Controlled Functionalization of Poly(4-methyl-1-pentene) Films for High Energy Storage

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Dielectric materials with a high electric energy density and a low dielectric loss play a very important role in modern electrical power systems, e.g., hybrid electric vehicles, medical defibrillators, filters and switched-mode power supplies. Compared to batteries and supercapacitors, dielectric capacitors offer many unique advantages, such as fast charge and discharge characteristics, a high power density, a high output voltage, and a wide operating temperature range. Compared to other dielectric capacitors, polymer film capacitors are more attractive for the applications mentioned above due to their higher breakdown strength and a more graceful failure mechanism. In addition, the development of dielectric-polymer-based capacitors has been motivated by the increasing demand for compact, low-cost, light-weight and flexible energy storage devices, which makes polymer films the material of choice for the next generation of high pulse capacitors

A new family of poly(4-methyl-1-pentene) ionomers [PMP-$(NH_3)_x$A-y] (x = 1, 2, 3 and A = Cl^-, SO_4^{2-}, PO_4^{3-}, y = NH_3 content) modified $(NH_3^+)_xA^{x-}$ ionic groups has been synthesized. The ionomers were synthesised using either a traditional Ziegler-Natta or a metallocene catalyst for the copolymerisation of 4-methyl-1-pentene and bis(trimethylsilyl)amino-1-hexene. A systematic study was conducted on the effect of the subsequent work-up procedures that can prevent undesirable side reactions during the synthesis of the [PMP-$(NH_3)_x$A-y] ionomers. The resulting PMP-based copolymers were carefully monitored by a combination of nuclear magnetic resonance (NMR), gel permeation chromatography (GPC), differential scanning calorimetry (DSC), mechanical property, dielectric properties, and electric displacement-electric field (*D*-*E*) hysteresis loop measurements. Our results reveal that the [PMP-$(NH_3)_x$A-y] ionomer films show a significantly enhanced dielectric constant (~5) and higher breakdown field (~ 612 MV/m) as compared with pure PMP films. Additionally, these PMP-based films show good frequency and temperature stabilities (up to 160 °C). A reliable energy storage capacity above 7 J/cm^3 can be obtained, and is twice the energy storage capacity of state-of-the-art biaxially oriented polypropylene films, which can be attractive for technological applications for the energy storage devices.