and fluids[1]. The previous research features the emerging worldwideplastic waste emergency and emphasizes the sincerity of fostering economic waste administrationsystems. The researchers highlight the difficulties related to traditional plastic removal techniquesand the requirement for inventive methodologies like pyrolysis to moderate the natural mischiefbrought about by plastic gathering[2,3].

Catalysts playan important role in enhancing reaction rates and the yields of the products.Catalysts work with the investigation of waste particles into less complexhydrocarbons, which can then be refined into energizers[4]. This tends to the waste removal issue aswell as adds to energy creation and reduces the petroleum products. Catalysts utilized in waste-to-fuelconversion can differ, including zeolites, metal oxides, and mixed metal catalysts[5]. The decision ofcatalysts relies upon factors like the arrangement of the waste feedstock and the ideal finishedresults. The catalysts speeds up the reaction as well as impact the item conveyance, working onthe yield of important energizes. One of the huge benefits of catalytic conversion is using variouswaste materials as potential. Strong waste, plastic waste, agricultural deposits, and even sewagemud can be changed into valuable energy. This decreases the weight oflandfills offers a reasonable solution for the energy demand[6]. Many catalyst have been used like ZSM-5 zeolite[5], clinoptilolite[7], silica-alumina[8], MCM-41 [9] etc. The use of catalystsassumes an essential part in speeding up the synthetic responses expected for a waste change. Byutilizing a suitable catalyst, the study means to work with the change of waste materials into helpful support, in this way decreasing the weight on landfills and limiting ecological contamination[10].

However, the use of nano metal carbonate catalysts offer more advantages like high surface region, upgraded synergist movement, and tunable selectivity, over the conventional catalysts[11,12]. By separating complex polymer structures into smaller hydrocarbon molecules, these catalysts work with the transformation of plastic waste into hydrocarbon-rich fuels resembling petroleum and diesel. This process reduces plastic accumulation as well as provides an imaginative approach to delivering elective fuels, adding to energy sustainability and decreasing greenhouse gas emissions[13]. The usage of nanometal carbonate catalysts introduces an original dimension to plastic waste management, making it ready for proficient waste-to-fuel conversion technologies. The researchreasoning for waste management of non-biodegradable plastics and their conversion into important petroleum and diesel substitutes using nanometal carbonate catalysts stems from the pressing needto address plastic contamination, resource consumption, and energy sustainability[14].

The utilization of nano-metallic carbonate impetuses in the transformation of non-biodegradableplastics, for example, LDPE, HDPE, PP and PS into significant oil and diesel substitutes addressesa significant development in the battle against natural issues and asset shortage[15]. These impetuses,with their enormous surface region, expanded reactant action and flexible selectivity can possiblyreform how plastic waste is discarded in the assembling of elective fills. The sturdiness of non-biodegradableplastics represents a serious danger to environments and human wellbeing becauseof their protection from debasement and restricted recyclability. The fundamental objective of theexamination is to foster a reasonable methodology that tackles the issue of plastic contamination,yet additionally utilizes the high energy content of plastic waste to deliver minimal expense fills.

Thus in the present study, we have synthesized of $CoCO_3$ nanoparticle catalysts. The catalyst developed will exhibit improved action,selectivity, and wellness because of their extraordinary properties at the nanoscale. The reactantchange cycle might possibly be improved to boost yield and limit ecological effects.Theinvestigation is different conversion techniques for producing alternative fuels from waste plastics.

2. Materials and Methods

2.1. Materials

Ammonium Carbonate, Cobalt Acetate

2.2. Synthesis of Nano $CoCO_3$

The metal carbonate catalysis that is produced here is$CoCO_3$ nanoparticle. For the synthesis of this catalyst the process that is used here is hydrothermalsynthesis. For the synthesis of $CoCO_3$ nanoparticle catalysts the materials those are used-

1. Aqueous solution of ammonium carbonates (1.86 g, 19.32 mol)
2. Aqueous solution of cobalt acetate (CO (CH_3-COO)$_2$) 4 H_2O.

