

SPECIFICATION

Thermoplastic polyesters, and method of making hollow articles therefrom

- 5 Poly(ethylene terephthalate) resins are excellent molding compounds for making various hollow articles
such as bottles for comestibles. Poly(ethylene terephthalate) has good fatigue resistance and
therefore its uses include applications where the product is subjected to fatigue inducing conditions, such as
molding compounds for bottles known as squeeze bottles, wherein the product can be ejected from the
container by a squeeze pressure. It is known to make various containers from poly(ethylene terephthalate) by
10 first injection molding a preform, reheating the preform to approximately blowing temperature, placing the 10
preform in the closed halves of a blow mold and blowing the preform to the desired shape.
The good fatigue resistance of poly(ethylene terephthalate) has been attributed to its crystalline structure
and its tendency to become oriented, which increases strength.
One deficiency, however, of poly(ethylene terephthalate) has been its low glass transition temperature,
15 which prevents its use as containers for many comestibles that are hot filled. 15
Another particular deficiency of poly(ethylene terephthalate) is that in the molten state it is a Newtonian
fluid and as a consequence has poor melt strength. The practical effect of this is that containers of po-
ly(ethylene terephthalate) cannot be produced by the process of extruding a soft tube of poly(ethylene
terephthalate) and enclosing the tube in a blow mold and completing the blowing. This is because the
20 poly(ethylene terephthalate) at the temperature necessary for extrusion as a tube will not maintain its tubular 20
shape while warm even long enough to enclose the tube in the blow mold, because of its Newtonian
behavior and poor melt strength. Thus, poly(ethylene terephthalate) preforms or parisons for blow molding
are made by injection molding.
The glass transition temperature of a polymer of terephthalic acid and ethylene glycol can be improved by
25 replacing part of the ethylene glycol with bis(4- β -hydroxy-ethoxyphenyl)- sulfone, but the resulting 25
copolyester is also a nearly Newtonian fluid and has poor melt strength and, consequently, also cannot be
used in the extrusion-blow molding method of making containers.
Newtonian flow is defined as the type of flow occurring in a liquid system where the rate of shear is directly
proportional to the shearing force. Non-Newtonian flow is observed when the rate of shear is not directly
30 proportional to the shearing force. Poly(ethylene terephthalate) exhibits Newtonian flow. The polyesters or 30
copolyesters of the present invention have non-Newtonian flow and such non-Newtonian flow characteris-
tics tend to impart melt strength to such polyesters.
It has now been found that a high polymer thermoplastic copolyester resulting from polymerizing certain
proportions of terephthalic acid, bis(4- β -hydroxy-ethoxyphenyl) sulfone (BSE), ethylene glycol (EG) and
35 small amounts of trimellitic acid (TMA) or its anhydride or its low alkyl, C₁ to C₄, esters has good melt 35
strength; the polymer so produced has non-Newtonian properties with a good relationship between the melt
viscosity and the shear rate. Such polymers have somewhat less fatigue resistance (or folding endurance)
than poly(ethylene terephthalate) but still entirely adequate for application to making squeeze bottles or
other products that undergo significant flexing in use. Other desirable properties of the polymers will be
40 discussed hereafter. 40
While it is believed that the desired non-Newtonian behavior of the polymer melt obtained by use of the
trimellitic acid or its anhydride is because of cross linking of the polymer molecules, it has been found that
the effect of such cross linking on folding endurance or fatigue resistance is really not predictable. Thus,
while the use of pentaerythritol instead of trimellitic acid as a cross linking agent also increases the melt
45 strength and creates the non-Newtonian property of the melt of such copolyesters, its use also nearly 45
completely destroys the fatigue resistance or folding endurance of the resulting polymer.
It is an object of the invention to provide new thermoplastic polyesters having improved rheological
properties combined with good physical properties.
It is another object of the invention to provide a new process for making hollow articles of ethylene
50 terephthalate polyesters having a desirable combination of properties. 50
Other objects, as well as aspects and advantages of the invention, will become apparent from the accom-
panying disclosure and discussion.
According to one aspect of the present invention there is provided a thermoplastic copolyester consisting
essentially of the polymeric reaction product of
55 (A) reactant(s) selected from terephthalic acid and its C₁ to C₄ alkyl esters, and 55
(B) reactants, bis(4- β -hydroxy-ethoxyphenyl) sulfone and ethylene glycol, and
(C) reactant(s) selected from trimellitic acid, its anhydride, and its C₁ to C₄ alkyl esters,
wherein the amount of said bis(4- β -hydroxy-ethoxyphenyl) sulfone is 2-25, usually 2-20, mol percent of the
amount of A reactants, the combined amount of B reactants is 110 to 300 mol percent of the amount of
60 A reactants, and the amount of C reactant(s) is 0.1 to 0.7 mol percent of said A reactants, said copolyester 60
having oxygen (O₂) and carbon dioxide CO₂ permeabilities in cc./mil/100in².day.atm. of less than 9 and less
than 62, respectively, a glass transition temperature, T_g, of at least 82° on an unoriented basis, said
copolyester further having non-Newtonian flow properties. When more of the C reactant is employed, the
folding endurance begins to decrease; moreover, the melt strength becomes so high that molding thereof is
65 to all intents and purposes not practicably possible if much over 0.7 mol percent is used. 65

