

POLY(ARYL ETHER SULFONE) COMPOSITIONS
COMPRISING POLY(PHENYLENE ETHER SULFONE)

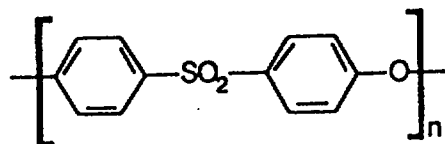
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DATE OF RECEIPT		25/2/96

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This invention is directed to immiscible poly(aryl ether sulfone) blends possessing improved properties comprising (a) from about 35 to about 99 percent by weight of a poly(biphenyl ether sulfone) preferably 60 to 99 percent by weight and (b) from about 1 to about 65 percent by weight of a second poly(phenylene ether sulfone) preferably 40 to 1 weight percent. The compositions described herein, particularly the preferred compositions, retain the very attractive characteristics of their constituents, and display excellent mechanical properties and heat resistance.

Articles made from these poly(aryl ether sulfones) can be steam-sterilized while under stresses of 500 psi or greater; moreover they are not affected by corrosion-reducing additives such as morpholine, for example. Also, the above materials demonstrate good chemical resistance in contact with commonly used hospital cleaners and detergents.

Poly(aryl ether sulfones) have been known for about two decades. They are tough linear polymers that possess a number of attractive features such as excellent high temperature resistance, good electrical properties, and very good hydrolytic stability. At least three poly(aryl ether sulfones) are commercially available. A poly(aryl ether sulfone) referred to herein as poly(phenylene ether sulfone) is available from Imperial Chemical Industries, Ltd. It has the formula (1)



(1)

and is produced by the polycondensation of 4,4'-dihydroxydiphenyl sulfone with 4,4'-dichlorodiphenyl sulfone as described in, for example, Canadian Patent No. 847,963. The polymer contains no aliphatic moieties and has a Tg of approximately 220°C.

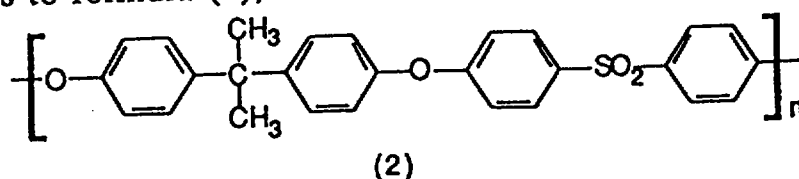
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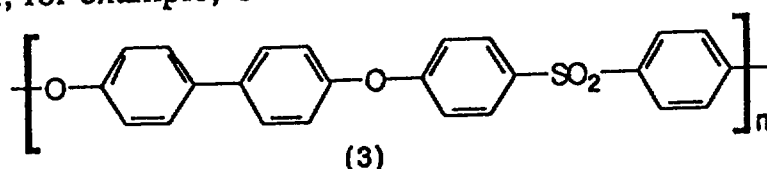


Another commercial poly(aryl ether sulfone) is available from Amoco Performance Products, Inc., under the trademark of UDEL®. It corresponds to formula (2),



5 has a Tg of about 190°C, and is made via the nucleophilic polycondensation of bisphenol-A di-sodium salt with 4,4'-dichlorodiphenyl sulfone, as described in U.S. Patent No. 4,108,837.

A third commercial poly(aryl ether sulfone) is also available from Amoco Performance Products, Inc., under the trademark of Radel® R. It corresponds to formula (3) has a Tg of about 220°C, and is produced by the polycondensation of biphenol with 4,4'-dichlorodiphenyl sulfone as described in, for example, Canadian Patent No. 847,963.



Over the years, there has developed a substantial body of patent and other literature directed to the formation and properties of poly(aryl ether sulfones and other poly(aryl ethers) (all hereinafter called "PAE"). A broad range of PAE's was achieved by Johnson et al., J. of Polymer Science, A-1, Vol. 5, 1967, pp. 2415-2427; Johnson et al., U.S. Patent Nos. 4,108,837 and 4,175,175. Johnson et al. show that a very broad range of PAE's can be formed by the nucleophilic aromatic substitution (condensation) reaction of an activated aromatic dihalide and an aromatic diol. By this method, Johnson et al. created a host of new PAE's.

Because of their excellent mechanical and thermal properties, coupled with outstanding hydrolytic stability, the poly(aryl ether sulfones) have been utilized in the medical market for a variety of purposes for at least ten years. These medical devices constitute a wide variety of articles. Obviously, one of the major attributes of the poly(aryl ether sulfones) is their ability to be steam autoclaved repeatedly without loss of properties. Steam autoclaving is a very severe test, requiring both high temperature and hydrolytic stability, and involving cyclical effects - wet/dry, hot/cold.

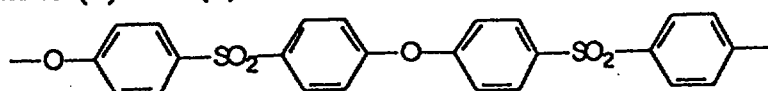
The poly(aryl ether sulfones) (1) and (2) show some important deficiencies, however. Indeed, parts molded from these materials, stress-



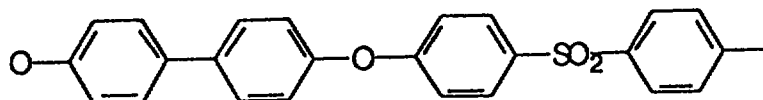
crack when steam sterilized under stresses of say 500 psi or greater especially when excessive concentration of boiler additives, such as morpholine are employed to reduce corrosion in the steam generating system; or, when in contact with commonly used hospital cleaners and
 5 detergents.

While poly(biphenyl ether sulfone) (3) and parts molded therefrom have substantially better properties than poly(aryl ether sulfones) (1) and (2) it is substantially more expensive than (1) and (2) due to the high cost of biphenol.