For the preparation of cobalt carbonate the first step is to use 60 ml of the aqueous solution of ammonium carbonate. The weight of this chemical that is used here is 1.86 g and it is of 19.32mmol. This chemical should have to use dropwise in the other solution of cobalt acetate. 20 mlcobalt acetate solution should have to use here. After the preparation of the reaction mixture thewhole mixture should have to place in an autoclave. The capacity of the autoclave should have to100 ml. The reaction mixture should have to heat at 160 degree centigrade for 24 hours [16]. After heating at 160 degree centigrade the mixture should have to get under room temperature that is 25 degree centigrade. At room temperature a pink color solution is obtainedafter the completion of the reaction. The product is known as cobalt carbonate. The product has tobe collect, then dry in oven at a temperature of 60 degree centigrade for the absorption of water.

The yield of the product is 94%, it is high amount. Almost pure product is formed.

2.3. Characterisation

2.3.1. Fourier Transform Infrared spectrophotometer

The catalyst was characterized using FTIR spectroscopy for the presence of the characteristic functional groups with a Perkin-Elmer Spectrum 100 spectrometer in the range 4000 to 500 cm^{-1} over 16 scans with a Universal ATR; the spectra were recorded with a resolution of 4 cm^{-1}.

2.3.2. X-ray diffraction analysis

X-ray diffraction (XRD) pattern of the catalyst were recorded using X-ray diffractometer (Miniflex 600, Rigaku, Japan) with Cu Kα radiation (k = 1.54 A^o) and scanning rate of 1 step/s with step size of 0.1°/step.

2.3.3. Morphological analysis

The surface morphology of the catalyst prepared was investigated using Field Emission Scanning Electron Microscopy (FESEM, QUANTA 200 FEG, MIRA3 TESCAN).

3. Results and Discussion

3.1. FTIR Analysis

The FTIR analysis of the particle $CoCO_3$ nanoparticles has been shown in figure 1. Absorbance vs wave number graph is shown in the above figure. The absorbance peak at 3502.73, 1217, 1082, 862 and 628 cm^{-1} is observed for the high purity of the $CoCO_3$ nanoparticle. The broad peak in the area of 3000-3600 $cm^{-1}$is observed for the presence of the water molecule in the particle, which is indicated by the vibration of the group O-H is the peak[17,18]. The peak at 1207 and 1082 $cm^{-1}$is observed for the presence of the anion CO_3^{2-} that is mainly carbonate anion[19]. The peaks are observed for the presence of Co-O bond and also the Co-C bond in the nanoparticle. D-3h symmetry is observed here. The peaks 862 and 628 $cm^{-1}$is observed for the presence of Cobalt- Oxygen (Co-O) bond in the catalysts[20]. Also the vibrational mode of the "carbonate anion" can be shown with the presence of the peak 2436 cm^{-1}[21].

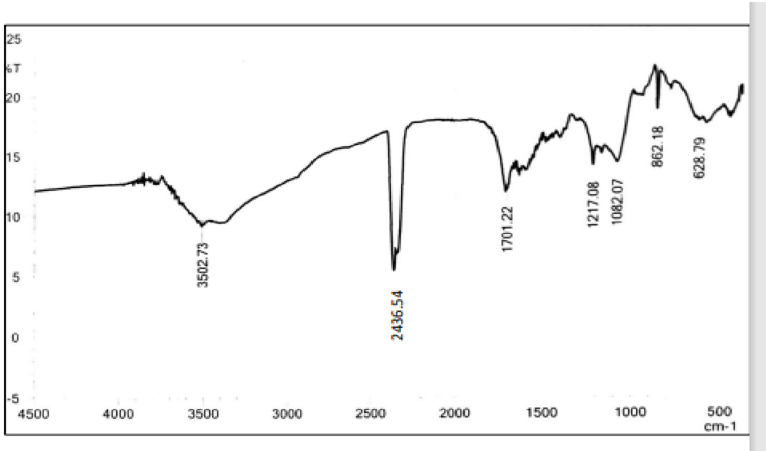

Figure 1: FTIR of $CoCO_3$ nanoparticle

3.2. X-Ray Diffraction Analysis

The XRD analysis of the catalysts $CoCO_3$ nanoparticle has been shown in Figure 2. The diffraction pattern is of relative intensity vs angle 2 theta (degree). The peaks of XRD diffractionindexed as a phase of pure hexagonal. The catalysts shows cell constant, a = 4.661 A^o andc = 14.96 A^o[21,22]. Through the XRD analysis the size of the catalysts that is $CoCO_3$nanoparticle can be revealed. Also, the XRD analysis can provide the crystallinity data of thenanoparticle. From the above XRD analysis it is observed that the nanoparticle is highly-crystalized.

