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Synthesis of Cobalt Oxide Thin Films by Chemical Solution Method and its Characterization

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ABSTRACT

Cobalt oxide thin film with nanotubes-like morphology was successfully synthesized by chemcical solution method such as sol-gel reflux method. The films were annealed at 773 K and characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM). The XRD studies reveal the cubic crystal structure of cobalt oxide. The SEM image of cobalt oxide films showed nanotube-like morphology with an average length of tube 250-300 nm.

KEYWORDS | Thin films, chemical solution method, sol-gel method, cobalt oxide

1. Introduction

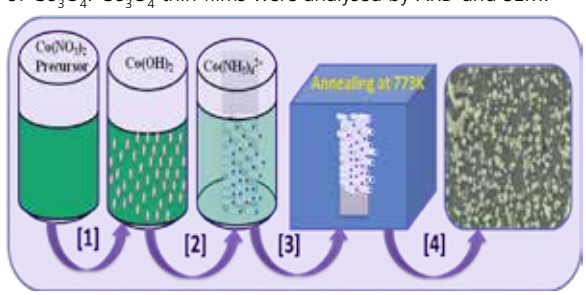
Today's world is much advanced as far as industrial innovations are considered. The industries include the producers of machines and components and also fabrications of say for example all means of transport including run our planes, trains, cars and buses, to drive our ships and submarines, to make the wheel move etc. And accordingly, to run the industries, there is great demand for the energy which is increasing day by day. It is well known since centuries back that, the coal and oil are the major sources of energy. But with the passage of time, coal and oil are bound to be used up, which will lead to big gap between demand and supply of the energy in all forms which is clear indication that the world is heading fast towards a major energy crisis [1].

There is an immediate need for efficient and clean sources of energy to provide optimum energy requirement for the rapidly developing global economy. At the same time care must be taken to discover sustainable and environmental friendly sources of energy. Simultaneously, this development will help to overcome the problem of the depletion of fossil fuels. If the clean sources of energy are invented and made use in practical sense on large scale, will definitely help to control the increasing environmental pollution. Amongst the other technologies and devices, some of the most effective and practical technologies for electrochemical energy conversion and storage are the batteries, fuel cells, and electrochemical supercapacitors. The electrochemical supercapacitors or ultracapacitors have attracted significant attention, mainly due to their high power density, long lifecycle, and bridging function for the power/energy gap between traditional dielectric capacitors (which have high power output) and batteries/fuel cells (which have high energy storage) [2,3].

Supercapacitors (SCs), featuring fast-growing demand for high performance energy storage devices for consumer and have received great interest for many potential applications such as electric vehicles, medical electronics, telecommunication devices and stand-by power systems, due to their high power density, energy efficiency, excellent reversibility and longer cycle life [4]. In SCs, active materials are playing important role for electrochemical performance [5]. Different metal oxide such as CoOx, RuOx, NiOx and IrOx have serve as excellent electrode materials for SCs with their charge-storage mechanism based on the pseudocapacitance. The Co_3O_4 electrode has been found good efficiency and long-term stability performance, good corrosion stability and low cost, due to this attractive properties it has potential applications in commercial fields such as energy storage [6].

2. Experimental work

The Co_3O_4 thin film was deposited on steel substrate by sol-gel reflux method, in which the 0.04M cobalt (II) nitrate hexahydrate (AR) precursor was prepared in doubly distilled water. Complexing agent ammonia (28%) was added to adjust pH~12. The complete formation of the Co_3O_4, in the form of thin film, takes place in about 2 hours. The films were then annealed at 773K. Fig.1 shows the schematic representation of Co_3O_4. Co_3O_4 thin films were analysed by XRD and SEM.



