Diversified Methodologies to Prepare Metal Oxide Thin Film for Super Capacitor Applications – A Review

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ABSTRACT

In this review, we focused on various deposition methods. Viewing to the literature, the metal oxides have been synthesized by many chemical and thermal treatments, including, chemical oxidation, reduction, chemical vapor deposition, calcinations, annealing, plus laser deposition, and arc discharge, chemical bath deposition etc.1-4. Thin film technology is applicable to various materials, like polymers or metals. Common substrate materials are silicon, steel. The deposition materials and the technology, properties of the substrate material could be enhanced for Specific applications by using Chemical Bath Deposition (CBD). In addition to this, recently thin film technology is applicable for plane objects. In broad view thin film has the number of applications like corrosion preventive, decorative coating, photo detector, image processing, optical memories and mainly storage of energy. With these basic ideas, thin-film is the very easiest accurate, sensitive method for deposition purposes. Apart from this technique, there are various methods for deposition. An innovative way of advancement of thin-film acceptable. Thin-film has more advantages in device preparation from electrochemical characterization. Electrochemical supercapacitor is unique electrochemical devices with high power density, high charge-discharge cycle life with high energy efficiency.

Keywords: Thin film, CBD, electrochemical characterization, deposition method

1 Introduction

Literature survey of supercapacitors shows that different types of metal oxide thin films have been studied. Namely, thin-films of MnO_2, NiO, Co_3O_4, Fe_3O_4, Bi_2O_3, $NiFe_2O_4$, $BiFeO_3$ etc Electrochemical capacitors are attracting significant interest in power storage of electric and fuel cell vehicles. Electrochemical capacitors are classified namely electric double-layer capacitors and redox supercapacitors. Redox supercapacitors make use of a reversible redox reaction in a rechargeable battery more than a traditional capacitor. For redox supercapacitors purpose different noble and transition metal oxides used like CoO_x, RuO_2, NiO_x, MnO_2, etc and conducting polymers have been employed as electrode materials. The materials like ruthenium oxide are a good redox supercapacitor exhibiting a specific capacitance up to 720 F/g. However, the cost is high in the large-scale commercial production of ruthenium oxide as a redox supercapacitor. Various methods including hydrothermal synthesis, chemical bath deposition, sol-gel method, and co-precipitation, have been used to produce electrodes for electrochemical capacitors. For Preparing prepare metal oxide electrodes for electrochemical capacitor applications is electrodeposition due to it leads to the direct deposition of oxide films on an electrode. Several reports show that binary metal oxides like manganese-nickel oxide and manganese-cobalt oxide increase the electrochemical capacitive study of manganese oxides and have good electrochemical properties than single metal oxide. The electrodeposition method is proven effective method to prepare a Nanocomposite film, which gives potential for real application as a supercapacitor electrode material, that contributes to the cycling capability and stability of the nanocomposite materials