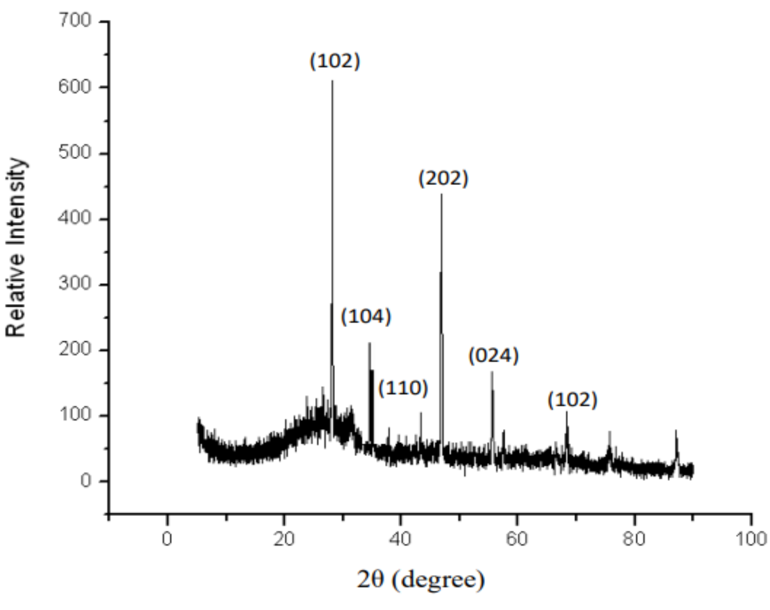

Figure 2: XRD Analysis of $CoCO_3$ nanoparticles

3.3. Morphological Analysis

The morphology $CoCO_3$nanoparticles has been shown in the figure 3. The image clearly represents the structure of the nanoparticle used as catalysts. It shows the high yield of the nanoparticle under optimum condition. The synthesized particle also shows uniformity. From the above picture it can be concluded that the morphological analysis of the particle is well-dispersed and also welldefined.The particles of the catalysts shows “sphere like” hierarchical structure[23,24]. The diameter ofthe sphere of the nanoparticle shows 10-20 nm.

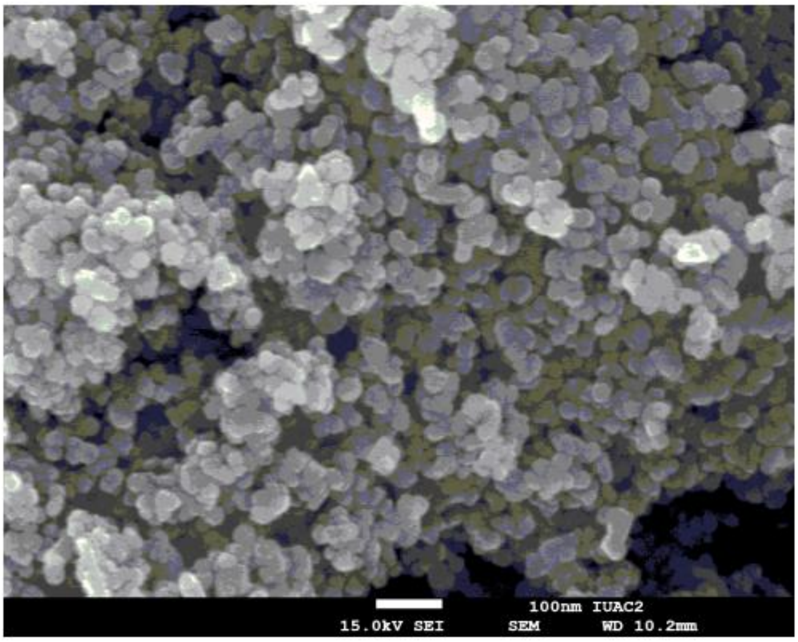

Figure 3: SEM image of $CoCO_3$ nanoparticle (Magnification 100X, 100 nm)

Conclusion

The aim of the study was to synthesize $CoCO_3$ nanomaterials using a hydrothermal synthesis method, which can be utilized in tackling non-biodegradable wasteand thus seeks to assist in waste management, which was confirmed by the FTIR results. The $CoCO_3$ nanoparticles were assessed for XRD and SEM analysis which indicated that the nanoparticles produced were highly crystalline and have regular spherical morphology.

