

METHOD FOR PREPARATION OF POLYESTER/POLYOLEFIN HOT-MELT ADHESIVE FOR USE IN A SOLAR CELL BUS BAR

TECHNICAL FIELD

This invention relates generally to methods of preparing a polyester/polyolefin hot-melt adhesive, and more particularly to methods of preparing a polyester/polyolefin hot-melt adhesive with a high weather resistance for use in a solar cell bus bar.

BACKGROUND

Bus bar strips, also known as laminated bus strips, are a kind of multi-layer laminated structures used as electrical couplings for power modules. They have a variety of characteristics, such as repeatable electrical properties, low inductance, high interference immunity, high reliability and space-saving, and find increasingly extensive use in power conversion devices thanks to the development of current conversion technology and increasing modularization of converters in this regard. In recent years, in particular with the increasing application of solar cells, there is great demand for developing hot-melt adhesives suited for use in bus bars of solar cells. To meet this demand, the hot-melt adhesives are required to have a light transmittance of 93%~94%, a melting point below the laminating temperature of 140 °C, good mechanical properties, high heat resistance and a thermal oxidative aging caused increase in yellowness index (ΔYI) of about 0.3.

Low-density polyethylene, LDPE for short, is one of the most commonly used polymer materials and is odorless and non-toxic and exhibits a wax like feel. It has excellent low temperature performance with its minimum usable temperature as low as -70 °C ~ -100 °C, high chemical stability, resistance to most acids and alkalis and

good electrical insulation properties, and is hence massively used in the production of films and injection molded products. However, LDPE is very sensitive to environmental stresses and has poor mechanical properties and low thermal aging resistance. On the other hand, although polyethylene naphthalate, PNT for short, is a polyester resin superior in mechanical properties and weather resistance, its application in certain fields is limited due to a relatively high melting point.

CN101628999A discloses a method in which polyethylene (PE) scraps are melt-blended as a raw material with a pre-prepared modifier and subjected to a number of processes to produce a plastic material having the same or similar quality as new PE material. CN101121792A discloses a method in which ethylene vinyl acetate/polyethylene (EVA/PE) blends are oxidized with ozone to produce an improved foaming material. Furthermore, there are numerous literatures regarding the modification of PE by physically blending it with, for example, polypropylene (PP), polycarbonate (PC), or polybutylene terephthalate (PBT), to improve its resistance to environmental stresses and mechanical properties.

While these patent literatures provide an effective practice of performance improvement of polyethylene, none of the modified materials can meet the aforementioned requirements for a suitable hot-melt adhesive for use in solar cell bus bars. The present invention is able to prepare a polyester/polyolefin hot-melt adhesive for use in solar cell bus bars through blending an LDPE with a PNT having a relatively low molecular weight.

SUMMARY OF THE INVENTION

The present invention is directed to a method of preparing a hot-melt adhesive for use in a solar cell bus bar, including the following steps:

- 1) sequentially adding 2,6-naphthalenedicarboxylic acid, ethylene glycol and a

titanium-based catalyst, in a predetermined ratio, into a three-necked flask equipped with a thermometer, a stirrer and a reflux condenser to initiate an esterification reaction under a normal pressure at a temperature of 200 °C ~ 245 °C, and terminating the esterification reaction when an amount of water resulting therefrom reaches 92% ~ 96% of an amount of calculation; 2) performing a polycondensation reaction at a temperature of 245 °C ~ 265 °C for 1.3 h ~ 1.8 h in vacuum with a pressure of 500 Pa ~ 650 Pa to result in a polyethylene naphthalate (PNT) with a weight-average molecular weight of 16,000 ~ 20,000; and 3) melt-blending the PNT resulting from step 2) with a compatibilizer and a low-density polyethylene (LDPE) to produce the hot-melt adhesive for use in a solar cell bus bar, wherein the 2,6-naphthalenedicarboxylic acid and the ethylene glycol are in a molar ratio of 1:1.8; wherein the hot-melt adhesive consists of 4.7% ~ 14% by weight of the PNT, 78% ~ 89% by weight of the LDPE, and 5.7%~ 8.2% by weight of the compatibilizer; wherein the LDPE exhibits a melt flow rate (MFR) of 2.0 g/10min ~ 3.0 g/10min at 190 °C/2.16 kg; and wherein the compatibilizer is an LDPE grafted by maleic anhydride at a grafting ratio of 1.0% ~ 2.0% and exhibits an MFR of 2.0 g/10min ~ 3.0 g/10min at 190 °C/2.16 kg.

The titanium-based catalyst may be tetrabutyl titanate or tetraethyl titanate with an amount of 0.045% ~ 0.055% by weight of a total weight of the 2,6-naphthalenedicarboxylic acid and the ethylene glycol.

