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Research paper

Study of PVDF Based Electrode Structure in Supercapacitors

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Abstract

Because of increasing demand there is a need for energy storage.Supercapacitor the new age energy storage device which can provide quick burst of energy. The study focuses on use of Polyvinylidene fluoride as the binder material in making of electrodes for supercapacitors. Polyvinylidene fluoride (PVDF) is a highly non-reactive thermoplastic fluoropolymer produced by the polymerization of vinylidene difluoride. It is a strong piezoelectric element. Piezoelectric effect is useful for generation of high voltages. Binder materials are responsible for holding the active material particles within the electrode. The study was focused on use of PVDF in Electric Double Layer Capacitors (EDLC) and Pseudo capacitors. In case of Electric Double Layer Capacitors the PVDF is used as binder material with activated carbon as electrode material. In case of Pseudo capacitor the PVDF is used as a binder material with activated carbon and metal oxide as electrode material. Research was performed with preparation of electrodes using 6 types of Activated carbons namely Vulcun XC 72, Pica, RP20, C60, NORIT and Graphene for different compositions. The test was conducted on single electrode and it was initially charged at a voltage of 2.2V and its discharge was recorded for a time period of 3 minutes. The research focuses on the material which is giving the best results in regarding to the key parameters of supercapacitors and also concentrates on the composition of Polyvinylidene fluoride (PVDF) which gives the highest value of capacitance with the lowest value of Equivalent series resistance in making electrodes for supercapacitors.

Keywords: *Capacitance; activated carbon; Equivalent series resistance; binder material; piezoelectric.*

1. Introduction

Energy storage is the key component for creating sustainable energy storage systems. Energy storage technologies have the potential to offset the sporadic problem of renewable energy sources by storing the generated intermittent energy and the making it accessible upon demand. Current technologies such as solar photovoltaic's and wind turbines can generate energy in a sustainable environment friendly manner; yet their intermittent nature still prevent them from becoming the primary energy carrier. Currently the dominating energy storage device remains the battery particularly lithium ion batteries but the problem with the batteries are they store energy electrochemically that means with the passage of time the storage capacity will decrease hence resulting in low cycle life [1].This problem is addressed by supercapacitors which uses different storage mechanism. In supercapacitors energy stored electro-statically that is on the surface of material and does not involve the chemical reactions. This is the reason binder material and electrode material plays an important role in supercapacitors. Presently supercapacitors face the problem of low energy density because of poor material composition. The Supercapacitors as an energy storage device provides high power with quick burst of time and magnificent cyclic stability. Hence supercapacitors found in applications requires many rapid charge and discharge cycles. Supercapacitors found its application on various electrical vehicles as a reserve for batteries; it is also used as power provider to gazettes which needs quick burst of energy such as camera flash which requires sufficient energy of light to focus under specific area in small period of time. Normally electrodes are fabricated by brushing the slurry on the metal substrate. The slurry is prepared by stirring the mixture of active material, binder and conducting agent together. The property of binder is to avoid the active material from falling off during working of electrode, increases the mechanical strength of electrode and pore size respectively. The use of binder enhances the electrochemical performance of supercapacitors. PVDF is used as binder material in making electrodes which has properties of high thermal stability, high dielectric constant, and excellent mechanical strength. Polyvinylidine difluoride is highly non reactive thermoplastic fluoropolymer produced by polymerization of vinylidene difluoride [2].

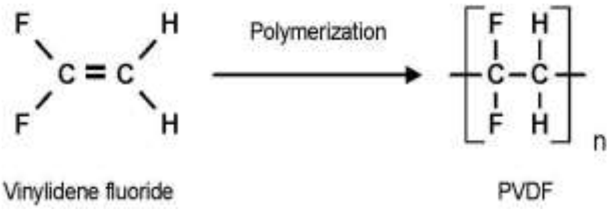

Fig.1: Chemical structure of Polyvinylidene fluoride

The electrodes play the key role in efficiency of supercapacitors. Wrong selection of electrode material or wrong composition of electrode and binder material often affects the key parameters of supercapacitors. Hence it's important to find the correct composition as well as correct electrode material for preparation of supercapacitors. The correct composition can be given mathematically as there is linear relationship between efficiency of electrode material and capacitance of supercapacitors.

2. Experimentation and Results

2.1 Experimentation:

The electrodes are prepared by brushing the slurry on wire mesh. The slurry preparation is different for two types of super-capacitors.

2.1.1Electric Double Layer Capacitors:

Different composition of Polyvinylidene Fluoride (PVDF) is dissolved in dimethyl sulphoxide (DMSO) solvent and then in this mixture activated carbon is added. Again solvent is added in to the mixture to bring honey like texture.

2.1.2 Pseudo capacitors:

Different composition of Polyvinylidene Fluoride (PVDF) is dissolved in dimethyl sulphoxide (DMSO) solvent and then in this mixture activated carbon and metal oxide is added. Again solvent is added in to the mixture to bring honey like texture.

