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Synthesis And Characterization Of Highly Dispersed Nickel Catalysts By Coprecipitation Method

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Abstract-

Nickel catalysts have been widely used in various industrial processes, including hydrogenation and dehydrogenation reactions. In this study, we report the synthesis of nickel catalysts by coprecipitation method using nickel nitrate and sodium hydroxide as precursors and silica as a support material. The effect of different synthesis parameters, such as the nickel to silica ratio, pH, and temperature, on the morphology and catalytic performance of the nickel catalysts was investigated. The synthesized nickel catalysts were characterized by XRD, SEM, and FTIR techniques. The results showed that the nickel catalysts had a high surface area and uniform distribution of nickel particles. The nickel catalysts exhibited excellent catalytic activity for hydrogenation and dehydrogenation reactions. The superior performance of the nickel catalysts was attributed to the high dispersion of nickel particles on the silica support and the formation of nickel-silica interface. The coprecipitation method was found to be a simple, efficient, and scalable method for the synthesis of nickel catalysts with high catalytic performance. This study provides insights into the design and synthesis of nickel catalysts for various industrial applications.

Keywords: Nanotechnology, Nickel Catalyst, Catalytic Activity, Co-precipitation, Nanocatalyst

1. Introduction

Catalysts play a critical role in nanotechnology, enabling the synthesis of a wide range of nanomaterials with unique properties and functionalities. Nanomaterials exhibit distinct properties due to their high surface area-to-volume ratio, size-dependent electronic properties, and unique structural features, making them highly desirable for various applications.

Catalysts are used in nanotechnology to control the nucleation, growth, and morphology of nanomaterials during synthesis. The choice of catalyst can significantly influence the properties of the resulting nanomaterials, such as size, shape, crystal structure, and surface chemistry. For example, metal catalysts, such as gold, silver, platinum, and palladium, are commonly used to synthesize nanoparticles by controlling the reduction of metal ions. Other catalysts, such as metal oxides and zeolites, are used to control the nucleation and growth of nanomaterials through templating or catalytic deposition methods.

In addition to their use in nanomaterial synthesis, catalysts are also essential in nanotechnology for catalytic reactions, such as the oxidation of pollutants, fuel cells, and CO_2 reduction. The unique properties of nanomaterials, combined with the high surface area and activity of catalysts, enable highly efficient catalytic reactions with low energy consumption and minimal waste generation [1].

Overall, the use of catalysts in nanotechnology has revolutionized the synthesis and application of nanomaterials, offering unprecedented opportunities for developing advanced materials and technologies.

Nickel catalysts are versatile and widely used in various industries due to their excellent catalytic properties, high selectivity, and cost-effectiveness. Nickel catalysts can be synthesized using various methods, including impregnation, precipitation, sol-gel, and coprecipitation. One of the commonly used methods for synthesizing nickel catalysts is the coprecipitation method [2] [3].

2. Experimental:

2.1 Materials:

Nickel Chloride, Merck (AR grade), Ultrapure Distilled water, Silica gel G (SDFCL Silica Gel Powder B. No. 25261K05), Sodium Hydroxide (Merck LR Grade), Sulfuric Acid 98% (Merck Make, 1.93400.0521)

2.2 Preparation of Nickel Catalyst:

Dissolved the nickel salt precursor, nickel chloride 5 gm, in 100 ml distilled water to prepare a homogeneous solution. The concentration of the precursor solution can be adjusted depending on the desired nickel loading on the support. The support material, 1 % silica, prepared by washing with distilled water to remove any impurities. The support material is then dried in an oven at a suitable temperature, at around 105 °C, for 24 hours. The 100 ml precursor solution is added dropwise to the support material while stirring continuously.10% sodium hydroxide as a precipitating agent, is added dropwise to the solution to precipitate nickel hydroxide onto the support material. The pH of the solution maintained between 9-11, and also ensured complete precipitation of the nickel hydroxide. The resulting mixture of nickel hydroxide and support is then dried in an oven at a temperature, 105 °C for 12 hrs. The dried material is then calcined at a 650 °C using acetylene gas in Chemical Vapor deposition (CVD) furnace it helps to convert nickel oxide to metallic nickel. Then impurities removed by purifying catalyst using 1% Sulfuric acid. Kept catalyst for soaking in 1% Sulfuric Acid for 24 hrs. Then maintained pH as 7-8 by giving washing of distilled water. Dried the catalyst for 10 hrs at 120 °C. Used it for further characterization [4].

