Solution Combustion Synthesis of Cobalt Oxide Nanoparticles: A Facile and Scalable Approach

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Abstract:

Here, we describe a straightforward solution combustion synthesis of Cobalt oxide (CoO) nanoparticles using glycine as a fuel. Through scanning, the morphological and structural characteristics of nanoparticles were examined. Fourier transform infrared (FT-IR), X-ray diffraction (XRD), electron microscopy (SEM), and UV-visible spectroscopic method. Co nanoparticles produced by solution combustion have a crystalline size of about 20 nm. SEM pictures show the accumulation of tiny particles with sizes between 30 and 50 nm. For Co nanoparticles, the FT-IR spectra display an absorption band at about 466 cm^{-1}. UV-Vis. Spectroscopy reveals an absorption band for Co at 400 nm and CoO at about 350 nm. Co nanoparticles are employed in a variety of applications, including as supercapacitors, CNT production, and catalysis.

Keyword: *CoO, glycine, catalyst, CVD, H2 gas, solution combustion, Particles of nanoparticles*

Introduction:

We discovered through a review of the literature that nanoparticles of transition metals, such as Fe, Co, Ni, etc. have been investigated in recent years by a number of scientists. Transition metal nanoparticles are becoming increasingly important. CoO has been created by a number of researchers using various techniques, including sol-gel (C N R Rao 1963) and surfactant-mediated synthesis (C N R Rao 1994), for a variety of applications, including catalysts (Patil K C 1997), super capacitors, gas sensors, biosensors, and supercapacitors. thermal breakdown (Rao K J and Ramesh P D 1995), solution combustion synthesis (S. Balamurugan and A.J. Linda Phillip 2016), and so forth. However, the solution combustion approach is the most effective and widely used laboratory synthesis. Different combinations of fuels and oxidizers—such as metal nitrate, metal chloride, metal sulphates, etc.as well as fuels—such as glycine, urea, citric acid, oxalic acid, glucose, sucrose, and aniline are employed in the solution combustion method.

The solution combustion synthesis described in the current article uses glycine as fuel and Cobalt nitrate hexahydrate as an oxidant. SEM, XRD, FTIR, and UV-Vis spectroscopy were used to characterize the produced CoO and Co nanoparticles.

Material Methods:

Cobalt oxide and Co nanoparticle synthesis It is well known that very tiny metal particles like Fe, Co and Ni play a catalytic role in the development of CNT (Schwarz et al., 1995). Thermal decomposition was used to create the Co catalyst. Glycine and cobalt nitrate hexahydrate were combined in 25 millilitre's of distilled water at a fixed 1:1 molar ratio, and the mixture was stirred for ten minutes. (Chatterjee and others, 2003). The mixture was then maintained at the glycine flash point of 350 degrees Celsius in a muffle furnace that had been preheated. Large volumes of carbon dioxide and ammonia are released during the extremely exothermic breakdown of glycine, and fine cobalt oxide is produced. fine cobalt oxide is ground into a fine powder using a hand pestle. After being ground and sonicated, cobalt oxide has a blackish hue. Here, an organic substance with carboxylate and/or amine (such as glycine) functions as fuel, whereas NO_3^- in metal nitrate acts as an oxidant. Fuel and oxidizer undergo exothermic redox breakdown in this autocatalytic, self-propagating reaction. The particle is crystallized using reaction enthalpy, or residual combustion energy. Ultra-fine crystallite powder is the consequence of the explosive gas blowing off the substance. In a CVD furnace, cobalt oxide was reduced by H2 at 600°C for two hours, producing an extremely tiny metal nanoparticle that served as a catalyst for the CVD growth of carbon nanotubes (CNTs) (Turano et al., 2006). For 20 minutes, ethyl alcohol was used to sonicate the produced CoO and Co. further investigated employing methods such as UV-Vis spectroscopy, FTIR, XRD, and SEM.

III. Result and Discussion

- **SEM and XRD study**

$D = 0.94\ \lambda/\ \beta^{1/2}\ COS(\theta)$, where λ is wavelength of XRD radiation's wavelength, β is the full width at plane's peak's half maximum of the peak, corresponding to plane θ is the angle derived from the XRD pattern's 2θ value. The powdered XRD yielded a crystalline size of 59.15 based on the strong peak at $2\theta = 44.77$.