10 British Patent Application No. 2,088,396 describes copolymers containing units (4) and (5):



(4)



(5)

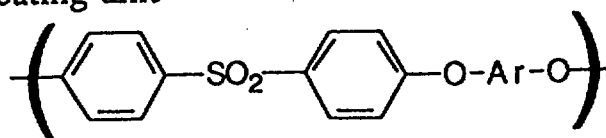
The claimed copolymers comprise about 80 to 10 mole percent of
 15 repeat units (4), and correspondingly about 20 to 90 mole percent of repeat units (5). The application states that the incorporation of (5) into the poly(aryl ether sulfone) (1) yields materials with improved resistance to hot water crazing. The application does not mention steam-sterilizability under load; nor does it teach that the copolymers show
 20 resistance to stress-cracking in the presence of boiler additives such as morpholine.

The general object of this invention is to provide blends of poly(biphenyl ether sulfones) having many of the base properties of the poly(biphenyl ether sulfone). Another object of this invention is to
 25 provide medical articles from blends of poly(biphenyl ether sulfones) which can be steam-sterilized while under stresses of 500 psi or greater without stress-cracking even in the presence of morpholine. Other objects appear hereinafter.

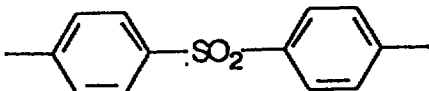
The general objects of this invention can be attained with
 30 immiscible blends comprising (a) from about 35 to about 99 percent by weight of a poly(biphenyl ether sulfone) and (b) from about 1 to 75 percent by weight of a poly(phenylene ether sulfone). Other things being equal blends of polyarylether (1) and poly(aryl ether sulfone) (3) wherein poly(aryl ether sulfone) (3) comprises at least 60% of the two polymers

have substantially the same properties as the more expensive poly(aryl ether sulfone) (3). The two polymers can also be used in weight percent ratios of poly(biphenyl ether sulfone) of from about 50 to 99 to poly(phenylene ether sulfone) of about 50 to 1 weight percent.

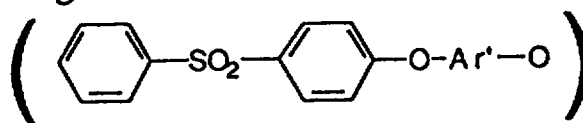
5 Briefly, the poly(biphenyl ether sulfones) useful in this invention comprise the repeating unit



10 wherein at least 50 and preferably at least 75 mole percent of the divalent Ar groups are p-biphenylene groups and the remainder (0 to 50 mole percent) at least one member selected from the group consisting of p-

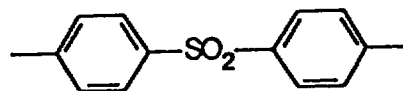
phenylene, , etc. In general, the higher the concentration of biphenyl or biphenylene groups the better the properties of the polymer.

15 The poly(phenylene ether sulfones) useful in this invention comprise the repeating unit



wherein at least 50 and preferably at least 75 mole percent of the divalent

Ar' groups are bisphenol S moieties



and the

remainder (0 to 50 mole percent) p-phenylene.

20 The poly(aryl ether sulfones) can be prepared by either of two methods, i.e., the carbonate method or the alkali metal hydroxide method.

In the carbonate method, the polymers are prepared by contacting substantially equimolar amounts of the hydroxy-containing compounds and dihalodiarylsulfones, e.g., 4,4'-dichlorodiphenyl sulfone or 4,4'-difluorodiphenyl sulfone, with from about 0.5 to about 1.0 mole of an alkali metal carbonate per mole of hydroxyl group in a solvent mixture comprising a solvent which forms an azeotrope with water in order to maintain the reaction medium at substantially anhydrous conditions during the polymerization.

30 The temperature of the reaction mixture is kept at about 170°C to about 250°C, preferably from about 210°C to about 235°C for about one to 15 hours.

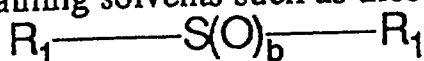


The reaction is carried out in an inert atmosphere, e.g., nitrogen, at atmospheric pressure, although higher or lower pressures may also be used.

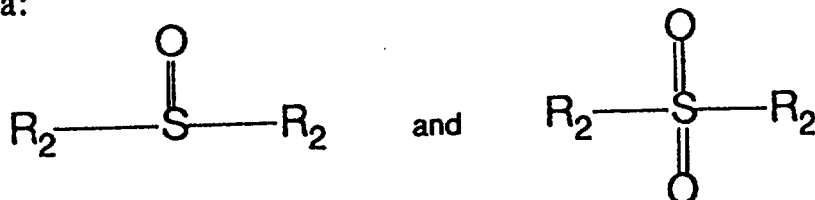
5 The polyarylethersulfone is then recovered by conventional techniques such as coagulation, solvent evaporation, and the like.

The solvent mixture comprises a solvent which forms an azeotrope with water and a polar aprotic solvent. The solvent which forms an azeotrope with water includes an aromatic hydrocarbon such as benzene, toluene, xylene, ethylbenzene, chlorobenzene, and the like.

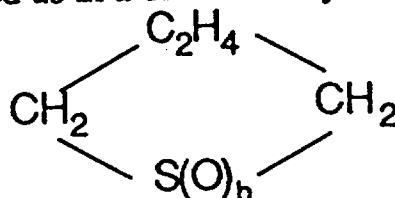
10 The polar aprotic solvents employed in this invention are those generally known in the art for the manufacture of polyarylether sulfones and include sulfur containing solvents such as those of the formula:



15 in which each R_1 represents a monovalent lower hydrocarbon group free of aliphatic unsaturation, which preferably contains less than about 8 carbon atoms or when connected together represents a divalent alkylene group with b being an integer from 1 to 2 inclusive. Thus, in all of these solvents, all oxygens and two carbon atoms are bonded to the sulfur atom. Contemplated for use in this invention are such solvents as those having
20 the formula:



where the R_2 groups are independently lower alkyl, such as methyl, ethyl, propyl, butyl, and like groups, and aryl groups such as phenyl and alkylphenyl groups such as the tolyl group, as well as those where the R_2
25 groups are interconnected as in a divalent alkylene bridge such as



in tetrahydrothiophene oxides and dioxides. Specifically, these solvents include dimethylsulfoxide, dimethylsulfone, diphenylsulfone, diethylsulfoxide, diethylsulfone, diisopropylsulfone, tetrahydrothiophene 1,1-dioxide (commonly called tetramethylene sulfone or sulfolane) and
30 tetrahydrothiophene-1 monoxide.