According to a further aspect of the invention there is provided a new method for making hollow articles. Thus, in the method of forming hollow articles from a polyester made from terephthalic acid or its lower esters and one or more diols by making a hollow preform and enclosing said preform in a softened temperature condition in a blow mold and thereafter blow molding said preform into conformance with said blow mold walls, there is provided the improvement comprising forming said hollow preform as a tubular shape by free extrusion of a copolyester of the invention as defined hereinbefore.

As before noted, the use of carefully selected amounts of trimellitic acid or its anhydride enables the making of hollow articles by extruding a tubular preform and, while still hot and soft, enclosing said preform in a blow mold and blowing same. The inclusion of the BSE component serves, among other things, to lower the melting point of the polymer and thus allows a lower extrusion and especially a lower blowing temperature to be used without encountering premature crystallization in producing the hollow article. This in turn helps minimize thermal and oxidative degradation problems to which polyesters made from ethylene terephthalate are prone.

In the following illustrative examples and in the claims the oxygen and the carbon dioxide permeabilities refer to the determinations made on substantially unoriented pressed films.

The glass transition temperature, T_g , and the melting point were determined using a Perkin-Elmer differential scanning calorimeter, model DSC-2, in a manner similar to that described in U.S. Patent 3,822,332 issued July 2, 1974, using a heating rate of 10°C./minute.

Figures 1 and 2 are plots of the apparent melt viscosity in poises versus shear rate. Such curves are explained in Severs, *Rheology of Polymers*, Rheinhold, New York, 1962, pp.25 et seq. Apparent viscosity is the ratio of the shear stress over shear rate. The data was obtained using an Instron Capillary Rheometer using a melt temperature of 270°C. Figure 1 includes a plot for 'pure' poly(ethylene terephthalate) (PET) which is an essentially Newtonian fluid having completely unsatisfactory melt strength. "Instron" is a Trade Mark.

The inherent viscosities were measured at 25°C, using a solution of 0.25 gms. of polymer dissolved in 100 milliliters of a mixture of 3 weight parts phenol with 2 weight parts 1,1,2,2 tetrachloro-ethane. All polymers of the invention have inherent viscosities of over 0.6 measured in this manner.

Examples 2, 3, 4, 5, 8 and 9 are examples of copolyesters within the scope of the invention and each has the combination of properties set forth hereinbefore for copolyester compositions of the invention.

EXAMPLE 1

Copolyester prepared from dimethyl terephthalate, ethylene glycol and bis(4-β-hydroxy-ethoxyphenyl) sulfone.

291.3 g of dimethyl terephthalate, 233.4 g of ethylene glycol and 0.0919 g of $Mn(OAc)_2 \cdot 4H_2O$ were charged into a 1-liter stainless steel reactor equipped with a stirrer, nitrogen gas inlet port and a condenser. The reaction mixture was heated to 190°C for 2 hours, 210°C for 2 hours under nitrogen atmosphere. Methanol was continuously distilled out during this period. Then 76.1 g of bis(4-β-hydroxy-ethoxyphenyl) sulfone, 0.1093 g of Sb_2O_3 , 0.255 g of $(PhO)_3P$ (i.e. triphenyl phosphite) and 0.0894 g of tetrakis [2,4-di-tertiary-butylphenyl] 4,4'-biphenyl-enediphosphonite were added into the reactor. The reaction temperature was raised to 260°C and maintained for 45 minutes. The nitrogen gas flow was turned off and a vacuum of less than 0.4 mm Hg was applied. The reaction was continued at 275°C for 4-1/4 hours. The inherent viscosity of the copolyester was 0.77. The polymer melt did not show adequate melt strength and was nearly Newtonian as shown in Figure 1. A pressed film of about 10 mil thick required 48 times of cyclic foldings before losing its tear strength completely. The copolyester had a T_g of 98°C, oxygen permeability of 8.2 cc.mil/100in².day.atm. and a carbon dioxide permeability of 56.8 cc.mil/100in².day.atm. The melting point was 215°C.