Thedeveloped nanoparticles will be utilized as catalysts to transform waste into usefulby-products like gasoline and fuel. Thus, the processanswers boththe earnest requirement for viable waste administration and the quest for economical arrangements.

Conflict of Interest

The authors declare no Conflict of Interest.

References

[1] P. Dwivedi, P.K. Mishra, M.K. Mondal, N. Srivastava, Non-biodegradable polymeric waste pyrolysis for energy recovery, Heliyon. 5 (2019) e02198. https://doi.org/10.1016/j.heliyon.2019.e02198.

[2] E. Singh, A. Kumar, R. Mishra, S. You, L. Singh, S. Kumar, R. Kumar, Pyrolysis of

waste biomass and plastics for production of biochar and its use for removal of heavy metals from aqueous solution, Bioresour. Technol. 320 (2021) 124278. https://doi.org/10.1016/J.BIORTECH.2020.124278.
[3] O. Dogu, M. Pelucchi, R. Van de Vijver, P.H.M. Van Steenberge, D.R. D'hooge, A. Cuoci, M. Mehl, A. Frassoldati, T. Faravelli, K.M. Van Geem, The chemistry of chemical recycling of solid plastic waste via pyrolysis and gasification: State-of-the-art, challenges, and future directions, Prog. Energy Combust. Sci. 84 (2021) 100901. https://doi.org/10.1016/J.PECS.2020.100901.
[4] G. Fadillah, I. Fatimah, I. Sahroni, M.M. Musawwa, T.M.I. Mahlia, O. Muraza, Recent Progress in Low-Cost Catalysts for Pyrolysis of Plastic Waste to Fuels, Catal. 2021, Vol. 11, Page 837. 11 (2021) 837. https://doi.org/10.3390/CATAL11070837.
[5] K. Sivagami, K. V. Kumar, P. Tamizhdurai, D. Govindarajan, M. Kumar, I. Nambi, Conversion of plastic waste into fuel oil using zeolite catalysts in a bench-scale pyrolysis reactor, RSC Adv. 12 (2022) 7612–7620. https://doi.org/10.1039/D1RA08673A.
[6] A.T. Hoang, P.S. Varbanov, S. Nižetić, R. Sirohi, A. Pandey, R. Luque, K.H. Ng, V.V. Pham, Perspective review on Municipal Solid Waste-to-energy route: Characteristics, management strategy, and role in circular economy, J. Clean. Prod. 359 (2022) 131897. https://doi.org/10.1016/J.JCLEPRO.2022.131897.
[7] B. Vasilkovová, E. Hájeková, P. Hudec, J. Česáková, M. Horňáček, M. Kaliňák, V. Jorík, Two-stage thermal and catalytic cracking of polypropylene using natural clinoptilolite in a catalytic step to petrochemicals and fuels, J. Anal. Appl. Pyrolysis. 167 (2022) 105679. https://doi.org/10.1016/J.JAAP.2022.105679.
[8] J.L. Wang, L.L. Wang, Catalytic Pyrolysis of Municipal Plastic Waste to Fuel with Nickel-loaded Silica-alumina Catalysts, Energy Sources, Part A Recover. Util. Environ. Eff. 33 (2011) 1940–1948. https://doi.org/10.1080/15567030903436814.
[9] N. Miskolczi, C. Wu, P.T. Williams, Fuels by Waste Plastics Using Activated Carbon, MCM-41, HZSM-5 and Their Mixture, MATEC Web Conf. 49 (2016) 05001. https://doi.org/10.1051/MATECCONF/20164905001.
[10] X. Zhao, M. Korey, K. Li, K. Copenhaver, H. Tekinalp, S. Celik, K. Kalaitzidou, R. Ruan, A.J. Ragauskas, S. Ozcan, Plastic waste upcycling toward a circular economy, Chem. Eng. J. 428 (2022) 131928. https://doi.org/10.1016/J.CEJ.2021.131928.
[11] C. Xu, S. De, A.M. Balu, M. Ojeda, R. Luque, Mechanochemical synthesis of advanced nanomaterials for catalytic applications, Chem. Commun. 51 (2015) 6698–6713. https://doi.org/10.1039/C4CC09876E.
[12] A.A. Pawar, D. Lee, W.J. Chung, H. Kim, Understanding the synergy between MgO-CeO2 as an effective promoter and ionic liquids for high dimethyl carbonate production from CO2 and methanol, Chem. Eng. J. 395 (2020) 124970. https://doi.org/10.1016/J.CEJ.2020.124970.
[13] H. Alhazmi, F.H. Almansour, Z. Aldhafeeri, Plastic Waste Management: A Review of Existing Life Cycle Assessment Studies, Sustain. 2021, Vol. 13, Page 5340. 13 (2021) 5340. https://doi.org/10.3390/SU13105340.
[14] M. Tamoor, N.A. Samak, Y. Jia, M.U. Mushtaq, H. Sher, M. Bibi, J. Xing, Potential Use of Microbial Enzymes for the Conversion of Plastic Waste Into Value-Added Products: A Viable Solution, Front. Microbiol. 12 (2021) 777727. https://doi.org/10.3389/FMICB.2021.777727/BIBTEX.
[15] B. Senthil Rathi, P. Senthil Kumar, G. Rangasamy, A sustainable approach on thermal and catalytic conversion of waste plastics into fuels, Fuel. 339 (2023) 126977. https://doi.org/10.1016/J.FUEL.2022.126977.
[16] M.Y. Nassar, Size-controlled synthesis of CoCO3 and Co3O4 nanoparticles by free-surfactant hydrothermal method, Mater. Lett. 94 (2013) 112–115.