Additionally, nitrogen containing solvents may be used. These include dimethylacetamide, dimethylformamide and N-methylpyrrolidone.

5 The azeotrope forming solvent and polar aprotic solvent are used in a weight ratio of from about 1:10 to about 1:1, preferably from about 1:5 to about 1:3.

10 In the reaction, the hydroxy containing compound is slowly converted, *in situ*, to the alkali salt thereof by reacting with the alkali metal carbonate. The alkali metal carbonate is preferably potassium carbonate. As indicated before, mixtures of carbonates such as potassium and sodium carbonate may also be used.

Water is continuously removed from the reaction mass as an azeotrope with the azeotrope forming solvent so that substantially anhydrous conditions are maintained during the polymerization.

15 It is essential that the reaction medium be maintained substantially anhydrous during the polycondensation. While amounts of water up to about one percent can be tolerated, and are somewhat beneficial when employed with fluorinated dihalobenzenoid compounds, amounts of water substantially greater than this are desirably avoided as the reaction of
20 water with the halo and/or nitro compound leads to formation of phenolic species and only low molecular weight products are secured. Consequently, in order to secure the high polymers, the system should be substantially anhydrous, and preferably contain less than 0.5 percent by weight water during the reaction.

25 Preferably, after the desired molecular weight has been attained, the polymer is treated with an activated aromatic halide or an aliphatic halide such as methyl chloride or benzyl chloride, and the like. Such treatment of the polymer converts the terminal hydroxyl groups into ether groups which stabilize the polymer. The polymer so treated has
30 good melt and oxidative stability.

While the carbonate method for preparing the polymer of this invention is simple and convenient, in some cases products of higher molecular weight can be made by the alkali metal hydroxide method. In the alkali metal hydroxide method, described by Johnson et al., U.S.
35 Patent Nos. 4,108,837 and 4,175,175, a double alkali metal salt of a dihydric phenol is contacted with a dihalobenzenoid compound in the presence of a sulfur containing solvent as herein above defined under substantially anhydrous conditions.



5 Additionally, the polymers of this invention can be prepared by other methods known in the prior art, in which at least one dihydric phenol and at least one dihalobenzenoid compound are heated, for example, with a mixture of sodium carbonate or bicarbonate and a second alkali metal carbonate or bicarbonate having a higher atomic number than that of sodium, as described in U.S. Patent No. 4,176,222.

10 The molecular weight of the poly(aryl ethers) utilized for manufacturing the devices of the instant invention is indicated by reduced viscosity data in an appropriate solvent such as methylene chloride, chloroform, N-methylpyrrolidone, and the like. The reduced viscosities of the materials, as measured at concentrations of 0.2g per 100 ml. at 25°C, are at least 0.3 dl/g, preferably at least 0.4 dl/g and, typically, not exceeding about 1.5 dl/g.

15 The compositions of this invention are prepared by any conventional mixing method. For example, a preferred method comprises mixing the two poly(aryl ether sulfones) in powder or pellets form in an extruder and extruding the mixture into strands, chopping the strands into pellets and molding the pellets into the desired article.

20 The poly(aryl ether sulfones) of the instant invention allow for the fabrication of medical devices having outstanding stress-crack resistance. These devices can be steam-sterilized under stresses of 500 psi or greater and in the presence of a variety of steam boiler additives. Typical boiler additives designed to reduce corrosion in steam generating systems are amino compounds such as morpholine, hydrazine, N,N-diethylaminoethanol ("NALCO 359" or "BETZ NA-9"), and
25 octadecylamine. Steam sterilization is also possible in the presence of various hospital cleaners and detergents, such as those sold under the tradenames of "Castle 7900" (a sonic cleaner), "Chem Crest 14" (an ultrasonic cleaner), "Tergitol Min Foam 2X" (a non ionic surfactant), and
30 the like.

The materials of the instant invention can include pigments, thermal stabilizers, ultraviolet light stabilizers, and other additives.

35 The instant poly(aryl ether sulfones) blends are useful for the fabrication of a wide variety of medical devices. They are of particular interest for autoclavable storage trays such as the systems for storage and delivery of sterile surgical instruments (thus eliminating the costs associated with wrapping); in the medical supply industry for shipment



and storage of implants, prostheses and other medical devices under sterile conditions; and in many other similar applications.

5 The compositions of this invention can also be fabricated into any desired shape, i.e., moldings, coatings, films, or fibers. They are particularly desirable for use as electrical insulation for electrical conductors.

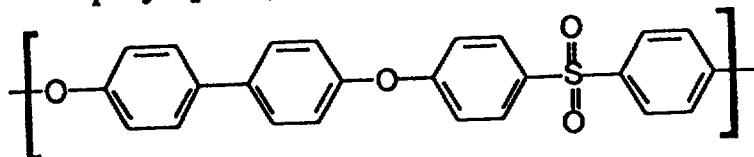
10 These compositions can include mineral fillers such as carbonates including chalk, calcite and dolomite; silicates including mica, talc, wollastonite, silicon dioxide, glass spheres, glass powders; aluminum; clay; quartz; and the like. Also, reinforcing fibers such as fiberglass, carbon fibers, and the like may be used. The compositions may also include additives such as titanium dioxide; thermal stabilizers, ultraviolet light stabilizers, plasticizers, and the like.

15 EXAMPLES

The following examples provide specific illustrations of the present invention and are not to be construed in any way as a limitation on its scope or generality.

