Chapter

Introductory Chapter: Cobalt Compounds and Applications

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1. Introduction

Cobalt has a subject of extensive research and application area due to being ferromagnetic with high thermostability, multivalent, a high-melting point (1493°C), and retaining its strength to a higher temperature [1]. Some of them are antimicrobial agents in biological systems, biocompatible magnetic-fluids, hybrid supercapacitors, magnetic resonance imaging and controlled drug delivery, nano-structured cobalt gas sensors, microwave absorbing paints and catalytic activity in some reactions, active sites for electrochemical applications [2].

Some of these extensive functions and applications can be mentioned. Cobalt ferrite ($CoFe_2O_4$) has a great physical and chemical stability and large anisotropy, making it suitable for biomedical applications. It has a magnetic property due to its tetrahedral (Td) and octahedral (Oh) sites, which include cation. Also, it is used to enhance the scope of materials in the biomedical field. Synthesis of $CoFe_2O_4$ is carried out by the following methods: sol-gel [3], solid-state reaction method [4], microemulsion [5], combustion [6], chemical coprecipitation [7], hydrothermal method [8], etc. [9].

The $CoFe_2O_4$ is a suitable material in energy harvesting/storage and conversion, pathogen detection, chemoresistive sensor, and dye degradation. Besides these features, it also has applications such as magnetic resonance imaging, magnetic fluid hyperthermia, drug delivery, and tissue repair. $CoFe_2O_4$ ferrite nanoparticles can be utilized in various antimicrobial applications that they have good antimicrobial activity against all tested bacteria, especially, Gram-negative bacteria. This feature of theirs can bring a new perspective to future studies in other ferrite and composite structures [10]. Also, the antimicrobial activity of $CoFe_2O_4$ was augmented with the addition of silver in some research [3, 11–13]. Kooti et al. [14] found that the antibacterial activity of Ag-coated $CoFe_2O_4$ nanocomposites is more efficient than Ag nanoparticles [9].

Cobalt oxide nanostructures have the matchless advantages of high theoretical capacity, highly active catalytic properties, and outstanding thermal/chemical stability. So, they are used as electrode materials for various electrochemical applications. Cobalt oxides are used in many research areas. They are abundant on earth and low cost and have environmental compatibility and excellent thermal stability and exceptional physical and chemical properties. Cobalt oxides have been successfully synthesized and used so far for various applications. These metal oxides stand out in applications of electrochemical energy devices. It will be used in theoretical calculations and simulations in the design of new cobalt oxide-based materials for practical applications in new studies. These studies encourage nanoscience and nanotechnology and the development of materials science, with regard to energy technologies [15].

In recent years, synthetic approaches have been developed for cobalt oxide-based nanomaterials [16]. Cobalt oxides are synthesized by a mild hydrothermal method using thioglycolic acid (TGA). Using hydrothermal method is provided with control of kinetic and thermodynamic factors [17]. At present, there is a quest to find the most suitable passivating material that can efficiently improve the performance of the cobalt oxide solar cell, and its success can be highly dependent on the understanding of the structures and properties of the passivating layer/cobalt oxide system. Further efforts should be made to clarify these mechanisms. Due to high crystallinity, size, morphology, optics, and good dispersion with Co_3O_4 particles, high solar cell yield was provided. The Co_3O_4 nanoparticles are preferred in low-temperature-fabricated solar cells for environmentally sensitive uses in the development of low-cost antireflection in processes [18].

In addition to all these studies, it is possible to see cobalt thin and ultrathin film structures in numerous new applications in industrial sectors. Cobalt has a wide range of uses due to its physical, mechanical, and electrical properties. Metallic cobalt films play an important role in the safety of integrated circuit devices. This is because metallic cobalt films have both a low tendency to diffusion exposure and have a higher resistance to electromigration.

The use of cobalt compounds in the biomedical field has recently been of interest to researchers. The use of cobalt/silica carriers to repair the retina removed in the relevant medical field is also under investigation [19].

In addition, one-dimensional layered $NH_4CoPO_4.H_2O$ microrods, which have high electrochemical activity, are low cost, and have natural richness, are obtained using a hydrothermal method. Although it utmost progress, it needs to studies for more stable and performance electrode materials for supercapacitors [20].

Then, microwave synthesis method was used to get bimetal phosphates, $NaNi_xCo_{1-x}PO_4.H_2O$; this method is favorable and timesaving in comparison with conventional hydrothermal [21], solvothermal [22], and pyrolysis methods [23]. Also, it satisfies a need for inexpensive electrodes in practical applications. This has proved that the combination of cobalt and nickel increases the specific capacity of the material. Cobalt can promote charge transfer owing to can act as electronic conductive species and can efficiently reduce the resistance and nickel can present high theoretical capacitance [21, 24–29]. At the end of the studies, optimized $NaNi_{0.33}Co_{0.67}PO_4.H_2O$ was obtained. The optimized $NaNi_{0.33}Co_{0.67}PO_4.H_2O$ exhibited a high electrochemical performance. The results show that it can be applied to practical devices that open a wide development potential for future supercapacitors.

In addition to all the mentioned properties of cobalt, it is a highly active catalyst for hydrogenation reactions. Supported in most cases, in low-temperature Fischer-Tropsch process, Co/Al_2O_3 or Co/SiO_2-ZrO_2 catalysts were used; CoO/SiO_2 and CoO/SiO_2-Al_2O_3 and CoO/ZrO_2-kieselguhr catalysts were used in the hydrogenation of oxoaldehydes, amination of alcohols, and amination of aldehydes and ketones for the production of ethylamine and propyl amines [30, 31].

It was determined that cobalt metal catalysts had higher activity when Ni and Co metal catalysts were compared. Cobalt-based catalysts exhibit high catalytic activity because the tendency of cobalt to react is higher due to its electron configuration. The results of the catalytic hydrolysis reaction of 2Co-1Ni-B/Magnesite catalyst and $NaBH_4$ synthesized by the co-loading of cobalt and nickel metals to the magnesite support material have increased the efficiency of the catalyst by adding Co [32].

Alloys are frequently used in the field of biomaterials of metal and metal alloys such as stainless steels, gold, and cobalt. Metallic biomaterials are preferred in the production of biomedical devices used for diagnostic and therapeutic purposes. The metals used in the prosthesis are suitable for the living body if used in small amounts [33]. Cobalt ferrite, barium, and strontium show promising magnetic behavior for medical applications [34]. Cobalt ferrite nanoparticles are more preferred for medical purposes than the other two nanoparticles. This is due to less toxic effects of cobalt ferrite. Cobalt ferrite has an application as a chip for diagnostic and laboratory applications and magnetic hyperthermia as minimally invasive tumor treatment [3, 35, 36].

Cobalt-chromium alloys are highly preferred materials in the biomedical field due to their high wear and corrosion resistance together with their load-bearing capabilities. Today, the surfaces of cobalt-chromium alloys are more biologically compatible with the surrounding tissue. That is, many studies have been done to make it bioactive. The surfaces of cobalt-chromium materials are tried to modify by being coated with bioactive glasses or metals with superior properties in terms of bioactivity. The cobalt-chromium alloy (ASTM F75) surfaces, which are used as orthopedic implant materials, were coated with titanium matrix composite material by cold dynamic gas spraying technique. Then, the thermal oxidation of the coatings was carried out in an air oven at 600°C for 60 hours [37].

All the features and applications we have mentioned so far prove how important cobalt is. The objective of this book is to serve as a one-stop comprehensive information resource on new cobalt and nanostructured cobalt compounds, from science to industry and health area.

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