EXAMPLE 2

Into a 1-liter stainless steel reactor equipped with a stirrer, nitrogen gas inlet port and a condenser, the following were added:

291.3 g of dimethyl terephthalate
233.4 g of ethylene glycol
76.1 g of bis(4-β-hydroxy-ethoxyphenyl) sulfone
0.0919 g of $Mn(OAc)_2 \cdot 4H_2O$
0.2882 g of trimellitic acid anhydride
(0.1 mol percent based on dimethyl terephthalate)

The reaction mixture was heated at 190°C for 2 hours and at 210°C for 2 hours under nitrogen atmosphere. Methanol was continuously distilled out during this period. Then the following compounds were added to the mixture in the reactor:

0.1093 g Sb_2O_3
0.225 g triphenyl phosphite
0.0894 g tetrakis [2,4-di-tertiary-butylphenyl] 4,4'-biphenyl-enediphosphonite

The reaction temperature was increased to 260°C and maintained for 1/2 hour under nitrogen atmosphere. Then the nitrogen gas flow was stopped and a vacuum of less than 0.4 mm Hg was applied. The reaction was continued at 275°C under vacuum for 4 hours, 10 minutes. The copolyester had an inherent viscosity of 0.77.

The polymer melt showed good melt strength. A pressed film of about 10 mil thick required 32 cyclic foldings before losing its tear strength. The melting point was 215°C. The glass transition temperature was 96°C. The oxygen and carbon dioxide permeabilities were 8.3 and 56.8 cc.mil/100in².day.atm., respectively.

EXAMPLE 3

Into a 1-liter stainless steel reactor equipped with a stirrer, nitrogen gas inlet port and a condenser, the following were added:

291.3 g of dimethyl terephthalate

5 233.4 g of ethylene glycol

0.0919 g of Mn (OAc)₂·4H₂O

The reaction mixture was heated at 190°C for 2 hours and at 210°C for 2 hours, 25 minutes under nitrogen atmosphere. Methanol was continuously distilled out during this period. Then the following compounds

10 76.1 g bis(4-β-hydroxy-ethoxyphenyl) sulfone

0.1093 g Sb₂O₃

0.225 g triphenyl phosphite

0.0894 g tetrakis [2,4-ditertiarybutylphenyl] 4,4'-biphenyl-enediphosphonite

0.8645 g trimellitic acid anhydride (0.3 mol percent based on dimethyl terephthalate)

15 The reaction temperature was increased to 260°C and maintained for 1 hour under nitrogen atmosphere. Then the nitrogen gas flow was stopped and a vacuum of less than 0.4 mm Hg was applied. The reaction was continued at 275°C under less than 0.4 mm Hg for 4 hours and 5 minutes. The copolyester had an inherent viscosity of 0.68. The polymer melt possessed good melt strength. A pressed film of about 10 mil thick required 28 cyclic foldings before losing its tear strength completely.

EXAMPLE 4

Into a 1-liter stainless steel reactor equipped with a stirrer, nitrogen gas inlet port and a condenser, the following were added:

291.3 g dimethyl terephthalate

233.4 g ethylene glycol

25 0.0919 g Mn (OAc)₂·4H₂O

The reaction mixture was heated, under nitrogen atmosphere, at 190°C for 2-1/4 hours and at 210°C for 2-1/4 hours. Methanol was continuously distilled out during this period. Then the following compounds were added to the reaction mixture in the reactor:

76.1 g bis(4-β-hydroxy-ethoxyphenyl) sulfone

30 0.1093 g Sb₂O₃

0.225 g triphenyl phosphite

0.0894 g tetrakis [2,4-di-tertiary- butylphenyl] 4,4'-biphenyl- enediphosphonite

1.441 g trimellitic acid anhydride (0.5 mol percent based on dimethyl terephthalate)

35 The reaction temperature was increased to 260°C. After 1 hour, the nitrogen gas flow was stopped and a vacuum of less than 0.4 mm Hg was applied. The reaction was continued at 275°C for 4 hours. The inherent viscosity of the copolyester was 0.80, T_g was 96°C and the melting point was 211°C. The polymer melt possessed good melt strength as shown in Figure 1. A pressed film of about 10 mil thick required 21 cyclic foldings before losing its tear strength completely. It had an oxygen permeability of 8.45 cc./mil/100in².day.atm., CO₂ permeability of 56.1 cc./mil/100in².day.atm.

