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High-Energy-Density Poly(styrene-co-acrylonitrile) Thin Films

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The dielectric response of poly(styrene-co-acrylonitrile) (PSAN) thin films fabricated by a solution casting process was investigated in this work. Linear dielectric behavior was obtained in PSAN films under an electric field at frequencies from 100 Hz to 1 MHz and temperature of −50°C to 100°C. The polymer films exhibited an intermediate dielectric permittivity of 4 and low dielectric loss (tan δ) of 0.027. Under 400 MV/m, the energy density of the PSAN films was 6.8 J/cm^3, which is three times higher than that of biaxially oriented polypropylene (BOPP) (about 1.6 J/cm^3). However, their charge–discharge efficiency (about 90%) was rather close to that of BOPP. The calculated effective dielectric permittivity of the PSAN films under high electric field was as high as 9, which may be attributed to the improved displacement of the cyanide groups (–CN) polarized at high electric fields. These high-performance features make PSAN attractive for high-energy-density capacitor applications.

Key words: Poly(styrene-co-acrylonitrile), linear dielectric, high energy density, low dielectric loss

INTRODUCTION

Polymer capacitors capable of storing high electric energy densities are highly desirable for a broad range of modern power electronic and electric systems, such as medical devices, hybrid electric vehicles (HEVs), and power weapon systems.[1–5] Commercial dielectric polymers such as polyethylene (PE), biaxially oriented polypropylene (BOPP), and polystyrene (PS) exhibit low energy density below 2 J/cm^3 under 500 MV/m electric field due to their low polarity.[4,6,7] Recently, an extremely high energy density (25 J/cm^3) was achieved in poly(vinylidene fluoride) (PVDF)-based ferroelectric polymers, such as poly(vinylidene fluoride-chlorotrifluoroethylene) [P(VDF-CTFE)] and poly(vinylidene fluoride-hexafluoropropylene) [P(VDF-HFP)],[6–9] which is very attractive for energy storage capacitor applications.

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Besides such high energy storage density, high charge–discharge efficiency and low loss are also desired in dielectric films, considering the concerns regarding safety and stability in high-electric-field applications. Unfortunately, the discharging energy efficiencies of these fluoropolymers are about 60% to 70% because of their ferroelectric relaxation behavior, being much lower than that of BOPP (about 90% to 95%). Their relatively low energy discharging efficiency might limit their applications in energy storage devices, which has attracted much recent research interest to reduce their energy loss by modifying these fluoropolymers chemically or physically.[5,10–13]

Based on the formula of energy density

$$U_e = \frac{1}{2}\varepsilon_0\varepsilon_r E_m^2, \quad (1)$$

where ε_0 is the vacuum permittivity (ε_0 = 8.85 × 10^{-12} F/m) and E_m is the maximum electric field, the energy density is governed by both ε_r and the value of E_m that can be applied to the dielectric. Therefore, great effort has been invested to improve