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Development and utilization of integral thin film capacitors

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Abstract

Since the deficiency of petrol, electric vehicles have great potential in the future transportation. The paper discusses some batteries used in the electric vehicle. Since the unique characteristics, integral thin film capacitors become the research focus. The properties and categories of the materials in the capacitors are introduced, as well as the methods to improve the energy density.

Keywords: capacitors; electric vehicles; dielectric constant; energy density

1. Introduction

Energy is the driving force of social development and all the human activities are based on energy, so energy consumption is the premise for social development. Life level is directly related to the energy consumption, and the increasing of comfortable life will need consume much energy. Energy is always insufficiency for people. How to make a good use of the limited energy has been subject discussed by people and attracted wide attention around the world recently. According to studies, the energy utilization rate is not high, as well as the capacity of energy storage materials is low. So it is necessary for human to find a way to improve energy utilization as far as possible.

To develop high performance energy storage capacitor is one significant aspect of new energy resource exploiting. The function of capacitors is storing energy when the energy is sufficient and releasing the stored energy to use when energy is insufficient. At present, the batteries are the main equipment to store electric power, but due to the inherent deficiency of electrochemical cell, such as slow charging and discharging speed, high energy consummation, potential safety problem and so on restrict the application of batteries in high power machinery such as electric vehicles. The capacitors with special physical storage mechanism has great advantage over the batteries for following advantages: not

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containing harmful metals (such as lead, etc.) will do not cause secondary pollution to the environment, much more charge and discharge cycle times, rapid charge and discharge speed, no change of form of energy during the charge and discharge process, being independent on the ambient temperature [1].

2. Energy-storage theory for integral thin film capacitors

The energy storage of integral thin film capacitors is influenced by the voltage and capacity, which can be shown in equation (1) [2]:

$$E = \frac{1}{2} C V^2 \tag{1}$$

where E refers to the stored electric energy of the capacitors, V refers to the broken-down voltage, C refers to the capacity of the capacitor.

From equation (1), there are two ways to acquire high E, one is to elevate the capacity (C), and the other is to increase the broken-down voltage (V). While in practice, there has been some specific ways to enhance the energy. Some are to increase the film number of the integral capacitors, such as MLCC, and others are to use the high dielectric constants materials as the film material, such as BT, CCTO or composite.

3. High permittivity dielectrics

Dielectrics offering great potential for high energy density and high charge speed can be used in the integral thin film capacitors to replace the discrete surface mount capacitors for bypassing, decoupling, termination and frequency determining functions. So far, there are three kinds of dielectrics used in the capacitors, ceramic dielectrics, polymer dielectrics, and ceramic-polymer composite dielectrics.

3.1. Ceramic dielectrics

Ceramic dielectrics mainly contain two categories, ferroelectric ceramic and semi-conductor. Such ceramic has very high dielectric constant ranging from 3 to more than 10000. For example, $Pb(Mg_{1/3}Nb_{2/3})O_3$ has as high as 10^4 at room temperature [3].

Though ceramic has considerably colossal permittivity, their flexibility and mechanism are not good. Ceramic is hard to be made into films, which restricts its use in thin film capacitors.

3.2. Polymer dielectric

Since 1960s chemists have conducted much research for the dielectric properties of polymers. They found that some polymers have relatively high dielectric constant. The dielectric constant of PVDF is 8.4, higher than that of SiO_2 (2.5). They also found that the dielectric constant is related to the polarity of polymer molecule. And most polymers whose dielectric constant is high have large polarity.

Compared with ceramic dielectric, the dielectric constant of polymer is low, but it has good flexibility and mechanism, which is the advantage over the ceramic in the application of thin film capacitors.

3.3. Ceramic/polymer composite

Since the ceramic and the polymer have intrinsic defaults, and can not meet the demands of the thin film capacitor, scientists try to prepare a composite made of ceramic particles as fillers and polymer as matrix so as to make full use of the advantages of the two dielectrics. The results show that the composite has both high dielectric constant and good mechanism and flexibility.

According to the size of the ceramic particles, the composite can be divided into nanocompostie and microcomposite. As the nano-particles have special chemical and physical characteristics, when it is added into the polymer, the composite could has some effects in the interfaces, and such composites have better integrated characteristics, which can be widely used in the thin films capacitors.

Table 1 shows the dielectric properties of some typical dielectrics.

Table 1. The dielectric properties of some typical dielectrics.