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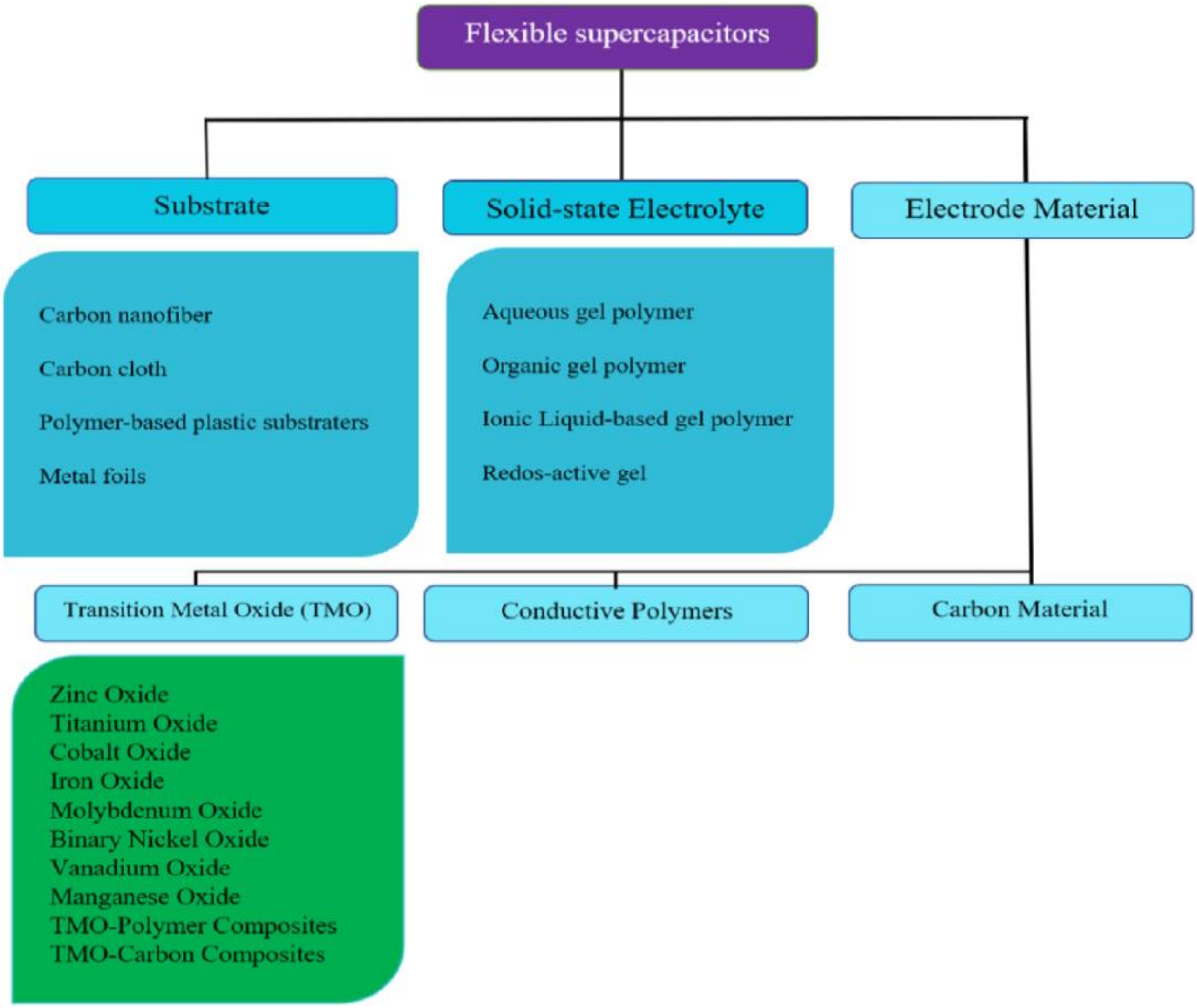

Fig1: Methods for preparation of Supercapacitor

2 Literature Review

Literature survey of supercapacitors shows that a variety of metal oxide thin films have been Bi_2O_3, IrO_2, $NiFe_2O_4$, $BiFeO_3$ etc.Various methods have been used for the synthesis of metal employed. These include thin films of RuO_2, MnO_2, NiO, In_2O_3, Co_3O_4, V_2O_5, Fe_3O_4, Theory and Calculation oxide nanoparticles. Mainly used methods include precipitation, sol–gel, reverse micelle, thermal decomposition, solvothermal, microwave-assisted and flow synthesis. A widely used In-situ precipitation method is reported in the literature for the preparation of iron oxide nanoparticles based on their applications in many aspects. By Simple co-precipitation method used for Nickel cobalt hexacyanoferrate (Ni_2CoHCF) the specific capacitance of the supercapacitor was 1300 F/g. Sol-gel method gives the highest specific capacitance of 484.6 F/g and energy density 10.8 WhKg−1 at the current density 1 mAcm−2 using as-synthesized 2 wt% Zn doped $MgFe_2O_4$. Methods are performed in an autoclave that can bear high temperatures and pressures. In the hydrothermal method, the solution is aqueous and in case of solvothermal method the solution is non-aqueous. Theoretical specific capacitance for $Ni(OH)_2$ is 2584 F/g and obtained 600.3 F/g. using [RSC] Microwave-assisted method of oxide synthesis is important due to its high reaction rate, efficient heat transfer, and environmental friendly nature. In this process material is directly heated by radiation leading to higher temperature homogeneity. SILAR (successive ionic layer adsorption and reaction) method is a simple, less expensive, and less time-consuming method for the deposition of binary semiconducting thin film oxides. It is also used in the deposition of large-area thin films oxide. Using Spin coating method applies a uniform film on a solid surface by using centrifugal force which requires a liquid-vapor interface. In a specific procedure, a liquid is placed at the center of a circular surface and is rapidly rotated to prepare uniform films of 1–10 μm in thickness. Chemical bath deposition (CBD), or chemical solution deposition (CSD), is a method for deposition of thin films and nonmaterial, first described in 1869. It can be used for large-area batch processing or continuous deposition thin film. This technique is mainly used to deposit buffer layers in thin-film photovoltaic cells. The technological development in modern thin-film synthesis over the past decade subsequently leads to the utilization of outstanding properties and develop of a wide range of applications in various engineering fields. As a result, the current activity in the thin film device fabrication technology which has been correlated in the field of nanotechnology, LEDs and displays solar cells etc.

