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Preparation and characterization of a novel antistatic poly(vinyl chloride)/quaternary ammonium based ion-conductive acrylate copolymer composites

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ABSTRACT

Antistatic poly(vinyl chloride)/quaternary ammonium salt based ion-conductive acrylate copolymer (PVC/QASI) composites were successfully prepared in a Haake torque rheometer. The surface resistivity of the PVC/QASI composites could be reduced to 10^7 Ω sq^{-1} order of magnitude when the QASI content reached 20 phr (parts per hundreds of resin). The surface resistivity of the composites was slightly sensitive to the relative humidity (RH), showing a good antistatic ability under an RH of 12%. Mechanical properties tests, differential scanning calorimetry (DSC) and scanning electron microscopy (SEM) were also used to investigate the tensile strength, elongation at break, thermal properties, and morphology of the PVC/QASI composites, respectively.

1. Introduction

Poly(vinyl chloride) (PVC) is one of the most common commodity plastics. It has been widely used in the automobile, building construction, and packaging field, due to its low cost, easy method of preparation and the broadening of the properties range [1–5]. However, the surface resistivity of neat PVC is ranged from 10^{13} to 10^{17} Ω sq^{-1}, which especially limits its large applications in some special fields that the antistatic property is required. To overcome the problem mentioned above, the following three methods are commonly used: (1) mixing with antistatic agents, including ionic and nonionic surfactants [6–9]; (2) coating of antistatic agents [10–12], and (3) blending with electron-conductive fillers [13–17], such as carbon blacks and metal fibres. Unfortunately, the normal antistatic agents with relatively small molecular weights cannot endow the PVC matrix with a persistently antistatic ability, due to its deterioration of antistatic performance with time. The traditional electron-conductive fillers suffer the problems of filler migration and decay in the polymer matrix and surface, which would further result in the damage of electronic devices and reduce the use age of the end products [18,19].

Quaternary ammonium salt (QAS), a cationic surfactant, is a conventional antistatic agent. However, its antistatic ability is invalidated under a low relative humidity (RH), because of that there are no enough oxygen atoms in water molecules to coordinate with the lone pairs in nitrogen atoms to dissociate the QAS and obtain more free quaternary ammonium cations under the low RH. Maki has reported a new (ethylene-*co*-methacrylic acid potassium) based ionomer with a fine antistatic property [20,21]. Unfortunately, the dependence of the surface resistivity of the ionomer on RH was not investigated. Recently, we have developed a series of solid-polymer-electrolyte (SPE) based composites having an excellent antistatic property even at a low RH [22–28]. In this article, we have synthesized a novel QAS based ion-conductive SPE (QASI) copolymerized of a side-chain QAS and side-chain acrylates, in which the QAS supplies free ions and the acrylates can effectively dissociate the QAS by coordination effects between N and O atoms [29]. Therefore, a permanently antistatic ability of the synthesized QASIs can be achieved even at a low RH. The soft PVC/QASI composites with different QASI contents have been prepared. The surface resistivity, thermal properties, mechanical properties, and morphology of the PVC/QASI composites are also evaluated and discussed.

