SYNERGISTIC EFFECT OF METAL – METAL OXIDE MATRIX NANOCOMPOSITES FOR SUPERCAPACITOR APPLICATION

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Abstract: Metal - metal oxide matrix nanocomposite material has advanced vastly in electronics application particularly in energy storage. It has found appropriate for supercapacitors application with high storage. Matrix is fabricated with nano metals or nano metal oxide for better physical, chemical and mechanical properties. The main advantage of these nanocomposites is high constancy, cost effective, light weight, effortless to fabricate, excellent capability intended for energy storage and owing to these reasons many investigation has done to improve the capability of the supercapacitors. Metal matrix nanocomposites can be reinforced by the combination of metal such as Al. Ag, Zn and metal oxides such as Fe_3O_4, ZnO, and MgO2 respectively, various methods can be used to synthesise but it depends on the application. This work is intended in reviewing most suitable method and material for supercapacitors application.

Keywords: metal-metal oxide matrix nanocomposites, method of synthesizing, sol-gel, direct coating, chemical vapour deposition, vacuum filtration method, CV analysis.

I. INTRODUCTION

A meal matrix nanocomposite is formed by the reinforcement of nano metal by several methods due its specifications in energy storage, in recent years several researches have made to explore its competence. Metal matrix nanocomposites has more advantageous comparing with basic materials and it is found suitable in electronics applications such as supercapacitors, diode and transistor respectively due to reduction in size, attains high significant in many field of research [1,2]. Capacitance of these heterogeneous materials depends on factors such as nanofillers shape, molecular orientation and interfacial interaction. Synergistic effect of metal or metal oxide makes more advanced in capacitance research. Nanofillers ought to encompass some of the specifications such as no toxic, operational window and theoretical value should be high, effortless in synthesizing, environment stability etc., makes appropriate material intended for electrode. Capacitors are categorized into two types as Electric double layer capacitors (EDLC) and Pseudocapacitor. EDLC stores electricity as electrostatic manner and carbon based material act as a electrode while in pseudo capacitors [3]. Transition-metal oxides/hydroxides have gained particular

attention for the advancement of high energy density electrodes even though they can yield vastly higher energy densities, consequently, a handful of techniques have been invented to create significant energy on oxide-based supercapacitor electrodes [4,5]. For better overall electrochemical performance, a specific strategy is to combine metal oxides with carbon - containing materials and/or conducting polymers, even as carbon materials can strengthen electric conductivity and contribute to rate and cycling performance. The basic difference between EDLC, Pseudocapacitor and hybrid capacitor is tabulated in Table 1.

TABLE 1 Basic comparison of supercapacitors

Electrochemical double layer capacitor (EDLC)	***Pseudocapacitor***	***Hybrid capacitors***
A component for electrodes is carbon.	Electrode materials include Metal oxides and Conducting polymers.	Both combinations are applied
Non fabric process	Fabric process	Both fabric and non-fabric process

In this review paper we have reported various methods of synthesizing electrodes with advanced properties of supercapacitors in future.

II. SYNTHESIZING METHODOLOGIES FOR ELECTRODE MATERIALS

There are several methods used to synthesize electrodes for the better results in supercapacitor applications, recent years more advanced features of techniques have been used to prepare electrodes with high life cycle and advance storage capability.