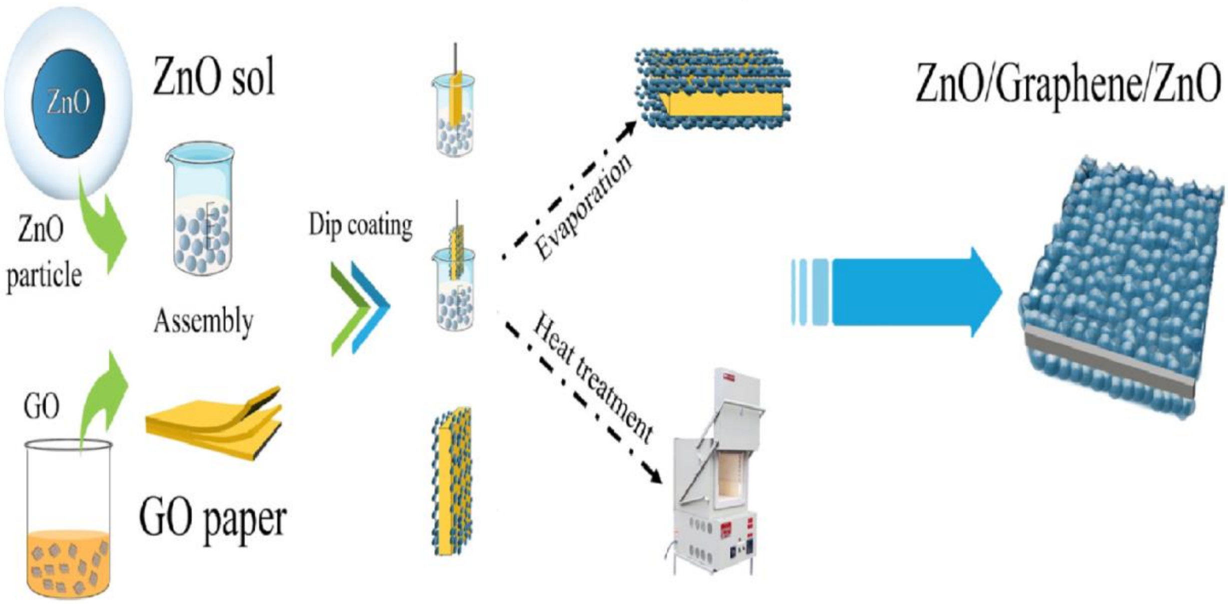

Fig2: Electro-deposition of ZnO

In the previous 30 years, there has been the elimination of pollutants by electrochemical methods, such as direct oxidation on an electrode surface, indirect oxidation, and electro-Fenton reactions through hydroxyl radicals. In the case of these methods, the main part is the anode used. Metal oxide anodes, which mostly consist of a titanium substrate covered with metallic oxide films, are the most widely used type, e.g. Ti/PbO_2, Ti/SnO_2–Sb_2O_5, Ti/RuO_2, At present, the methods used for anode preparation include thermal decomposition, electrodeposition, spray pyrolysis, sol-gel process, sputtering, chemical vapor deposition and electron beam evaporation. MXene is applicable in energy storage devices like electrodes of Li-ion batteries, pseudocapacitors, etc. The researchers have been envisioned its use for reinforcement in composites, which increase its mechanical properties and decrease gas permeability of polymers. MXenes are prepared from a bulk crystal hence it is called MAX. MXenes have excellent volumetric capacitance and very good conductivity because they are molecular sheets made from the carbides and nitrides of transition metals like titanium. MXenes found applications ranging from energy storage to medicine and optoelectronics. What makes MXenes so interesting is the fact that this material class could conceivably consist of any of various possible arrangements of transition metals like molybdenum or titanium, and also carbon and nitrogen. By using a high-output computational platform and scanning through the formation energies of millions of alloying configurations, researchers estimate that there are more than a million stable MXene compounds remaining to be discovered (ACS Nano).