2.3 Characterization:

The resulting nickel catalyst characterized using various techniques, such as X-ray diffraction, scanning electron microscopy, and Fourier transform infrared spectroscopy, to determine its properties and performance.

Morphology of Nickel Catalyst was analyzed by using Bruker make X-ray diffraction analysis (XRD) to determine crystallographic structure of nano catalyst, to understand functional groups present in nano-catalyst FTIR and also used scanning electron microscope (SEM) to measure the size distribution of Nano-catalyst.

3. Results and Discussion

Nickel catalysts synthesized using coprecipitation method. The support material, silica, is prepared by washing and drying to remove impurities. A solution of nickel salts, nickel chloride, is prepared in water.

The support material is mixed with the precursor solution under stirring to allow the nickel ions to adsorb onto the surface of the support material. A precipitating agent, sodium hydroxide, is added to the mixture to precipitate the nickel ions as nickel hydroxide. The mixture is aged for a period of time to promote the formation of uniform nickel particles, and then washed with water to remove any impurities. The resulting nickel catalyst is dried and calcined at high temperature to remove any residual water and converted to nickel oxide.

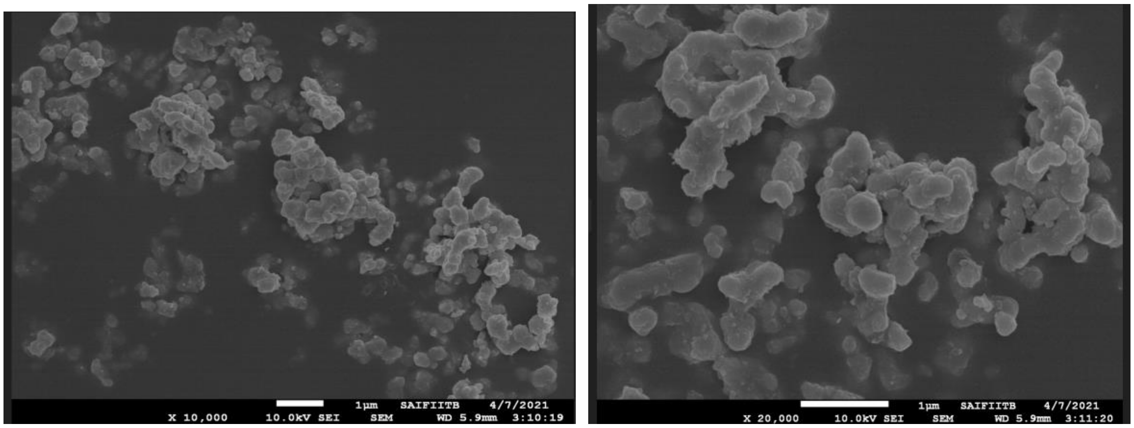

Figure 1 SEM Images of Nickel Catalyst using Co-precipitation method

SEM image Figure 1 helps to understand size of Nickel nano catalyst around 50-60 nm, which we observed at different scale and magnification [5].