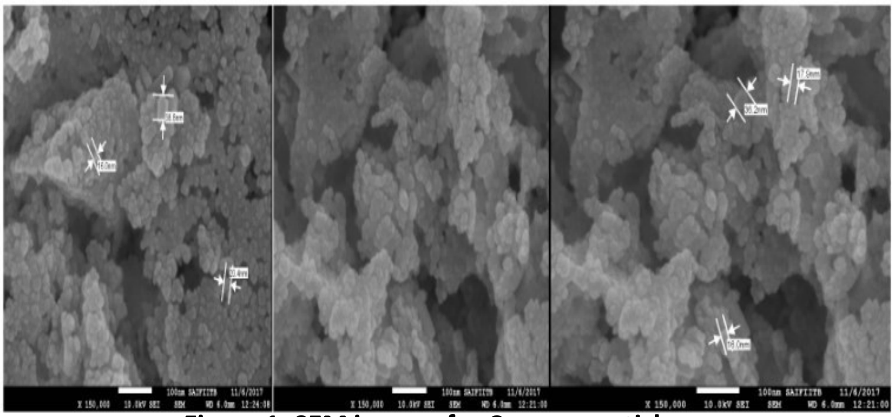

Figure 1. SEM images for Co nanoparticles

The SEM micrographs of cobalt oxide reveal a highly agglomerated nanostructured morphology. The surface is composed of nearly spherical nanoparticles clustered into irregular, porous aggregates. Individual particle sizes appear to be in the tens of nanometre range, as indicated by the scale bars. The rough and cauliflower-like texture suggests a high surface area, which is beneficial for electrochemical and catalytic applications. Interconnected grains and voids are clearly visible, indicating good porosity within the cobalt oxide network. Peak broadening implies the formation of nanosized crystallites, consistent with the SEM observations

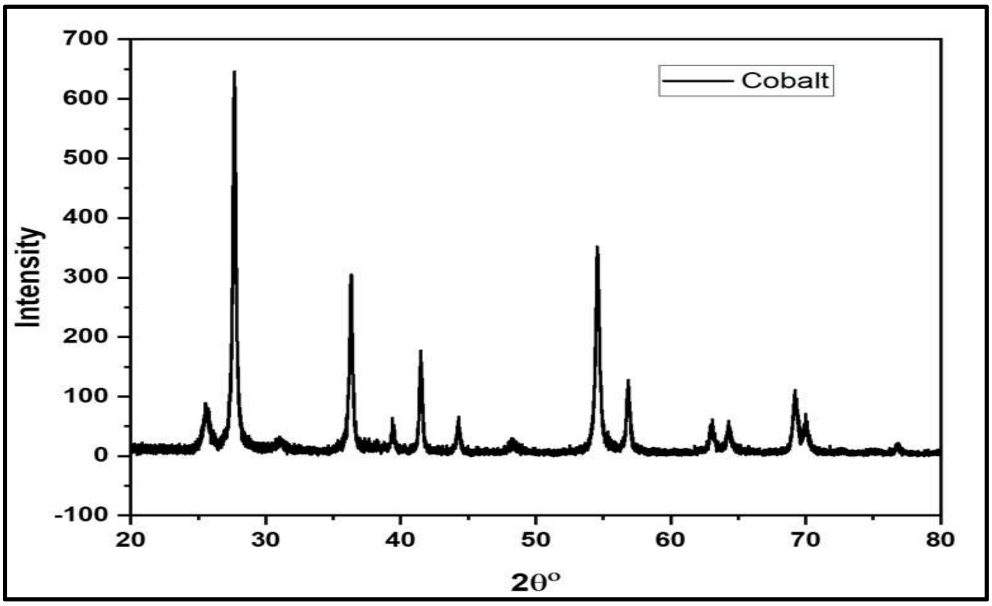

Figure 2: XRD for Cobalt Oxide

The XRD pattern of cobalt oxide shows well-defined and sharp diffraction peaks, confirming its crystalline nature. The observed peaks can be indexed to the characteristic crystal planes of cobalt oxide, indicating phase purity with no significant impurity phases. The high intensity of the major peaks suggests good crystallinity of the synthesized material..