https://doi.org/10.1016/J.MATLET.2012.12.039.
[17] P. Kumari, Y. Singh, N. Kumar, R. Kumar, S. Rattan, Chemical initiator-free synthesis of Poly (acrylic acid-co-itaconic acid) using radiation-induced polymerization for application in dental cements, Radiat. Phys. Chem. 198 (2022) 110243. https://doi.org/10.1016/j.radphyschem.2022.110243.
[18] P.K. Kashyap, S. Chauhan, Y.S. Negi, N.K. Goel, S. Rattan, Biocompatible carboxymethyl chitosan-modified glass ionomer cement with enhanced mechanical and anti-bacterial properties, Int. J. Biol. Macromol. 223 (2022) 1506–1520. https://doi.org/10.1016/j.ijbiomac.2022.11.028.
[19] S. Savoye, L. Legrand, G. Sagon, S. Lecomte, A. Chausse, R. Messina, P. Toulhoat, Experimental investigations on iron corrosion products formed in bicarbonate/carbonate-containing solutions at 90°C, Corros. Sci. 43 (2001) 2049–2064. https://doi.org/10.1016/S0010-938X(01)00012-9.
[20] M. Rahimi-Nasrabadi, H.R. Naderi, M.S. Karimi, F. Ahmadi, S.M. Pourmortazavi, Cobalt carbonate and cobalt oxide nanoparticles synthesis, characterization and supercapacitive evaluation, J. Mater. Sci. Mater. Electron. 28 (2017) 1877–1888. https://doi.org/10.1007/S10854-016-5739-Z/METRICS.
[21] M.Y. Nassar, I.S. Ahmed, Hydrothermal synthesis of cobalt carbonates using different counter ions: An efficient precursor to nano-sized cobalt oxide (Co3O4), Polyhedron. 30 (2011) 2431–2437. https://doi.org/10.1016/J.POLY.2011.05.039.
[22] J.Q. Zhao, Y. Wang, High-capacity full lithium-ion cells based on nanoarchitectured ternary manganese–nickel–cobalt carbonate and its lithiated derivative, J. Mater. Chem. A. 2 (2014) 14947–14956. https://doi.org/10.1039/C4TA02574A.
[23] S. Lu, C. Yang, M. Nie, Hydrothermal synthesized urchin-like nickel-cobalt carbonate hollow spheres for sensitive amperometric detection of nitrite, J. Alloys Compd. 708 (2017) 780–786. https://doi.org/10.1016/J.JALLCOM.2017.03.059.
[24] J. Xiao, J.F. Wang, Y.D. Liu, J. Li, Y.X. Liu, Preparation of spherical cobalt carbonate powder with high tap density, J. Cent. South Univ. Technol. (English Ed. 13 (2006) 642–646. https://doi.org/10.1007/S11771-006-0008-6/METRICS.