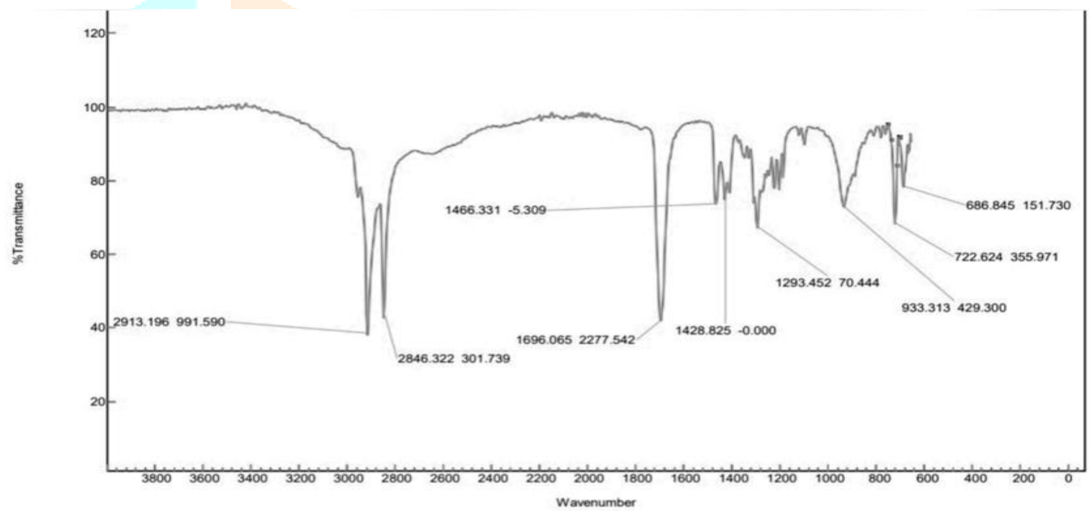

Figure 2 FTIR Spectra obtained of Nickel catalyst using Co-precipitation method

FTIR spectra Figure 2 shows peaks between 400-850 cm^{-1} i.e. 686 and 722.6 shows vibration of Ni-O stretching. Peaks in the region of 2800-3000 cm^{-1} indicates the presence of O-H bonds, The band observed at 1696 cm^{-1} is due to the OH bending of water [6].

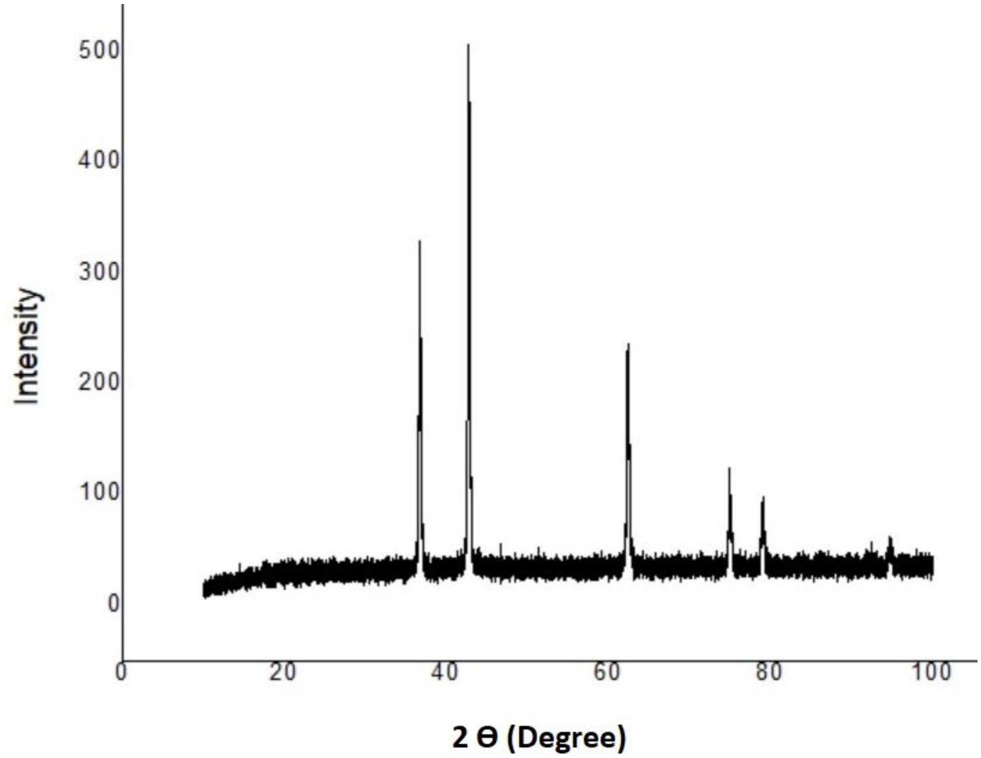

Figure 3 XRD spectra obtained of Nickel catalyst using Co-precipitation method

XRD spectra Figure 3 shows 2ϴ at 38, 41.8, 62,78.3 and 80.1 respectively which helps understand average size of crystals using Scherrer Formula:

$D = K\lambda / (\beta \cos \theta)$

Where, K is Scherrer constant, λ is X-Ray wavelength, β is Line broadening in radians (FWHM), θ is Bragg Angle, So, using Scherrer formula average crystalline size of Nickel Catalyst is 17.8 nm. With the XRD spectra it is shows Ni Catalyst particles are highly pure.

4. Conclusion

Overall, the coprecipitation method is a common approach for synthesizing nickel catalysts, and the resulting catalyst tailored by adjusting the reaction conditions. The synthesized Nickel Catalyst can useful in wide range of applications in various fields due to their unique properties and versatility. Nickel catalysts are used in environmental remediation processes to remove pollutants from wastewater and other industrial effluents and their unique properties make them an essential tool for many chemical processes.

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