- **UV Spectroscopy**

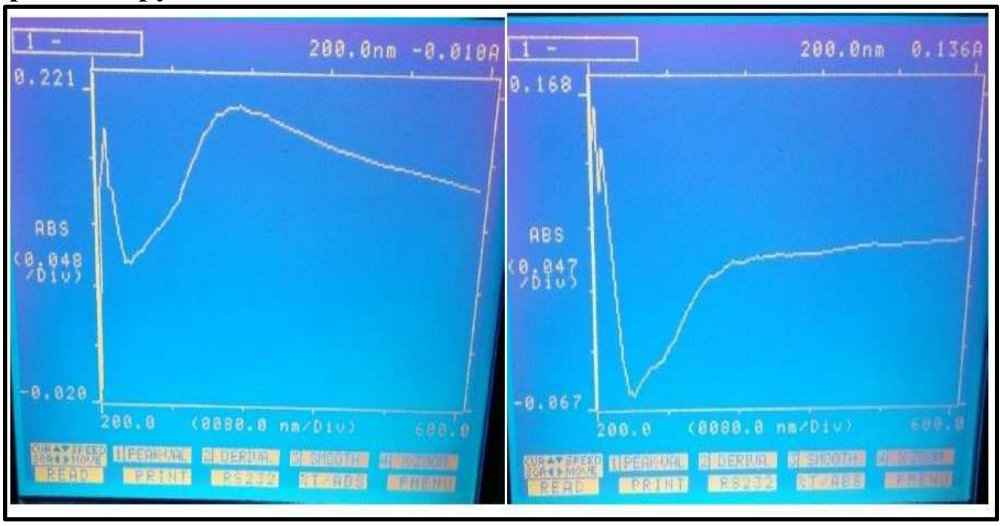

Figure 3: UV-Vis spectrum for CoO

The optical absorption behaviour of the produced CoO and Co was investigated in the UV-visible absorption range (200-600 nm). Figures 3. show the usual absorption spectrum for CoO, with two UV absorption peaks at around 209 and 350 nm indicating the presence of CoO. from a review of the literature. The UV–Vis absorption spectra exhibit strong absorption in the UV region, attributed to charge transfer transitions in cobalt oxide. broad absorption tail extending into the visible region indicates semiconductor behavior. The absorption features suggest the presence of Co^{2+}/Co^{3+} electronic transitions. These optical properties highlight the suitability of cobalt oxide for photocatalytic and optoelectronic applications.

- **FTIR spectrum**

The existence of Co nanoparticles is indicated by the greatest absorption shown at 400 nm in Figure 4. and FT-IR confirms this. Co nano particle peaks at about 466 cm^{-1}

The FTIR spectrum of cobalt oxide shows characteristic absorption bands in the low-wavenumber region around 500–700 cm^{-1}, corresponding to Co–O stretching vibrations. These bands confirm the formation of cobalt–oxygen bonds in the oxide lattice. A broad band around 3400 cm^{-1} is attributed to O–H stretching of adsorbed water or surface hydroxyl groups. The weak peak near 1600–1650 cm^{-1} is associated with H–O–H bending vibrations. Minor bands at higher wavenumbers may arise from residual organic species from the synthesis process.

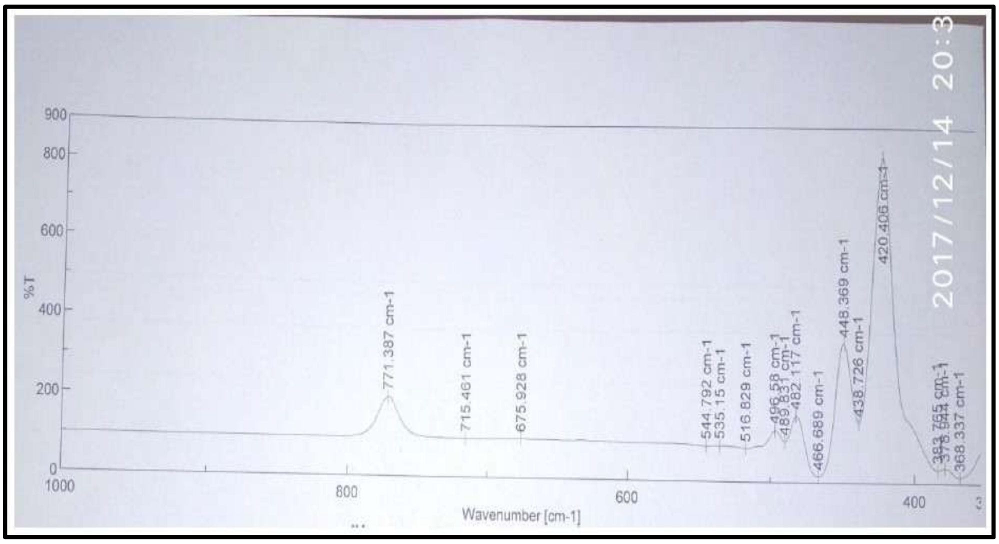

Figure 4. FT-IR spectrum for Co nanoparticle

The FTIR spectrum of cobalt oxide provides clear evidence for the formation of metal–oxygen bonding and surface functional groups. Strong absorption bands observed in the low wavenumber region, typically between 500 and 700 cm⁻¹, are attributed to Co–O stretching vibrations, confirming the presence of cobalt oxide in the spinel lattice. A broad and intense band around 3200–3500 cm⁻¹ corresponds to O–H stretching vibrations, indicating adsorbed moisture or surface hydroxyl groups commonly found in nanostructured oxides. The band appearing near 1600–1650 cm⁻¹ is assigned to the bending mode of H–O–H vibrations of physically adsorbed water molecules. In some cases, weak bands in the range of 1000–1500 cm⁻¹ may be related to residual organic species or carbonate groups originating from precursor materials. Overall, the FTIR results confirm the successful formation of cobalt oxide with minor surface-bound species, supporting the structural and chemical integrity of the synthesized material.

IV. Conclusion:

Utilizing glycine as fuel, Co nanoparticles were effectively created utilizing the solution combustion method with a decent yield of 10–12%. The produced nanoparticles, which ranged in size from 20 to 40 nm, were extremely pure and nearly uniform. The produced nanoparticle will be appropriate for possible use in electrochromic devices, biosensors, and catalytic supercapacitors. In our ongoing research, we are employing plant oil as a precursor and created Co nanoparticles for CNT manufacture via CVD.

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