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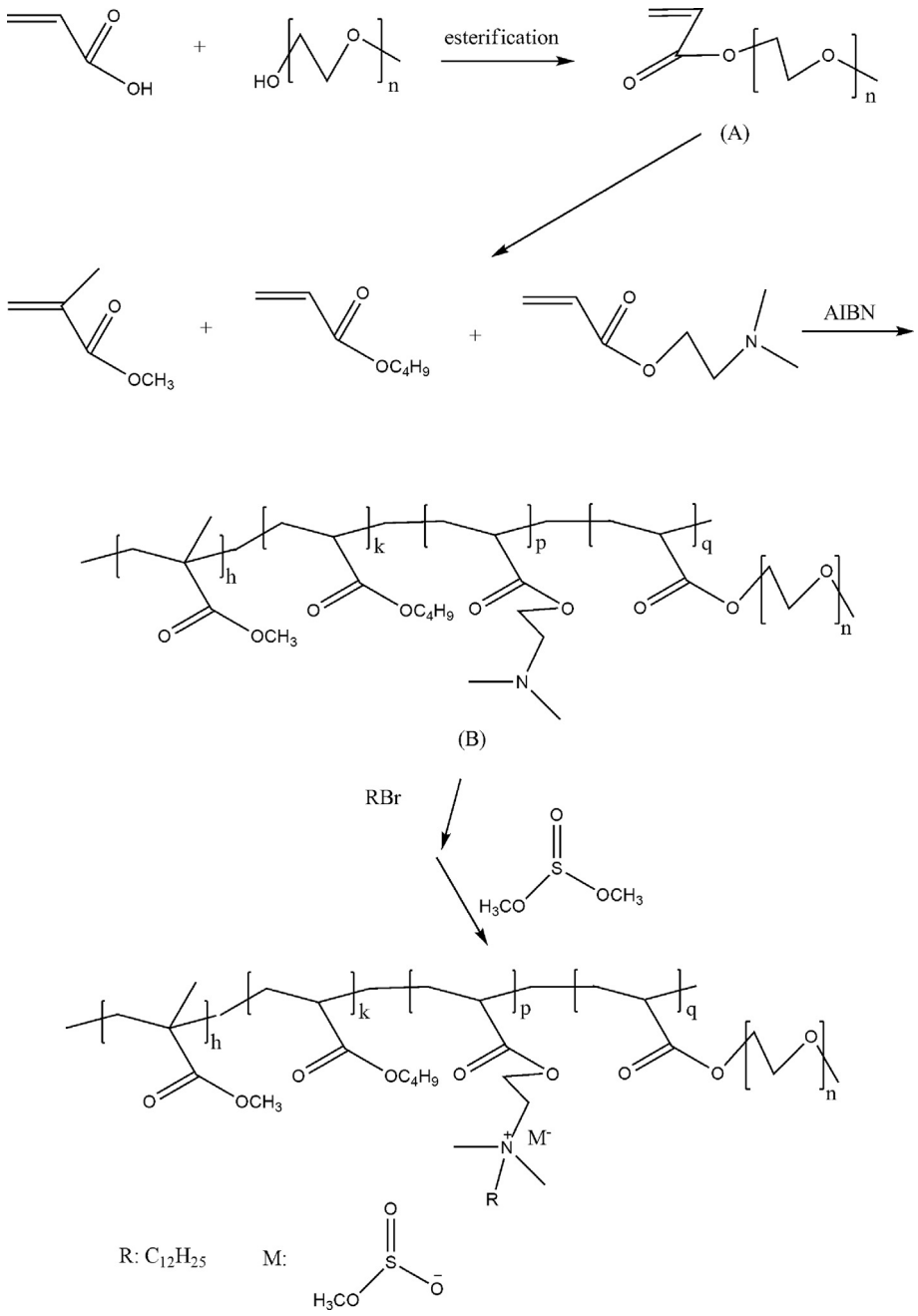

Scheme 1. Synthesis route of the QASI.

2. Experimental

2.1. Materials

Acrylic acid (AA, analytical grade, Kelong Chemical Reagent Co., Chengdu, China), butyl acrylate (BA, analytical grade, Kelong Chemical Reagent Co., Chengdu, China), methyl methacrylate (MMA, analytical grade, Bodi Chemical Reagent Co., Tianjin, China) were distilled under reduced pressure and stored in a refrigerator. Mono-methyl-poly (ethylene glycol) (MPEG), purchased from Jicheng Reagent Co. (Jiangsu, China), was dried under vacuum at 80 °C for 24 h before use. Dimethyl-aminoethylene acrylate (DAEA) was kindly supplied by Changxing Chemical Reagent Co. (Guangdong, China), and used without further purification. All the other chemicals used in the present experiment were analytically pure.

PVC (SG-V) and compound stabilizer (Baeropan SMS318) were provided by Tianyuan Co. Ltd. (Yibin, China) and Baerlocher Co. (Germany), respectively. Dioctyl phthalate (DOP) was purchased from Qilu Petrochemical Co. Ltd. (Shandong, China), and used as received.

2.2. Synthesis of QASI

The QASIs were obtained by the following two stages. (1) The stoichiometric AA, MPEG, catalyst and toluene were added into a three necked flask equipped with a water segregator. The temperature of 110 °C was used for the esterification of MPEG acrylate (MPEGA). The reaction was stopped when the theoretically stoichiometric water was obtained from the water segregator. The solvent of toluene and the unreacted reactants were distilled under reduced pressure. The resulting mixture was precipitated in