EXAMPLE 5

Into a 1-liter stainless steel reactor equipped with a stirrer, nitrogen gas inlet port and a condenser, the following were added:

291.3 g dimethyl terephthalate (DMT)

233.4 g ethylene glycol

45 0.0919 g Mn (OAc)₂·4H₂O

The reaction mixture was heated, under nitrogen atmosphere, at 190°C for 2 hours and at 210°C for 2 hours. Methanol was continuously distilled out during this period. Then the following compounds were added to the reaction mixture in the reactor:

76.1 g bis(4-β-hydroxy-ethoxyphenyl) sulfone

50 0.1093 g Sb₂O₃

0.225 g triphenyl phosphite

0.0894 g tetrakis [2,4-di-tertiary- butylphenyl] 4,4'-biphenyl- enediphosphonite

2.0174 g trimellitic acid anhydride (0.7 mol percent based on DMT)

55 The reaction temperature was increased to 260°C. After 45 minutes, the nitrogen gas flow was stopped, and the reaction was continued at 275°C for 4 hours, under less than 0.4 mm Hg vacuum. The inherent viscosity of the copolyester was 0.89, T_g was 96°C and the melting point was 212°C. The polymer melt had good melt strength as shown in Figure 1. A pressed film of about 10 mil thick required 21 cyclic foldings before losing its tear strength completely.

EXAMPLE 6

60 Into a 1-liter stainless steel reactor equipped with a stirrer, nitrogen gas inlet port and a condenser, the following were added:

291.3 g dimethyl terephthalate (DMT)

233.4 g ethylene glycol

0.0919 g Mn (OAc)₂·4H₂O

65 The reaction mixture was heated, under nitrogen atmosphere, at 190°C for 2 hours and at 210°C for 2

hours, 20 minutes. Methanol was continuously distilled out during this period. Then the following compounds were added to the reaction mixture in the reactor:

76.1 g bis(4- β -hydroxy-ethoxyphenyl) sulfone

0.1093 g Sb₂O₃

5 0.225 g triphenyl phosphite

0.0894 g tetrakis [2,4-di-tertiary- butylphenyl] 4,4'-biphenylenedi- phosphonite

2.882 g trimellitic acid anhydride (1 mol percent based on DMT)

The reaction temperature was increased to 260°C. After 1 hour 20 minutes, the nitrogen gas flow was stopped, and the reaction was continued at 275°C for 3 hours 45 minutes, under a vacuum of less than 0.4 mm Hg. The inherent viscosity of the copolyester was 1.08, the melting point was 212°C and T_g was 98°C. The polymer melt strength was excessively high when using 1 mol percent as in this example, and in fact the apparent viscosity vs. shear rate curve could not be measured. Melt strength was thus too high for successful blow molding or extrusion. A pressed film of about 10 mil thick required 12 times of cyclic foldings before losing its tear strength completely.

15 EXAMPLE 7

Into a 1-liter stainless steel reactor equipped with a stirrer, nitrogen gas inlet port, and a condenser, the following were added:

291.3 g dimethyl terephthalate (DMT)

76.1 g bis(4- β -hydroxy-ethoxyphenyl) sulfone

20 218.6 g ethylene glycol

0.0919 g Mn (OAc)₂·4H₂O

The reaction mixture was heated, under nitrogen atmosphere, at 190°C for 4 hours. Methanol was continuously distilled out during this period. Then the following compounds were added to the reaction mixture in the reactor:

25 0.1093 g Sb₂O₃

0.09309 g triphenyl phosphite

0.1788 g tetrakis [2,4-di-tertiary- butylphenyl] 4,4'-biphenylene- diphosponite

0.6127 g Pentaerythritol (PE) (0.3 mol percent based on DMT)

The reaction temperature was increased to 250°C. After 1 hour, the nitrogen gas flow was stopped, and the reaction was continued at 275°C under 0.35 mm Hg vacuum for 4 hours. The inherent viscosity of the copolyester was 0.72. The polymer melt had fair melt strength as shown in Figure 2. A pressed film of about 10 mil thick required 11 cyclic foldings before losing its tear strength completely. The copolyester had a T_g of 98°C, oxygen permeability of 8.4 cc.mil/100in².day.atm., CO₂ permeability of 61.2 cc.mil/100in².day.atm. and a melting point of 210°C.