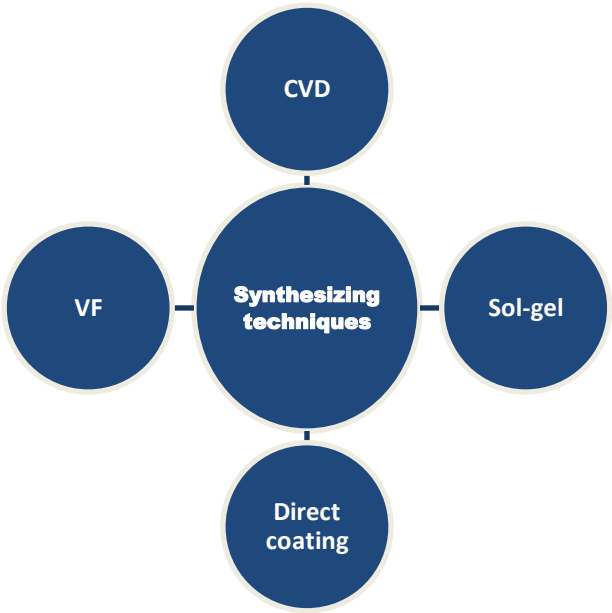

Fig. 1 diverse methods of synthesizing Supercapacitors electrode

a. Sol – Gel method

This method is used for high purity and homogeneity materials. It got its name by the resultant of the precipitate as sol-gel form, combined together with high purity. Several researchers have approached sol gel method such as Yusin and his team reported that $Ni(OH)_2$ can be prepared with the combination of ACMF and results revealed that the sample was better algometric and suitable for the capacitance with C_s in the range of 370 to 382 F/g, he also added that the results depends on the composites structure, shape and crystallinity. Thin film shaped supercapacitors have been developed by Liu and his team to strengthen the capability of the capacitance by using $NiCo_2O_4$ as main composite material. The results were more advanced as C_s with the rate of 2157F/g at 0.133mAcm^{-2} with better cyclic stability. From this analysis it is evident that sol gel method is suitable for supercapacitor application [6-8].

b. Direct Coating method

Mixing of constituent materials directly for the supercapacitor electrode and the resultant will be as slurry and applied to the substrate. Various polymers are used by the combination of electric conductivity material such as metal oxides and carbon related compounds. The host material is used as metal oxides such as Nio, ZnO CuO MnO_2 is mixed up with the polyvinyl alcohol, polypyrrole etc [9-11]. Latest investigation has undergone by the combination of NiO and PVDF, Jana and his research team to fabricate the supercapacitor electrode, from his investigation 10% of PVDF is mixed with 90% of Nio on to stainless steel result proves that the electrode is highly stable with storage capacity but the results were not succeeded as other methods

c. Vacuum Filtration method

This is advanced and easily processing method of nanocomposites for supercapacitor application. This technique involves vacuum filtration and filtrate of the composite materials. One of the researchers Zhang has developed graphene – Ni nanocomposites with better results such as good cyclic property, C_s approximately180F/g at 0.5mA cm^{-2}. Another composite of polymer incorporated with graphene reveals better result with discharge cycle of 5000 charge / discharge cycle [13-15]. These results suggested that Vacuum filtration method has succeeded in the application of supercapacitor.

d. Chemical vapour deposition method

This method is commonly used in all types of applications such as dielectric, electric conductivity, supercapacitor and battery applications. The process of synthesizing is under vapour pressure at various temperatures. Graphite based materials is suitable for this process and various metal oxide such as MgO, CuO etc can be mixture together as to obtain high capability of capacitance [16-19]. Kamal and his research team has performed a hybrid supercapacitors by the combination of graphene and MgO with high cyclic capacity and E_s.

III. ELECTRODE MATERIALS

Supercapacitor electrode should have some of the specification such as healthy chemical stability, high corrosion resistance, cost effective and environment friendly.

The ability of charging and discharging capability should be sustained with higher values for long life thus life cycle of the electrode has to be in higher level, small pores can be used for better E_d.

a. CPs based electrode

Conducting polymers have attained higher achievement in the supercapacitors by the combination of metal oxide owing to the specifications such as lost cost, non toxic and easily available. Organic material based supercapacitors have developed due to the availability of metal oxides from it. Polythiophene incorporated with $FeCl_3$ is one of the best investigations with C_s as 117F/g also the same nanocomposite has been altered with small band gap with maximum conductivity of 10^{-3} S/cm. PANI-Eml nano petal is the another interesting nanocomposite which attains better C_s in the range of 420 -600Wh/Kg. All these results suggested that these combinations of materials are suitable for supercapacitor application [20].

b. MOs Based electrode

Metal oxide or transmission metal oxide is highly significant material for supercapacitor application due to all the properties of supercapacitor application. The availability of these materials is getting lower due to the high usage in many fields. Recent research has been undergone to obtain MOs from natural resources such as plants and animals, but it is developed only from the plants [21]. Highly suggested MOs such as NiO, MnO_2 Fe_2O_3 etch has suggested by BE Conway due to higher capability of E_s and charging and discharging ability. Various researchers such as Rao, Wang, Juodkazhis has revealed that Co_3O_4 MnO_2, RuO_2 has achieved C_s as 548 F/g, 476 F/g and 3800F/g, which leads to higher suitability for supercapacitor application.

IV. CONCLUSION

Supercapacitors composed from electrochemical material are proved to be efficient energy storage technology. The electrode materials derived from carbon materials, CPs, MOs, and their composites were described in detail in this review. For high-performance SC electrodes that can simultaneously guarantee high capacitance, cyclic stability, and excellent rate, more is needed. For the goal of developing high-performance SC electrodes, the review finds that more exploration should be focused on various nanocomposite materials made of carbon, MOs, and CPs

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