20 Sample Preparations and Test Procedures

There were two types of polymeric materials used in all the preparations of this invention: polybiphenylsulfone and bisphenol-S based polysulfone. The polybiphenylsulfone is a polymer having the repeat unit

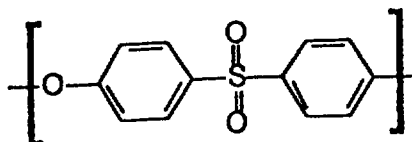


25 It is available commercially from Amoco Performance Products, Inc. under the trade name Radel R 5000. It has a reduced viscosity of approximately 0.60 dl/g as measured in N-methyl pyrrolidone at a concentration of 0.2 g/dl and 25°C. It has a number-average molecular weight of about 20,000 as measured by gel permeation chromatography using methylene chloride as a solvent and a polystyrene molecular weight
30 calibration. This polymer is referred to hereafter as PSF-I.

One bisphenol-S polysulfone used is the commercial product Victrex 4100 G available from Imperial Chemical Industries, PLC. It is a polymer having the formula repeat unit

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It has a reduced viscosity of about 0.50 g/dl in N-methylpyrrolidone at 25°C and a concentration of 0.2 g/dl. Its number-average molecular weight by gel permeation chromatography is about 17,000 using methylene chloride as solvent and a polystyrene molecular weight calibration. This polymer is referred to hereafter as PES-I. The polymers were used in pellet form and all are transparent, by virtue of their amorphous character, and have a slight amber color.

10 Controls A and B

Two neat polymers PSF-I and PES-I were dried overnight in a Lydon dehumidified recirculating air oven at a temperature of 300°F. Parts were then injection molded on a Battenfeld injection molding machine with a 3 oz injection capacity to produce standard ASTM test specimens. Mechanical properties and heat deflection temperatures (HDT) were measured per the ASTM procedures shown below. All tests were conducted on 1/8" thick specimens except HDT which was run on both 1/8" and 1/4" specimens.

20	Property	ASTM Method No.
	Tensile Modulus	D-638
	Tensile Strength	D-638
	Elongation at Break	D-638
25	Notched Izod Impact Strength	D-256
	Tensile Impact Strength	D-1822
	Heat Deflection Temperature	D-648
	Flexural Modulus	D-790
	Flexural Strength	D-790

30

Examples 1 to 6

The compositions shown in Table I were mixed well as pellets and placed in a dehumidified air oven at 300°F for about 16 hrs (overnight) for drying. The dry blends were then extruded using a 25 mm twin screw double vented BERstorff extruder having an L/D ratio of 33/1



5 according to the conditions profile shown in Table I. The first vent port was open to the atmosphere, the second was connected to a vacuum pump. The extruder was fitted with a double strand die. The polymer extrudate was pelletized after passing through a water trough for cooling. All blends were extruded and pelletized without incident at the throughput rates indicated in Table 1. Between successive blend compositions, two pounds of extrudate were designated as "transition" material and discarded. From past experience, this amount is sufficient to effectively displace the melt in the extruder so as the compositions of the final blends do not differ from those of the dry pellet mixes.

10 The six blends were dried again overnight in the Lydon oven at 300°F and injection molded the following day on the Battenfeld injection molding machine described above to generate the needed ASTM parts. All blends appeared translucent on molding and the magnitude of the translucency increased towards the middle of the composition scale and became progressively less at the compositions rich in one polymer or the other. The lack of clarity in these blends is an indication of immiscibility between the two homopolymers.

20 Mechanical Properties

ASTM mechanical properties for the controls and blends are shown in Table II. The strength and modulus values for all blends appear to vary linearly with respect to PSF-I content in the blend. As a measure of ductility, elongation at break of all the blends can be considered equivalent to that of PSF-I within the variability of this measurement. The tensile impact, a discriminating test of polymer unnotched toughness is likewise similar for all compositions. All these mechanical properties confirm the very good mechanical compatibility of the blends of this invention. For compositions rich in PSF-I (examples 1, 2, and 3), little or no loss in the high notched Izod of PSF-I is observed. Accordingly, compositions comprising from 60 to 99 weight percent PSF-I and correspondingly from 1 to 40 weight percent PES-I have many of the excellent physical properties of PSF-I.

35 Immiscible polymer blends which have poor mechanical compatibility are typically characterized by low strength for parts containing "weld lines" as a result of a multi-gated mold configuration. To ascertain the mechanical compatibility of these blends the weld-line strengths were measured against the base case with no weld line. ASTM

5 tensile bars containing weld lines were produced on a Van Dorn injection molding machine fitted with a double gated tensile bar mold. Molding was performed at conditions similar to those used for the standard single gate case. Results are shown in Table III illustrating the retention of tensile strength over weld-line sections for all blends.

Steam Sterilization

10 To assess the steam sterilization resistance of the PSF-I/PES-I blend compositions, the following test was employed. 5"x1/2"x1/8" ASTM bars were mounted by fixing the bar horizontally from one end in a cantilever fashion, and a weight was suspended on the free end. The weight attached to the specimen was such that a maximum flexural stress of about 1000 psi was generated at the fixed end surface of the bar. The samples which were mounted side by side in a stainless steel drawer were then placed in a steam autoclave. The autoclave was operated at a steam pressure of 27 psig, and a temperature of 270°F, and the autoclave chamber was charged with water containing 50 part per million (ppm) morpholine. Each autoclave cycle consisted of a 5-minute heat-up and pressurization step followed by a hold at the set conditions for 30 minutes after which the autoclave was vented and allowed to cool down for 10 minutes. The samples were typically inspected at the completion of 15-25 cycles and all samples were tested in duplicates.

25 Table IV summarizes the results from the steam sterilization performance study. Quite unexpectedly, the performance of all blends except that of example 6 is comparable to that of PSF-I. None showed any evidence of stress cracking following 450 cycles of steam sterilization as described above. In comparison, PES-I experienced a rupture after only 45 cycles. The blend of example 6 had a rupture at 166 cycles - still significantly better than PES-I. The unbroken duplicate of example 6 and control B were cracked extensively and the test was not continued on them as they are also considered failures from the practical standpoint of the test. Accordingly, compositions comprising about 35 to 99 weight percent PSF-I and about 65 to 1 weight percent PES-I have improved resistance to steam containing amine stabilizers.