35 EXAMPLE 8

Into a 1-liter stainless steel reactor equipped with a stirrer, nitrogen gas inlet port and a condenser, the following were added:

291.3 g dimethyl terephthalate (DMT)

233.4 g ethylene glycol

40 10.15 g bis(4- β -hydroxy- ethoxyphenyl) sulfone

0.919 g Mn (OAc)₂·4H₂O

0.5764 g Trimellitic acid anhydride (0.2 mol percent of dimethyl terephthalate)

The reaction mixture was heated at 190°C for 2 hours and at 210°C for 50 minutes under nitrogen atmosphere. Methanol was continuously distilled out during this period. Then the following compounds were

45 added to the mixture in the reactor:

0.1093 g Sb₂O₃

0.225 g triphenyl phosphite

0.0894 g tetrakis [2,4-di-tertiary- butylphenyl] 4,4'-biphenylene- diphosponite

0.0369 g 2,2',4,4' tetrahydroxy-genzophenone

50 The reaction temperature was increased to 260°C and maintained for 1 hour under nitrogen atmosphere.

Then the nitrogen gas flow was stopped and a vacuum of less than 0.4 mm Hg was applied. The reaction was continued at 275°C under vacuum for 4 hours. A pressed film of about 10 mil thick required 144 cyclic foldings before losing its tear strength completely. The copolyester had an inherent viscosity of 0.80. The polymer melt showed good melt strength. The melting point was 244°C and T_g was 84°C. The oxygen and carbon dioxide gas permeabilities were 8.4 and 55.9 cc.mil/100in².day.atm., respectively.

55 EXAMPLE 9

Using the same apparatus used in Example 7, the following were added:

291.3 g dimethyl terephthalate

233.4 g ethylene glycol

60 0.0919 g Mn (OAc)₂·4H₂O

The reaction mixture was heated at 190°C for 2 hours and at 210°C for 2 hours under nitrogen atmosphere. Methanol was continuously distilled off during this period. Then the following compounds were added to the mixture in the reactor:

126.9 g bis(4- β -hydroxy-ethoxyphenyl) sulfone

65 0.1093 g Sb₂O₃

65

0.225 g triphenyl phosphite
0.0894 g tetrakis [2,4-di-tertiary- butylphenyl] 4,4'-biphenylene- diphosponite
1.441 g trimellitic acid anhydride (0.5 mol percent of dimethyl terephthalate)

The reaction temperature was increased to 260°C and maintained for 35 minutes under nitrogen atmosphere. Then the nitrogen gas flow was stopped and a vacuum of less than 0.4 mm Hg was applied. The reaction was continued for 4 hours and 15 minutes under vacuum at 275°C. The copolyester had an inherent viscosity of 0.71. A pressed film about 10 mil thick required 17 cyclic foldings before losing its tear strength completely. The polymer had good melt strength and was non-crystalline. The oxygen and carbon dioxide gas permeabilities were 8.1 and 59.8 cc.mil/100in².day.atm., respectively. The Tg is 100°C.

10 EXAMPLE 10

Using the same apparatus used in Example 7, the following were added:

291.3 g dimethyl terephthalate
233.4 g ethylene glycol
152.2 g bis(4-/-hydroxy- ethoxyphenyl) sulfone

15 0.0919 g Mn (OAc)₂·4H₂O
0.5764 g trimellitic acid anhydride (0.2 mol percent DMT)

The reaction mixture was heated at 190°C for 2 hours and at 210°C for 1 hour under nitrogen atmosphere. Methanol was continuously distilled off during this period. Then the following compounds were added to the mixture in the reactor:

20 0.1093 g Sb₂O₃
0.0894 g tetrakis [2,4-di-tertiary- butylphenyl] 4,4'-biphenylene- diphosponite
0.225 g triphenyl phosphite

The reaction temperature was increased to 260°C and maintained for 1/2 hour under nitrogen atmosphere. Then the nitrogen gas flow was stopped and a vacuum of less than 0.4 mm Hg was applied. The reaction was continued at 275°C for 3 hours and 40 minutes under vacuum. A pressed film about 10 mil thick required 12 cyclic foldings before losing its tear strength completely. The copolyester had an inherent viscosity of 0.62. The polymer had good melt strength and was non-crystalline. The O₂ and CO₂ permeability were 8.7 and 66.2 cc.mil/100in².day.atm., respectively. The Tg was 105°C.

