Semiconducting Nanoparticles/PVDF Nanocomposites with High Dielectric strength for Capacitive Energy Storage

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By

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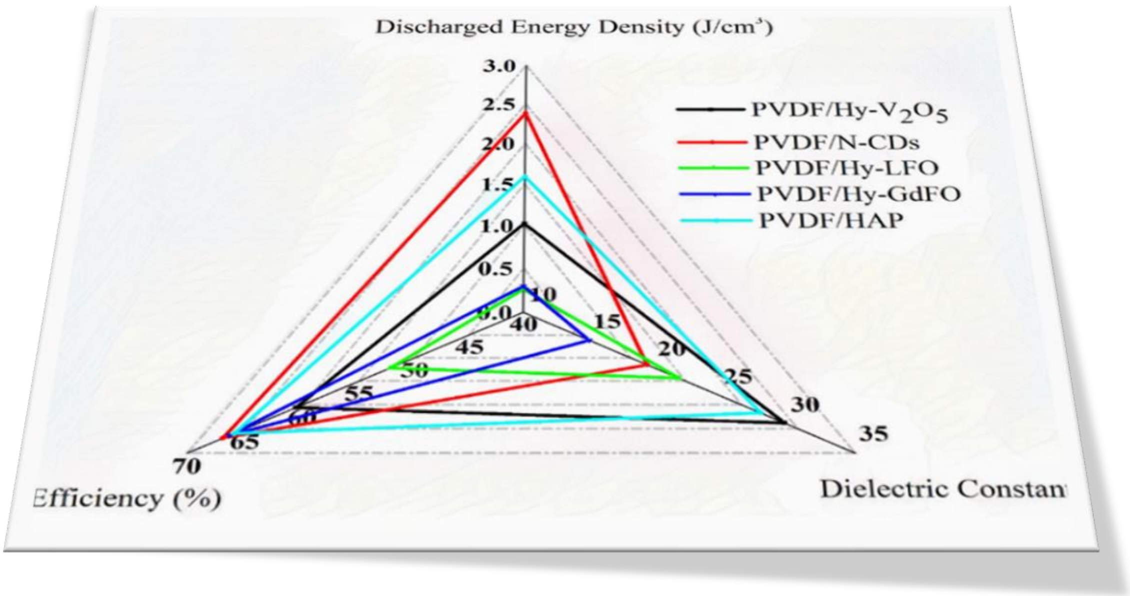
Chapter 7

Summery and suggestions for future



9.1 Conclusion

We have demonstrated the promising potential using semiconducting fillers to PVDF based nanocomposite and employed it as capacitive energy storage device and the understanding the mechanism of the enhancement of the dielectric properties of nanocomposite with the help of semiconducting nanoparticles loading in the PVDF matrix as nanofiller

The PVDF based flexible capacitors that employed the semiconducting fillers enabled increased dielectric with high polarization resulted in enhancement in the capacitive energy storage and maintained the high efficiency, breakdown strength without degrading the mechanical properties as the film can be able to withstand higher electric field supply. The large value of the energy density is due to the large value of the polarization of the nanocomposite films, the higher breakdown strength also contributes in the same. The goal of this research is to understand and optimise the processes involved in the synthesizing the PVDF nanocomposite dielectric films that include a high dielectric constant, high discharged energy density, a suitable breakdown strength, and a low cost.

The main findings of our research work are followed.

1. The PVDF/Hy-V_2O_5-based flexible nanocomposite films with different amounts of filler were synthesized using a simple solution-cast method. We discussed in detail about how Hy-V_2O_5 filler affects the dielectric property, phase structure, and energy storage density of nanocomposite films. The DSC helped in to know the phase of the pure PVDF and its nanocomposite films. Crystallinity of the film also increased with the loading of the filler. The XPS analysis is done to check the presence Hy-V_2O_5 in nanocomposite films. AFM micrographs and an isotropic PSD profile were used to get idea of the storage phenomena of film. The dielectric constant increased from 9 (pure

PVDF) to 29.86, and the maximum discharge energy storage density went from 0.32 (pure PVDF) to 1.024 J/cm^3 (a 220% increment). This was done with just 5% of Hy-V_2O_5 in the PVDF matrix, which maintained the breakdown strength at 1766.93 kV/cm. Overall, the work shows that loading of semiconducting Hy-V_2O_5 to PVDF film makes its storage properties better, so PVDF/Hy-V_2O_5 nanocomposite can be used as flexible energy storage films.