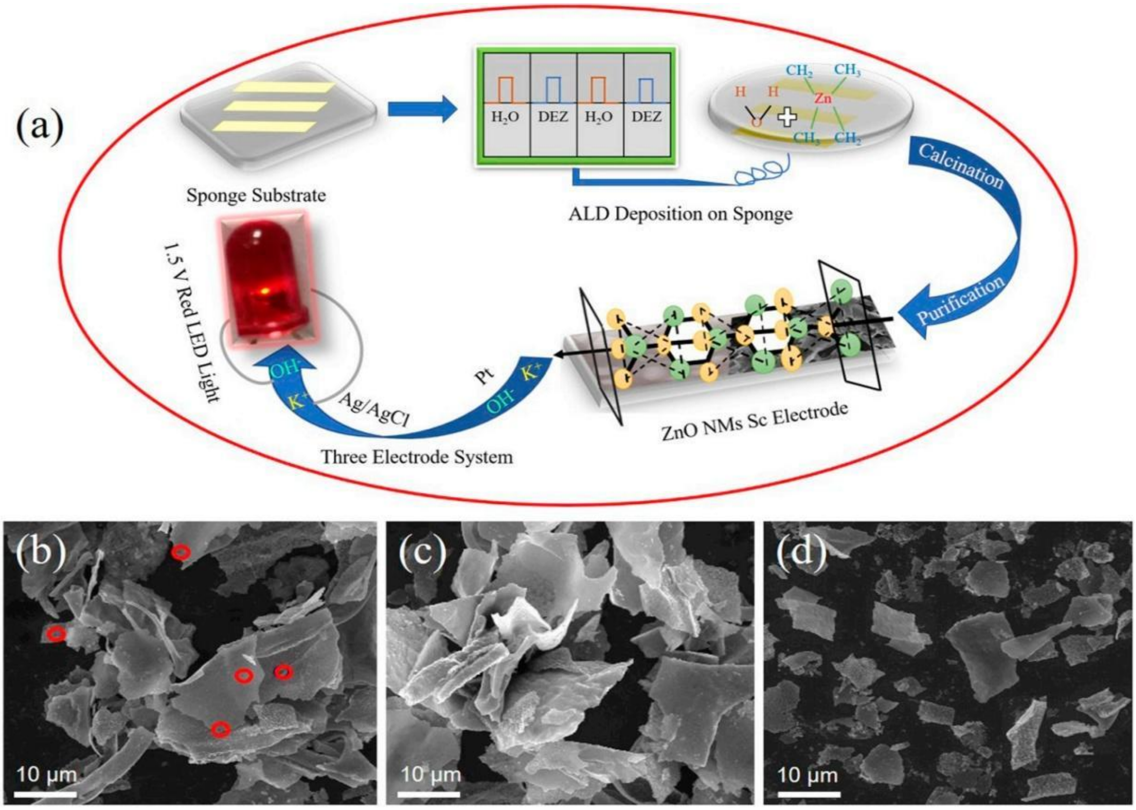

Fig 3: ZnO electrode for product design

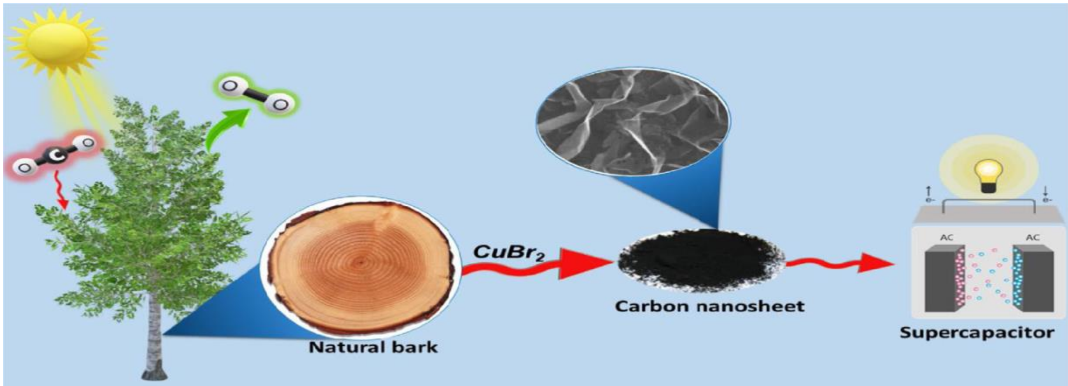

Fig 4: Naturally prepared Carbon Nanosheets for supercapacitor applications

3 Discussion

Table 1: *Advantages and Disadvantages of the TFE*

Methods	Materials for TFEs	Advantages	Disadvantages
Hydrothermal	Carbon materials	High conductivity, long cycling stability	Low specific capacitance
CBD	Metal oxides	Large specific capacitance	Low conductivity
Oxidative Polymerisation	Conducting polymers	Large specific capacitance, good conductivity	Poor cycling stability
Sol-gel	Metal nitride	High conductivity	Low specific capacity
Chemical Vapour Deposition	Transition metal dichalcogenides (TMDs)	Tunable band gap, 2D channels	Poor structure stability
Hydrothermal	MXenes	High conductivity, good mechanical property, good hydrophilicity 2D channels	Stacking issue

4 Conclusion

With the literature survey and available local facilities, it is has been observed that the chemical bath deposition method has great advantages over the other method viz. large specific capacitance, good porous structure with the adhesion of electrolyte on a substrate. The main advantage of CBD is that it requires only solution containers and substrate mounting devices which is very simple and easily available. The chemical bath deposition method gives stable, adherent, uniform, and also hard films with good reproducibility. Thin films growth depends on growth conditions, such as duration of deposition, composition, and temperature of the solution, and topographical and chemical nature of the substrate.

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