EXAMPLE 11

30 (This example is a repeat of Example 2 in U.S. Patent 3,558,557 using ethoxylated Bisphenol A, 10% mol ethoxylated Bisphenol A).

Using the same apparatus used in Example 7, the following were added:

291.3 g dimethyl terephthalate
232.8 g ethylene glycol
35 47.5 g ethoxylated Bisphenol A
0.4078 g pentaerythritol (0.199 mol % of DMT)
0.0919 g Mn (OAc)₂·4H₂O

The reaction mixture was heated at 190°C for 2 hours under N₂ atmosphere. Methanol was continuously distilled off during this period. Then the following compounds were added to the mixture in the reactor:

40 0.1093 g Sb₂O₃
0.225 g triphenyl phosphite
0.0894 g tetrakis [2,4-di-tertiary- butylphenyl] 4,4'-biphenylene- diphosponite

The reaction temperature was increased to 260°C and maintained for 50 minutes under N₂ atmosphere. Then the N₂ gas flow was stopped and a vacuum of less than 0.4 mm Hg was applied. The reaction was continued at 270°C for 3 hours, 50 minutes, under vacuum. The copolyester had an inherent viscosity of 0.69. A pressed film about 10 mil thick required 52 cyclic foldings before losing its tear strength completely. The melting point was 225°C and Tg was 76°C. The O₂ and CO₂ gas permeabilities were 10.6 and 65.2 cc.mil/100in².day.atm., respectively. The polymer had good melt strength.

EXAMPLE 12

50 Poly(ethylene terephthalate) was prepared as follows:

Into a 500 ml 3-necked round bottom flask, equipped with a nitrogen gas inlet tube, stirrer and a condenser, the following compounds were added:

46.5 g dimethyl terephthalate
35.4 g ethylene glycol
55 0.0263 g zinc acetate dihydrate
0.01398 g antimony trioxide

The contents of the flask were heated at 220°C under nitrogen atmosphere for 3 hours. During this time, methanol was distilled off. Then the reaction temperature was raised to 280°C, nitrogen flow was stopped and vacuum was gradually applied until less than 0.5 mm Hg. Excess ethylene glycol was continuously distilled off. The reaction was stopped after 4 hours. The inherent viscosity was 0.83, the glass transition temperature was 72°C, the oxygen permeability was 8.5 cc.mil/100in².day.atm. and the carbon dioxide permeability was 55.3 cc.mil/100in².day.atm. The product had very poor melt strength and had a melting point of 252°C.

Reference is made to U.S. Patent 3,558,557, issued January 26, 1971. From the disclosures of the monomer components of this patent it would be possible to pick the four reactants of the present invention. However,

this patent is directed toward making polyesters especially for fiber applications, and properties pertinent to such application are emphasized.

Moreover, one would not know to pick the combination here disclosed in the amounts here disclosed to obtain the properties here set forth. For instance, column 5 equates trimellitic acid and pentaerythritol. As 5 shown herein pentaerythritol will not give the combination of properties sought in that the folding endurance is unsatisfactory. See Example 7. Nor is Example 7 suggested, i.e. there is no suggestion that terephthalic acid and ethylene glycol be polymerized specifically with BSE and pentaerythritol.

When one substantially repeats Example 2 of the patent (as in Example 11 herein) it is noted that in this 10 example, which uses bis-phenol-A-diglycol ether instead of BSE, the oxygen and the carbon dioxide permeabilities are entirely unsatisfactory.

Other prior art in the general field is to be found on pages 2-3 of my copending U.S. application Ser. No. 812,921 filed July 5, 1977, but none of these references disclose or suggest the compositions or the process of the present invention.

As will be evident to those skilled in the art, various modifications of this invention can be made or 15 followed in the light of the foregoing disclosure and discussion without departing from the spirit and scope of the disclosure or from the scope of the claims.