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3 RESULTS AND DISCUSSION

3.1 Mechanism of formation of Co_3O_4 thin films

The Co_3O_4 thin films were deposited on stainless steel substrates by sol-gel reflux method. Initially cobalt (II) nitrate hexahydrate was used as a source of cobalt and aqueous ammonium hydroxide solution was added to form the precipitation of $Co(OH)_2$ and the solution appeared become turbid at pH~9 is due to the ionic product of $Co(OH)_2$ exceeds the solubility product and the possible reaction is,

$$Co(NO_3)_2 \cdot 6H_2O + 2NH_4OH \rightarrow Co(OH)_2 + 2NH_4 + 2NO_3$$

Further excess ammonium hydroxide reduces Co2+ ion, by producing the complex ion of type Co(NH3)y2+, which results formation of clear and transparent solution at higher pH. This can be represented by the following reaction,

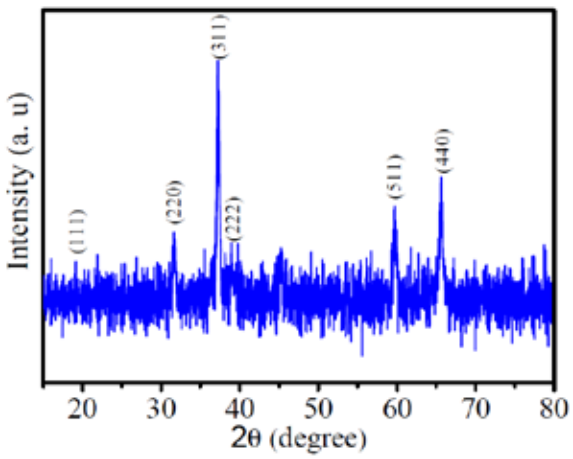
$$Co(OH)_2 + 4NH_4^+ \rightarrow Co(NH_3)_4^{+2} + 2H_2O + 2H^+$$

The $Co(OH)_2$ complex was deposited on steel substrate due to cohesive/Vander Walls/chemical attractive forces. Further, the $Co(OH)_2$ on annealing at 773 K to form pure Co_3O_4 shown below

$$Co(OH)_2 + O_2 \rightarrow Co_3O_4 + H_2O$$

3.2 X-ray Diffraction Study

The structural properties of the synthesized Co3O4 were evaluated by XRD in the 2θ range of 20-800 as shown Fig. 2. It exhibits major XRD peaks of Co_3O_4 phase due to the diffraction peaks at angles (2θ) of 19.05°, 31.34°, 36.93°, 44.92°, and 59.54° are assigned to the (111), (220), (311), (400), and (511) planes of the cubic crystals lattice of Co3O4 respectively. FCC type Co3O4 is in good agreement with (JCPDS- 01-074-1656). No other peaks are observed indicating high purity Co_3O_4.



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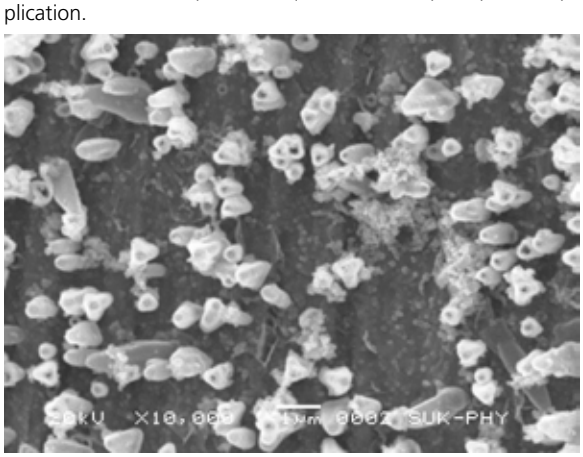
3.3 Scanning Electron Microscopy Study

Fig. 3 shows the SEM image Co_3O_4 thin film. It shows the nanotubes like structure, which is used for supercapacitor application. The SEM images revealed the development of well adherent and nanotube like formation with evident length of tube in the range of 250-300 nm, such type of morphology provide accessibility of OH- ions of electrolyte and electrode, which is the most important requirement in supercapacitor application.



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4. Conclusion

The Co_3O_4 thin film was successfully synthesized by sol-gel reflux method. Co_3O_4 films annealed at 773 K were characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM). The XRD studies reveal the cubic crystal structure of Co_3O_4. The SEM image of Co_3O_4 films showed nanotube-like morphology with an average length of tube 250-300 nm. These properties could be taken an advantage for applications of cobalt oxide films as electrodes in supercapacitor.

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