35



Table I: Extrusion Conditions for Preparation of PSF-I/PES-I Blends of Examples 1-6.*

Example	1	2	3	4	5	6
5						
Percent PSF-I	80	70	60	50	40	25
Percent PES-I	20	30	40	50	60	75
Temperatures (C)						
Zone 1	330	330	320	320	320	320
10 " 2	340	340	330	330	330	330
" 3	350	350	340	340	340	340
" 4	350	350	350	340	340	340
" 5	350	350	350	340	340	340
" 6	360	350	350	340	340	340
15 " 7 (Die)	350	340	340	340	340	340
Melt	388	382	378	374	371	371

* Conditions common to all runs were approximately as follows:

20 screw speed = 200 rpm
throughput rate = 29 lbs/hr
Vent 2 vacuum reading = 30 in Hg
Vent 1 open to the atmosphere

25 Table II: Mechanical Properties of PSF-I, PES-I and 6 Blend Compositions of the Two Polymers.

Example	PSF-I (%)	Tensile Strength (kpsi)	Tensile Modulus (kpsi)	Elongation at Break (%)	Flexural Strength (kpsi)	Flexural Modulus (kpsi)
30						
Control A	100	10.3	337	109	12.8	339
1	80	10.6	335	99	13.5	361
2	70	10.8	341	117	14.1	374
3	60	10.9	344	107	14.4	382
35 4	50	11.0	346	107	14.9	386
5	40	11.4	345	115	15.3	398
6	25	11.6	355	101	15.5	393
Control B	0	12.1	402	36	16.2	409



Example	PSF-I (%)	Notched Izod (ft-lb/in)	Tensile Impact (ft-lb/in ²)	Heat Deflection Temp.	
				[1/8"] (C)	[1/4"] (C)
5	Control A	100	16.0	235	193
	1	80	15.2	207	196
	2	70	15.7	179	196
	3	60	8.5	226	194
	4	50	2.5	222	195
10	5	40	2.2	195	192
	6	25	1.8	181	193
	Control B	0	1.3	175	193

15 Table III: Weld Line Strengths of PSF-I/PES-I Blends Compared with the Strength of Non-weld Line Specimens.

Example	PSF-I (%)	Tensile Strengths	
		No Weld Line (kpsi)	Weld Line (kpsi)
20	Control A	100	10.3
	1	80	10.6
	2	70	10.8
	3	60	10.9
	4	50	11.0
25	5	40	11.4
	6	25	11.6



Table IV: Steam Sterilization* Performance of PSF-I, PES-I and 6 Blend Compositions of the Two Polymers.

5	Example	PSF-I (%)	Number of Cycles Steam Sterilization	Observations
10	Control A	100	450	No Changes
	1	80	450	No Changes
	2	70	450	No Changes
	3	60	450	No Changes
	4	50	450	No Changes
	5	40	450	No Changes
	6	25	166	Cracks/Rupture
	Control B	0	45	Cracks Rupture

15 * Steam Sterilization Conditions: 1000 psi flexural stress, 27 psig steam with 50 ppm morpholine, 270 deg F steam, 30-minute autoclaving cycle.

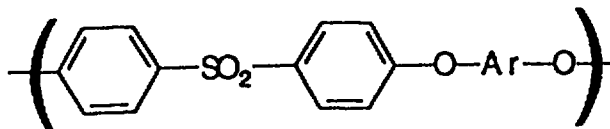
20 Essentially the same results can be obtained by replacing PES-I with Radel A-200 sold by Amoco Performance Products, Inc., which is the condensation product of dichlorodiphenyl sulfone with a 3:1 molar ratio of Bisphenol S to hydroquinone.



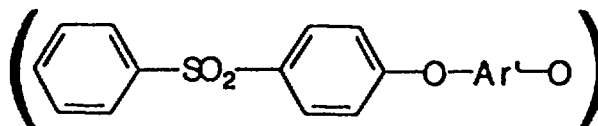


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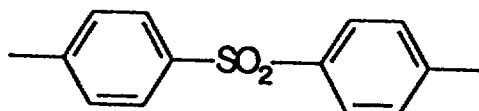
1. A composition comprising a blend of (a) poly(biphenyl ether sulfone) consisting essentially of the repeating unit:



- and (b) a second poly(aryl ether sulfone) consisting essentially of the repeating unit:

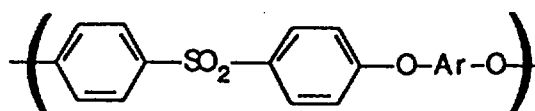


wherein Ar is a divalent group comprising at least 50 mole percent p-biphenylene and Ar' is a divalent group comprising at least 50 mole percent



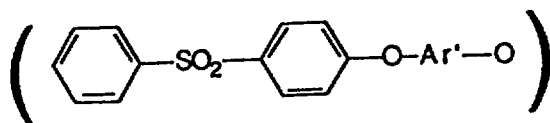
and the weight ratio of (a) to (b) is from about 25 to 99 to 75 to 1.

2. A composition comprising a blend of (a) from about 60 to about 99 percent by weight of a poly(biphenyl ether sulfone) comprising the repeating unit

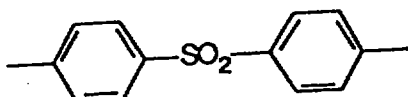


and (b) from about 1 to 40 percent by weight of a second poly(aryl ether sulfone) comprising the repeating unit





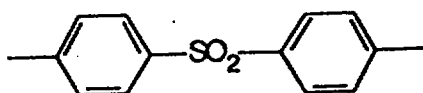
5 wherein Ar comprises biphenylene and Ar' comprises



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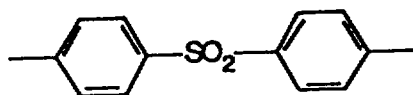
3. A composition as claimed in claim 2 wherein Ar comprises at least 50 mole percent biphenylene and Ar' comprises at least 50 mole percent

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20 4. A composition as claimed in claim 3 wherein from 0 to 50 mole percent of Ar is at least one member selected from the group consisting of p-phenylene and

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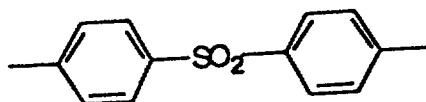


from 0 to 50 mole percent of Ar' is p-phenylene.