The novelty of the present invention lies in blending an LDPE with a PNT having a relatively low molecular weight (16000 ~ 20000) as a modifier and a maleic anhydride grafted LDPE as a compatibilizer to produce a polyester/polyolefin hot-melt adhesive that possesses good mechanical properties and high heat and weather resistance and is thus particularly suitable for use in a solar cell bus bar.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The invention is explained in greater detail below on the basis of some embodiments which are illustrative and not limitative of the invention.

EMBODIMENT 1

179.4 g of 2,6-naphthalenedicarboxylic acid and 120.6 g of ethylene glycol were charged into a 1-L reactor, followed by further adding therein 0.135 g of tetrabutyl titanate, which was introduced as a catalyst and had a weight of 0.045% of the total weight of the 2,6-naphthalenedicarboxylic acid and the ethylene glycol, to initiate an esterification reaction. The reaction was run under the normal pressure at a temperature of 200 °C to 242 °C and was terminated when the amount of water resulting therefrom reached 93% of the amount of calculation. Afterward, the reactor was vacuumed to a pressure of 500 Pa and a polycondensation reaction was initiated and maintained at a temperature of 243 °C to 263 °C for 1.8 hours to result in a PNT, whose weight-average molecular weight was measured as 18,000 by gel permeation chromatography (GPC). The PNT was then melt-blended uniformly with a low-density polyethylene (LDPE) that exhibited a melt flow rate (MFR) of 2.0 g/10min when 2.16 kg of it was measured at a temperature of 190 °C and another LDPE serving as a compatibilizer that was grafted by maleic anhydride at a grafting ratio of 1.0% and also exhibited an MFR of 2.0 g/10min when 2.16 kg of it was measured at a temperature of 190 °C, such that the blend, namely, a hot-melt adhesive for use in solar cell bus bars of the invention, consisted of, by weight, 4.7% of the PNT, 89% of the LDPE and 6.3% of the compatibilizer. After the blend was extracted out from the reactor, it was hot pressed into a film and resulted in a sample P1.

EMBODIMENT 2

179.4 g of 2,6-naphthalenedicarboxylic acid and 120.6 g of ethylene glycol were charged into a 1-L reactor, followed by further adding therein 0.153 g of

tetraethyl titanate, which was introduced as a catalyst and had a weight of 0.051% of the total weight of the 2,6-naphthalenedicarboxylic acid and the ethylene glycol, to initiate an esterification reaction. The reaction was run under the normal pressure at a temperature of 202 °C to 243 °C and was terminated when the amount of water resulting therefrom reached 92% of the amount of calculation. Afterward, the reactor was vacuumed to a pressure of 550 Pa and a polycondensation reaction was initiated and maintained at a temperature of 242 °C to 265 °C for 1.5 hours to result in a PNT, whose GPC-measured weight-average molecular weight was 16,000. The PNT was then melt-blended uniformly with an LDPE that exhibited an MFR of 3.0 g/10min when 2.16 kg of it was measured at a temperature of 190 °C and another LDPE serving as a compatibilizer that was grafted by maleic anhydride at a grafting ratio of 2.0% and exhibited an MFR of 2.0 g/10min when 2.16 kg of it was measured at a temperature of 190 °C, such that the blend, namely, a hot-melt adhesive for use in solar cell bus bars of the invention, consisted of, by weight, 7.3% of the PNT, 87% of the LDPE and 5.7% of the compatibilizer. After the blend was extracted out from the reactor, it was hot pressed into a film and resulted in a sample P2.

EMBODIMENT 3

179.4 g of 2,6-naphthalenedicarboxylic acid and 120.6 g of ethylene glycol were charged into a 1-L reactor, followed by further adding therein 0.147 g of tetraethyl titanate, which was introduced as a catalyst and had a weight of 0.049% of the total weight of the 2,6-naphthalenedicarboxylic acid and the ethylene glycol, to initiate an esterification reaction. The reaction was run under the normal pressure at a temperature of 203 °C to 245 °C and was terminated when the amount of water resulting therefrom reached 96% of the amount of calculation. Afterward, the system was vacuumed to a pressure of 660 Pa and a polycondensation reaction was initiated and maintained at a temperature of 245 °C to 262 °C for 1.7 hours to result in a PNT,

whose GPC-measured weight-average molecular weight was 17,000. The PNT was then melt-blended uniformly with a LDPE that exhibited an MFR of 2.6 g/10min when 2.16 kg of it was measured at a temperature of 190 °C and another LDPE serving as a compatibilizer that was grafted by maleic anhydride at a grafting ratio of 1.0% and exhibited an MFR of 3.0 g/10min when 2.16 kg of it was measured at a temperature of 190 °C, such that the blend, namely, a hot-melt adhesive for use in solar cell bus bars of the invention, consisted of, by weight, 10.8% of the PNT, 81% of the LDPE and 8.2% of the compatibilizer. After the blend was extracted out from the reactor, it was hot pressed into a film and resulted in a sample P3.