2. An effective strategy is shown for improving the dielectric and ferroelectric properties of a PVDF/N-CDs nanocomposite film so that it can be used in energy storage devices. Solvothermal was used to make the N-CDs, and HR-TEM was used to figure out their size distribution. Using Tauc's plot of UV-Vis spectroscopy, the band gap of N-CDs was found. Loading of N-CDs as fillers into the PVDF matrix helped developing more amount of the electroactive phase of PVDF, which led to an increase in the nanocomposite's dielectric constant and energy density. Weibull probability analysis is used to figure out which nanocomposite films, including pure PVDF, have the best dielectric breakdown strength. With the addition of N-CDs as filler, the dielectric constant (ε_r = 19.59) and energy density (U_d= 2.38J/cm^3) get a big boost.
3. Sb_2O_3 is hydroxylated, and its phase is found with the help of XRD and FTIR, which showed that it has a pyrochlore structure with Fd3m (227) space group that is actually hydrated antimony pentoxide. In this work, the solution cast synthesis process for making a nanocomposite film was used. With the help of XRD, FTIR, and SEM, the phase and structure of the synthesized PVDF/HAP nanocomposite films studied and analized. With 8 vol%, the dielectric constant is 28.08, Pmax is 2.88 (μC/cm^2), and the energy density is 1.59 J/cm^3, which is better than pure PVDF at 1400 kV/cm.
4. Using a high-energy ball mill, we synthesized the orthorhombic $LaFeO_3$ and $GdFeO_3$ nanoparticles. The facile solution cast method was used to make nanocomposite films

out of polyvinylidene fluoride (PVDF) matrix and rare earth ferrite. With the help of FESEM, morphological analyses show that the films are smooth and have no flaws. There are also no spherulites in the films. The hydroxylation of ferrite fillers can be seen with FTIR, XRD and FTIR analyses show that polar phases (β, γ-phase) are in dominance. At higher temperatures, the dielectric properties of nanocomposites are better than those of pure PVDF (ε_r = 58). The experimental values for dielectric properties have been used to compare the three theoretical models. With the help of loaded hydroxylated $LaFeO_3$ filler and $GdFeO_3$, we were able to improve the nanocomposite's dielectric constant (ε_r = 22) and ferroelectric properties (Pm = 1.01μC/cm^2). We also got a better energy density (0.294 J/cm^3) and found that the discharge energy efficiency was around 66.37%.

Final conclusion includes,

The semiconducting filler have enhanced the capacitive energy storage properties with large enhancement in the energy density. The enhancement with the fillers is considered due to the phase change from non-polar to polar phase with measure contribution of the space charge polarization. The phase change has been evidenced with the help of XRD analysis, DSC analysis and FTIR spectroscopy. Space charge polarization evidence is with the help of the impedance spectroscopy as the frequency increased from 10^3 to 10^6 Hz, the value of the dielectric constant decreased. The improvement in the electric polarization was attributed to the Maxwell-Wagner interfacial polarization as the result of space charge accumulation and formation of Gouy-Chapman-Stern Layers at the highly interactive interfaces among the multiple dielectric materials. There has not been substantial decrement in the breakdown strength with the semiconducting filler loading due to low amount.

9.2 Suggestion for the future work

This work is dedicated to the improvement of the dielectric storage properties that leads to enhancement in the energy density. The films have been synthesized with the low-cost solution cast methods. More sophisticated methods can also be used to synthesize better films. The spin coater might be a better choice to make very thin film so that higher value of applied electrical field during the PE loop analyzer could be reached.

Few important suggestions are given below to future work to get better outputs.

- The fillers of different shape and size can be used with the different modifying agents to get better nanocomposite with the PVDF or any other polymer like Nylon.
- Intermolecular interactions are present between the filler nanoparticles and PVDF matrix functional groups which contribute to get better breakdown strength and energy density. To understand and analyze the intermolecular interaction, there could be better theoretical studies and methodologies.
- The interfacial interaction or space charge polarization have remarkable contribution in the enhancement of the dielectric constant and energy density. We have just got the idea of interfacial interaction with the help of the impedance spectroscopy dielectric properties (dielectric constant vs frequency). The better characterization techniques can be used to measure the interface thickness between the nanoparticles and PVDF. A suitable HRTEM can be used to measure the thickness.
- Further, theoretical techniques with the simulation can also be used to understand the filler behaviour and it's compatibility with the matric to synthesize better nanocomposite.