30 5. A composition as claimed in claim 2 wherein Ar consists essentially of biphenylene.

6. A composition as claimed in claim 2 wherein Ar' consists essentially of

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7. A composition as claimed in claim 1 wherein said blend comprises at least 50 weight percent poly(biphenyl ether sulfone) and up to 50 weight percent poly(phenylene ether sulfone).

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8. A composition as claimed in claim 1 wherein the poly(biphenyl ether sulfone) comprises from 50 to 99 weight percent.

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9. A process which comprises steam sterilizing an article formed from a composition as claimed in any one of the preceding claims.

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10. Use of a composition as claimed in any one of claims 1 to 8 in making articles for medical use or electrical insulation for electrical conductors.

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* C L N S *

ABSTRACT

POLY(ARYL ETHER SULFONE) COMPOSITIONS
COMPRISING POLY(PHENYLENE ETHER SULFONE)

5 A poly(aryl ether sulfone) blend comprising (a)
from about 25 to about 99 percent by weight of a
poly(biphenyl ether sulfone) and (b) from about 1 to
10 about 75 percent by weight of a second poly(phenylene
ether sulfone).

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POLY(ARYL ETHER SULFONE) COMPOSITIONS
COMPRISING POLY(PHENYLENE ETHER SULFONE)

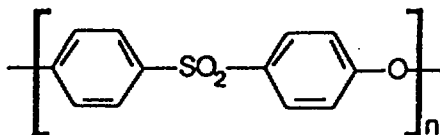
REPLACED SHEETS		SG
☒ Description	: paged .../... to paged .../14...	
☒ Claim(s)	: paged .../15... to paged .../17...	
☐ Drawing(s)	: paged .../... to paged .../...	
☒ Abstract	: paged .../18... to paged .../...	
DATE OF RECEIPT		18/10/96

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This invention is directed to immiscible poly(aryl ether sulfone) blends possessing improved properties comprising (a) from about 35 to about 99 percent by weight of a poly(biphenyl ether sulfone) preferably 60 to 99 percent by weight and (b) from about 1 to about 65 percent by weight of a second poly(phenylene ether sulfone) preferably 40 to 1 weight percent. The compositions described herein, particularly the preferred compositions, retain the very attractive characteristics of their constituents, and display excellent mechanical properties and heat resistance.

Articles made from these poly(aryl ether sulfones) can be steam-sterilized while under stresses of 500 psi or greater; moreover they are not affected by corrosion-reducing additives such as morpholine, for example. Also, the above materials demonstrate good chemical resistance in contact with commonly used hospital cleaners and detergents.

Poly(aryl ether sulfones) have been known for about two decades. They are tough linear polymers that possess a number of attractive features such as excellent high temperature resistance, good electrical properties, and very good hydrolytic stability. At least three poly(aryl ether sulfones) are commercially available. A poly(aryl ether sulfone) referred to herein as poly(phenylene ether sulfone) is available from Imperial Chemical Industries, Ltd. It has the formula (1)



(1)

and is produced by the polycondensation of 4,4'-dihydroxydiphenyl sulfone with 4,4'-dichlorodiphenyl sulfone as described in, for example, Canadian Patent No. 847,963. The polymer contains no aliphatic moieties and has a Tg of approximately 220°C.

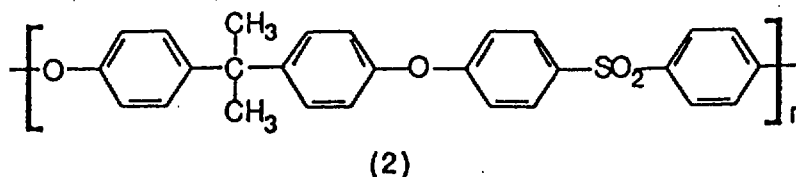
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Another commercial poly(aryl ether sulfone) is available from Amoco Performance Products, Inc., under the trademark of UDEL®. It corresponds to formula (2),



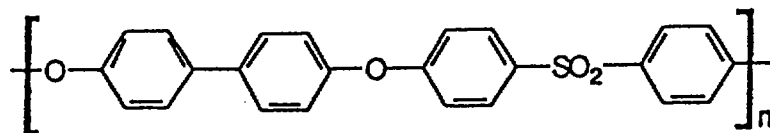
(2)

REPLACEMENT SHEET

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has a Tg of about 190°C, and is made via the nucleophilic polycondensation of bisphenol-A di-sodium salt with 4,4'-dichlorodiphenyl sulfone, as described in U.S. Patent No. 4,108,837.

A third commercial poly(aryl ether sulfone) is also available from Amoco Performance Products, Inc., under the trademark of Radel® R. It corresponds to formula (3) has a Tg of about 220°C, and is produced by the polycondensation of biphenol with 4,4'-dichlorodiphenyl sulfone as described in, for example, Canadian Patent No. 847,963.



(3)

Over the years, there has developed a substantial body of patent and other literature directed to the formation and properties of poly(aryl ether sulfones and other poly(aryl ethers) (all hereinafter called "PAE"). A broad range of PAE's was achieved by Johnson et al., J. of Polymer Science, A-1, Vol. 5, 1967, pp. 2415-2427; Johnson et al., U.S. Patent Nos. 4,108,837 and 4,175,175. Johnson et al. show that a very broad range of PAE's can be formed by the nucleophilic aromatic substitution (condensation) reaction of an activated aromatic dihalide and an aromatic diol. By this method, Johnson et al. created a host of new PAE's.

Because of their excellent mechanical and thermal properties, coupled with outstanding hydrolytic stability, the poly(aryl ether sulfones) have been utilized in the medical market for a variety of purposes for at least ten years. These medical devices constitute a wide variety of articles. Obviously, one of the major attributes of the poly(aryl ether sulfones) is their ability to be steam autoclaved repeatedly without loss of properties. Steam autoclaving is a very severe test, requiring both high temperature and hydrolytic stability, and involving cyclical effects - wet/dry, hot/cold.