The prepared electrodes were heated at a temperature of 200 to 300 degree Celsius in a muffle furnace for about 45 min. Then these electrodes were immersed in aqueous electrolyte which is made by using Potassium sulphate (K2SO4) and the electrodes were tested at the voltage of 2.2V and discharge current is noted for 3 minutes.

2.2 Results:

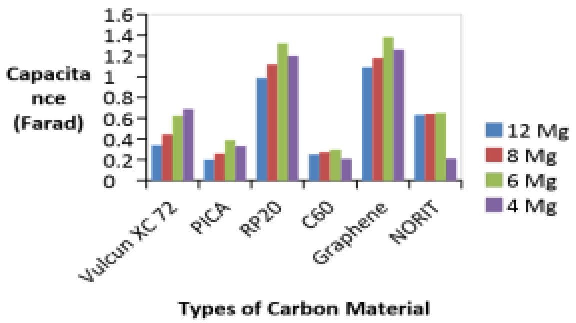

Fig.2: Comparison of Capacitance for various types of activated carbon materials with different Composition (For EDLC).

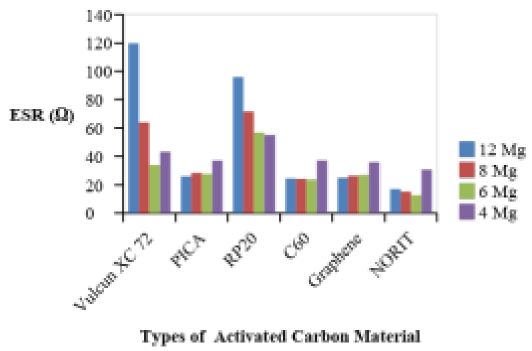

Fig.3: Comparison of Capacitance for various types of activated carbon materials with different Composition (For EDLC).

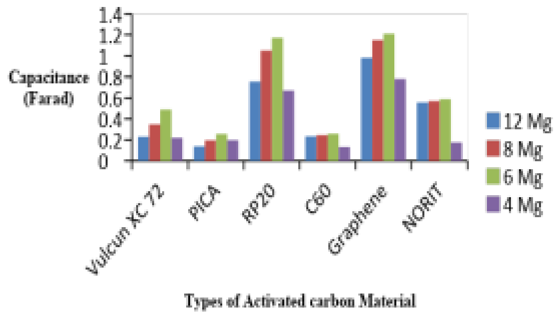

Fig.4: Comparison of capacitance for various types of activated carbon materials with different Composition (For pseudo capacitors)

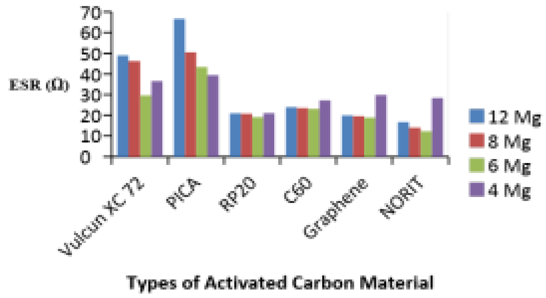

Fig.5: Comparison of ESR for various types of activated carbon materials with different Composition (For Pseudo capacitors)

2.3 Mathematical Equation:

A mathematical proportion can be formulated as to how much PVDF should be taken for total slurry of PVDF and activated carbon, through this study the lab experiments have shown 6 mg PVDF material used as binder material given the best results in case of capacitance and equivalent series resistance when total slurry of activated carbon and PVDF was 240 mg hence it can be said in case of 6 mg

$$PVDF=1/40x \quad (1)$$

1/40 is the multiplying factor which has given the best result in this experiment and x represent the total slurry of PVDF and activated carbon used.

3. Conclusion

The presented work focused on the problem of poor composition and choice of electrode material. The experiment shows the importance of composition of electrode and binder materials used in making of supercapacitors. The work also reflected the importance of PVDF as a binder material coupled with the electrode material to enhance the key parameters of supercapacitors. The PVDF as a binder material prevents the activated carbon material from falling off during the discharging process of supercapacitor. The work gives an insight on mathematical equation for the composition of PVDF to be used with electrode materials in the preparation of supercapacitors. The lab results showed RP-20 and Graphene gives best results in case of key parameters of supercapacitors. This work also shows that 6mg composition of PVDF gives the best results in terms of capacitance and equivalent series resistance of supercapacitors. .PVDF is known as a polymeric binder, PVDF when mixed with aqueous solution forms a latex type formation due to which activated carbons stick to it during discharge process hence leading to less contact area between binder material and electrode material resulting in less internal resistance. When PVDF is used as binder material with Mno2 in Pseudo capacitors the results are better as compared to Electric Double Layer Supercapacitors. Use of PVDF causes improved electrochemical performance which can be attributed to the formation of chemical bonds that leads to rapid electron transfer and low charge transfer resistance. presently adhesive are used as binder material which increases the contact area between electrode material and binder material hence this study also provides a novel idea of using PVDF as binder material to reduce the ESR in supercapacitors.

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