EMBODIMENT 4

179.4 g of 2,6-naphthalenedicarboxylic acid and 120.6 g of ethylene glycol were charged into a 1-L reactor, followed by further adding therein 0.165 g of tetrabutyl titanate, which was introduced as a catalyst and had a weight of 0.055% of the total weight of the 2,6-naphthalenedicarboxylic acid and the ethylene glycol, to initiate an esterification reaction. The reaction was run under the normal pressure at a temperature of 201 °C to 244 °C and was terminated when the amount of water resulting therefrom reached 94% of the amount of calculation. Afterward, the system was vacuumed to a pressure of 600 Pa and a polycondensation reaction was initiated and maintained at a temperature of 244 °C to 264 °C for 1.3 hours to result in a PNT, whose GPC-measured weight-average molecular weight was 20,000. The PNT was then melt-blended uniformly with a LDPE that exhibited an MFR of 3.0 g/10min when 2.16 kg of it was measured at a temperature of 190 °C and another LDPE serving as a compatibilizer that was grafted by maleic anhydride at a grafting ratio of 1.5% and exhibited an MFR of 2.0 g/10min when 2.16 kg of it was measured at a temperature of 190 °C, such that the blend, namely, a hot-melt adhesive for use in solar cell bus bars of the invention, consisted of, by weight, 14.0% of the PNT, 78%

of the LDPE and 8.0% of the compatibilizer. After the blend was extracted out from the reactor, it was hot pressed into a film and resulted in a sample P4.

Each of the samples P1 to P4 was subjected to a differential scanning calorimetry (DSC) test, a light transmittance test and a test for measuring thermo-oxidative aging caused change in yellowness index (i.e., ΔYI) and the results were presented in the following Table 1. Wherein, the ΔYI was measured according to the Chinese National Standard GB2409-80 “Test Method for Yellowness Index of Plastics”.

Table 1 Measurement results of samples of EMBODIMENTS 1-4

Sample	DSC measured melting point (°C)	Light transmittance (%)	Thermo-oxidative aging caused change in yellowness index (ΔYI)
P1	109	95	0.30
P2	108	94	0.31
P3	110	94	0.29
P4	112	93	0.30

What is claimed is:

1. A method of preparing a polyester/polyolefin hot-melt adhesive for use in a solar cell bus bar, comprising the steps of:

1) sequentially adding 2,6-naphthalenedicarboxylic acid, ethylene glycol and a titanium-based catalyst, in a predetermined ratio, into a three-necked flask equipped with a thermometer, a stirrer and a reflux condenser to initiate an esterification reaction under a normal pressure at a temperature of 200 °C ~ 245 °C, and terminating the esterification reaction when an amount of water resulting therefrom reaches 92% ~ 96% of an amount of calculation;

2) performing a polycondensation reaction at a temperature of 245 °C ~ 265 °C for 1.3 h ~ 1.8 h in vacuum with a pressure of 500 Pa ~ 650 Pa to result in a polyethylene naphthalate (PNT) with a weight-average molecular weight of 16,000 ~ 20,000; and

3) melt-blending the PNT resulting from step 2) with a compatibilizer and a low-density polyethylene (LDPE) to produce the hot-melt adhesive for use in a solar cell bus bar,

wherein the 2,6-naphthalenedicarboxylic acid and the ethylene glycol are in a molar ratio of 1:1.8;

wherein the hot-melt adhesive consists of 4.7% ~ 14% by weight of the PNT, 78% ~ 89% by weight of the LDPE, and 5.7%~ 8.2% by weight of the compatibilizer;

wherein the LDPE exhibits a melt flow rate (MFR) of 2.0 g/10min ~ 3.0 g/10min at 190 °C/2.16 kg; and

wherein the compatibilizer is an LDPE grafted by maleic anhydride at a grafting ratio of 1.0% ~ 2.0% and exhibits an MFR of 2.0 g/10min ~ 3.0 g/10min at 190 °C/2.16 kg.

2. The method of claim 1, wherein the titanium-based catalyst is tetrabutyl

titanate or tetraethyl titanate with an amount of 0.045% ~ 0.055% by weight of a total weight of the 2,6-naphthalenedicarboxylic acid and the ethylene glycol.