The poly(aryl ether sulfones) (1) and (2) show some important deficiencies, however. Indeed, parts molded from these materials, stress-

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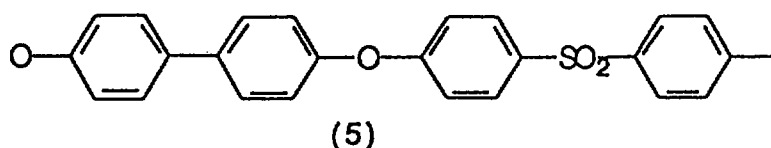
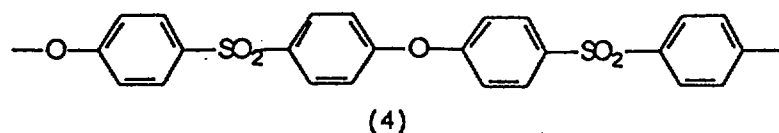
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crack when steam sterilized under stresses of say 500 psi or greater especially when excessive concentration of boiler additives, such as morpholine are employed to reduce corrosion in the steam generating system; or, when in contact with commonly used hospital cleaners and detergents.

While poly(biphenyl ether sulfone) (3) and parts molded therefrom have substantially better properties than poly(aryl ether sulfones) (1) and (2) it is substantially more expensive than (1) and (2) due to the high cost of biphenol.

British Patent Application No. 2,088,396 describes copolymers containing units (4) and (5):



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The claimed copolymers comprise about 80 to 10 mole percent of repeat units (4), and correspondingly about 20 to 90 mole percent of repeat units (5). The application states that the incorporation of (5) into the poly(aryl ether sulfone) (1) yields materials with improved resistance to hot water crazing. The application does not mention steam-sterilizability under load; nor does it teach that the copolymers show resistance to stress-cracking in the presence of boiler additives such as morpholine.

The general object of this invention is to provide blends of poly(biphenyl ether sulfones) having many of the base properties of the poly(biphenyl ether sulfone). Another object of this invention is to provide medical articles from blends of poly(biphenyl ether sulfones) which can be steam-sterilized while under stresses of 500 psi or greater without stress-cracking even in the presence of morpholine. Other objects appear hereinafter.

The general objects of this invention can be attained with immiscible blends comprising (a) from about 35 to about 99 percent by weight of a poly(biphenyl ether sulfone) and (b) from about 1 to 75 percent by weight of a poly(phenylene ether sulfone). Other things being equal blends of polyarylether (1) and poly(aryl ether sulfone) (3) wherein poly(aryl ether sulfone) (3) comprises at least 60% of the two polymers

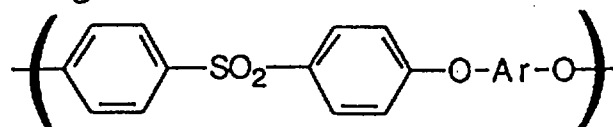
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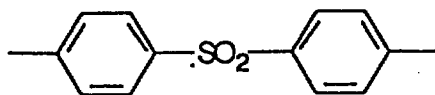
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have substantially the same properties as the more expensive poly(aryl ether sulfone) (3). The two polymers can also be used in weight percent ratios of poly(biphenyl ether sulfone) of from about 50 to 99 to poly(phenylene ether sulfone) of about 50 to 1 weight percent.

Briefly, the poly(biphenyl ether sulfones) useful in this invention comprise the repeating unit

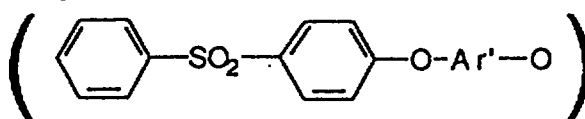


wherein at least 50 and preferably at least 75 mole percent of the divalent Ar groups are p-biphenylene groups and the remainder (0 to 50 mole percent) at least one member selected from the group consisting of p-

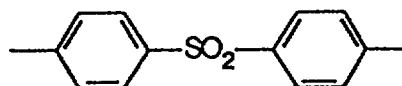


phenylene, , etc. In general, the higher the concentration of biphenyl or biphenylene groups the better the properties of the polymer.

The poly(phenylene ether sulfones) useful in this invention comprise the repeating unit



wherein at least 50 and preferably at least 75 mole percent of the divalent



Ar' groups are bisphenol S moieties and the remainder (0 to 50 mole percent) p-phenylene.

The poly(aryl ether sulfones) can be prepared by either of two methods, i.e., the carbonate method or the alkali metal hydroxide method.

In the carbonate method, the polymers are prepared by contacting substantially equimolar amounts of the hydroxy-containing compounds and dihalodiarylsulfones, e.g., 4,4'-dichlorodiphenyl sulfone or 4,4'-difluorodiphenyl sulfone, with from about 0.5 to about 1.0 mole of an alkali metal carbonate per mole of hydroxyl group in a solvent mixture comprising a solvent which forms an azeotrope with water in order to maintain the reaction medium at substantially anhydrous conditions during the polymerization.

The temperature of the reaction mixture is kept at about 170°C to about 250°C, preferably from about 210°C to about 235°C for about one to 15 hours.

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The reaction is carried out in an inert atmosphere, e.g., nitrogen, at atmospheric pressure, although higher or lower pressures may also be used.

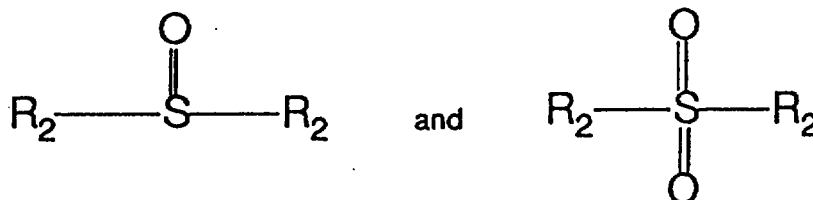
The polyarylethersulfone is then recovered by conventional techniques such as coagulation, solvent evaporation, and the like.