Dielectrics	Measured conditions	Dielectric constant	Ref
BT ($BaTiO_3$)	25 ℃, 1 kHz	≈2000	[3]
CCTO ($CaCu_3Ti_4O_{12}$)	25 ℃, 1 kHz	10^5	[4]
PVDF	25 ℃, 1 kHz	8.4	[5]
BT/PVDF	25 ℃, 1 kHz	≈18	[5]

4. Integral thin film capacitors used as the electric vehicles battery

Since the deficiency of the petrol energy, almost every country and community is dedicated to develop electric vehicles to deal with the energy crisis. Electric vehicles use batteries as the power rather than the gas, so it not only can be a good solution to the energy crisis but also release minor pollution such as carbon dioxide to the environment [4]. As electric vehicle batteries require high energies density, there are several kinds of batteries now which could be used, such as lithium battery, nickel-hydrogen battery, fuel cells. For the considerably high energy density and rapid charge and discharge speed of the integral thin film capacitors, it can be a good choice to the electric vehicles batteries [6].

Lithium ion battery is a conventional battery which has high energy density, being environment friendly and cheap, has attracted great attention of car and batteries manufacturers, but its stability, security and high cost restrict its future application. Though nickel-hydrogen battery has rapid charge and discharge speed, its low energy density cannot meet the demands. Fuel cells have high energy density, but it is so expensive that manufacturers would not like to use it. While with the unique characteristics, integral thin film capacitors can fully meet the demands of the electric vehicles batteries, and such capacitors have become the focus of research now. Table 2 shows the performance of the electric vehicle batteries.

Table 2. The performances of electric vehicle batteries [7].

Batteries	Energy per weight/($Wh\cdot kg^{-1}$)	Cycling times	Charging time
Lithium battery	120.0	1200 times	6.0 h
Nickel-hydrogen battery	80.0	1000 times	1.5 h
Fuel cells	230.0	10 years	Don't need charging
Thin film capacitors	342.0	10000000 times	3-6 minutes

From Table 2, it can be concluded that the thin film capacitors have larger advantage over other batteries in the aspects of energy density, cycling times and charge time. Such capacitors can basically improve the role the electric vehicles in the future transportation.

Nowadays, many countries are dedicated to applying the capacitors to electric vehicles. For example, the fuel cells-super capacitor hybrid vehicle of Honda's FCX is the earliest vehicle which is commercialized. Moreover, the capacitors developed by Maxwell Company have been widely used in variety of electrical vehicles and bicycles [8-10].

5. Conclusion

Thin film capacitors have drawn more and more attention for its unique power characteristics and high energy density. It can be the only power source for electrical vehicles as well as hydride power source mixed with other batteries to enhance the power. It is much promising in the field of electrical vehicle by optimizing every technologies.

References

[1] Yu LF. Thin-film capacitor and flat mini thin-film capacitor overview. *Markets & Trends* 2003; **11**: 18–19.

[2] Ramaj L. Effect of silane as coupling agent on the dieleetrie properties of $BaTiO_3$-epoxy composites. *ComPosit* 2007; **38**: 1852–1859.

[3] Homes CC, Volt T, Shapiro SM. Optical response of high-dielectric-constant perovskite-related oxide. *Science* 2001; **293**: 673–676.

[4] Subramanian MA, Sleight AW. $ACu_3Ti_4O_{12}$ and $ACu_3Ru_4O_{12}$ perovskites: high dielectric constants and valence degeneracy. *Solid State Sciences* 2002; **4**: 347–351.

[5] Dietze M, Souni M. Structural and functional properties of screen-printed PZT PVDF-TrFE composites. *Sensors and Actuators A-Physical* 2008; **142**:329–334.

[6] Market T, Simpson A. Energy storage consideration for grid-charged hybrid electric vehicles. IEEE Vehicular Technologies Conference, Chicago, 2005; p. 7–9.

[7] Wang HY, Zhang JH, Yang CR, Chen HW. Research progress of super ceramic capacitors. *Electronic Components and Materials* 2010; **29**: 68–70.

[8] Cao BG, Cao JB, Li JW, Xu H, Xu P. Ultracapacitor with applications to electric vehicle. *Journal of Xi'an Jiaotong University* 2008; **42**(11): 1317–1325.

[9] Xu JH, Wang R, Chen JK, Wang Y. Research progress on application of supercapacitor in electric vehicles. *Chinese Batteries Industry* 2008; **13**(5): 344–348.

[10] Zhang DJ, Ouyang H, Hu H. Application of supercapacitor on electric vehicles. *Auto Engineer* 2009; **6**: 56–58.