CLAIMS

1. A thermoplastic copolyester consisting essentially of the polymeric reaction of
 (A) reactant(s) selected from terephthalic acid and its C₁ to C₄ alkyl esters, and
 20 (B) reactants, bis (4-beta-hydroxy- ethoxyphenyl) sulfone and ethylene glycol, and
 (C) reactant(s) selected from trimellitic acid, its anhydride, and its C₁ to C₄ alkyl esters,
 wherein the amount of said bis (4-beta-hydroxy- ethoxyphenyl) sulfone is 2-25 mol percent of the amount of
 A reactant(s), the combined amount of B reactants is 110 to 300 mol percent of the amount of A
 reactant(s), and the amount of C reactant(s) is 0.1 to 0.7 mol percent of said A reactants,
 25 said copolyester having oxygen and carbon dioxide permeabilities in cc.mil/100 in.².day.atm. of less than 9
 and less than 62, respectively, a glass transition temperature, T_g, of at least 82° on an unoriented basis, said
 copolyester further having non-Newtonian flow properties.
2. A copolyester of claim 1 wherein the amount of said bis(4-beta-hydroxy- ethoxyphenyl) sulfone is 2-20
 mol percent of the amount of A reactant(s).
- 30 3. A method of forming a hollow article, comprising freely extruding a copolyester as claimed in claim 1
 or claim 2 through an annular orifice to form a hollow preform, enclosing said preform in a blow mold at a
 temperature suitable for blow-molding, and thereafter blow-molding said preform into conformance with
 the walls of said mold.
4. A method of forming hollow articles as claimed in claim 3, substantially as hereinbefore described.
- 35 5. A thermoplastic copolyester as claimed in claim 1, substantially as hereinbefore described.



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Moreover, one would not know to pick the combination here disclosed in the amounts here disclosed to obtain the properties here set forth. For instance, column 5 equates trimellitic acid and pentaerythritol. As 5 shown herein pentaerythritol will not give the combination of properties sought in that the folding endurance is unsatisfactory. See Example 7. Nor is Example 7 suggested, i.e. there is no suggestion that terephthalic acid and ethylene glycol be polymerized specifically with BSE and pentaerythritol.

When one substantially repeats Example 2 of the patent (as in Example 11 herein) it is noted that in this example, which uses bis-phenol-A-diglycol ether instead of BSE, the oxygen and the carbon dioxide per- 10 meabilities are entirely unsatisfactory.

Other prior art in the general field is to be found on pages 2-3 of my copending U.S. application Ser. No. 812,921 filed July 5, 1977, but none of these references disclose or suggest the compositions or the process of the present invention.

As will be evident to those skilled in the art, various modifications of this invention can be made or 15 followed in the light of the foregoing disclosure and discussion without departing from the spirit and scope of the disclosure or from the scope of the claims.

CLAIMS

1. A thermoplastic copolyester consisting essentially of the polymeric reaction of
(A) reactant(s) selected from terephthalic acid and its C₁ to C₄ alkyl esters, and
20 (B) reactants, bis (4-beta-hydroxy- ethoxyphenyl) sulfone and ethylene glycol, and
(C) reactant(s) selected from trimellitic acid, its anhydride, and its C₁ to C₄ alkyl esters,
wherein the amount of said bis (4-beta-hydroxy- ethoxyphenyl) sulfone is 2-25 mol percent of the amount of
A reactant(s), the combined amount of B reactants is 110 to 300 mol percent of the amount of A
reactant(s), and the amount of C reactant(s) is 0.1 to 0.7 mol percent of said A reactants,
25 said copolyester having oxygen and carbon dioxide permeabilites in cc.mil/100 in.².day.atm. of less than 9
and less than 62, respectively, a glass transition temperature, T_g, of at least 82° on an unoriented basis, said
copolyester further having non-Newtonian flow properties.
2. A copolyester of claim 1 wherein the amount of said bis(4-beta-hydroxy- ethoxyphenyl) sulfone is 2-20
mol percent of the amount of A reactant(s).
- 30 3. A method of forming a hollow article, comprising freely extruding a copolyester as claimed in claim 1
or claim 2 through an annular orifice to form a hollow preform, enclosing said preform in a blow mold at a
temperature suitable for blow-molding, and thereafter blow-molding said preform into conformance with
the walls of said mold.
4. A method of forming hollow articles as claimed in claim 3, substantially as hereinbefore described.
- 35 5. A thermoplastic copolyester as claimed in claim 1, substantially as hereinbefore described.