The solvent mixture comprises a solvent which forms an azeotrope with water and a polar aprotic solvent. The solvent which forms an azeotrope with water includes an aromatic hydrocarbon such as benzene, toluene, xylene, ethylbenzene, chlorobenzene, and the like.

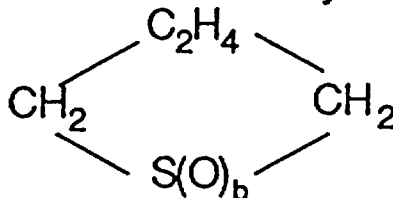
The polar aprotic solvents employed in this invention are those generally known in the art for the manufacture of polyarylether sulfones and include sulfur containing solvents such as those of the formula:



in which each R_1 represents a monovalent lower hydrocarbon group free of aliphatic unsaturation, which preferably contains less than about 8 carbon atoms or when connected together represents a divalent alkylene group with b being an integer from 1 to 2 inclusive. Thus, in all of these solvents, all oxygens and two carbon atoms are bonded to the sulfur atom. Contemplated for use in this invention are such solvents as those having the formula:



where the R_2 groups are independently lower alkyl, such as methyl, ethyl, propyl, butyl, and like groups, and aryl groups such as phenyl and alkylphenyl groups such as the tolyl group, as well as those where the R_2 groups are interconnected as in a divalent alkylene bridge such as



in tetrahydrothiophene oxides and dioxides. Specifically, these solvents include dimethylsulfoxide, dimethylsulfone, diphenylsulfone, diethylsulfoxide, diethylsulfone, diisopropylsulfone, tetrahydrothiophene 1,1-dioxide (commonly called tetramethylene sulfone or sulfolane) and tetrahydrothiophene-1 monoxide.

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Additionally, nitrogen containing solvents may be used. These include dimethylacetamide, dimethylformamide and N-methylpyrrolidone.

The azeotrope forming solvent and polar aprotic solvent are used in a weight ratio of from about 1:10 to about 1:1, preferably from about 1:5 to about 1:3.

In the reaction, the hydroxy containing compound is slowly converted, *in situ*, to the alkali salt thereof by reacting with the alkali metal carbonate. The alkali metal carbonate is preferably potassium carbonate. As indicated before, mixtures of carbonates such as potassium and sodium carbonate may also be used.

Water is continuously removed from the reaction mass as an azeotrope with the azeotrope forming solvent so that substantially anhydrous conditions are maintained during the polymerization.

It is essential that the reaction medium be maintained substantially anhydrous during the polycondensation. While amounts of water up to about one percent can be tolerated, and are somewhat beneficial when employed with fluorinated dihalobenzenoid compounds, amounts of water substantially greater than this are desirably avoided as the reaction of water with the halo and/or nitro compound leads to formation of phenolic species and only low molecular weight products are secured. Consequently, in order to secure the high polymers, the system should be substantially anhydrous, and preferably contain less than 0.5 percent by weight water during the reaction.

Preferably, after the desired molecular weight has been attained, the polymer is treated with an activated aromatic halide or an aliphatic halide such as methyl chloride or benzyl chloride, and the like. Such treatment of the polymer converts the terminal hydroxyl groups into ether groups which stabilize the polymer. The polymer so treated has good melt and oxidative stability.

While the carbonate method for preparing the polymer of this invention is simple and convenient, in some cases products of higher molecular weight can be made by the alkali metal hydroxide method. In the alkali metal hydroxide method, described by Johnson et al., U.S. Patent Nos. 4,108,837 and 4,175,175, a double alkali metal salt of a dihydric phenol is contacted with a dihalobenzenoid compound in the presence of a sulfur containing solvent as herein above defined under substantially anhydrous conditions.

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Additionally, the polymers of this invention can be prepared by other methods known in the prior art, in which at least one dihydric phenol and at least one dihalobenzenoid compound are heated, for example, with a mixture of sodium carbonate or bicarbonate and a second alkali metal carbonate or bicarbonate having a higher atomic number than that of sodium, as described in U.S. Patent No. 4,176,222.

The molecular weight of the poly(aryl ethers) utilized for manufacturing the devices of the instant invention is indicated by reduced viscosity data in an appropriate solvent such as methylene chloride, chloroform, N-methylpyrrolidone, and the like. The reduced viscosities of the materials, as measured at concentrations of 0.2g per 100 ml. at 25°C, are at least 0.3 dl/g, preferably at least 0.4 dl/g and, typically, not exceeding about 1.5 dl/g.

The compositions of this invention are prepared by any conventional mixing method. For example, a preferred method comprises mixing the two poly(aryl ether sulfones) in powder or pellets form in an extruder and extruding the mixture into strands, chopping the strands into pellets and molding the pellets into the desired article.

The poly(aryl ether sulfones) of the instant invention allow for the fabrication of medical devices having outstanding stress-crack resistance. These devices can be steam-sterilized under stresses of 500 psi or greater and in the presence of a variety of steam boiler additives. Typical boiler additives designed to reduce corrosion in steam generating systems are amino compounds such as morpholine, hydrazine, N,N-diethylaminoethanol ("NALCO 359" or "BETZ NA-9"), and octadecylamine. Steam sterilization is also possible in the presence of various hospital cleaners and detergents, such as those sold under the tradenames of "Castle 7900" (a sonic cleaner), "Chem Crest 14" (an ultrasonic cleaner), "Tergitol Min Foam 2X" (a non ionic surfactant), and the like.

The materials of the instant invention can include pigments, thermal stabilizers, ultraviolet light stabilizers, and other additives.

The instant poly(aryl ether sulfones) blends are useful for the fabrication of a wide variety of medical devices. They are of particular interest for autoclavable storage trays such as the systems for storage and delivery of sterile surgical instruments (thus eliminating the costs associated with wrapping); in the medical supply industry for shipment

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and storage of implants, prostheses and other medical devices under sterile conditions; and in many other similar applications.

The compositions of this invention can also be fabricated into any desired shape, i.e., moldings, coatings, films, or fibers. They are particularly desirable for use as electrical insulation for electrical conductors.

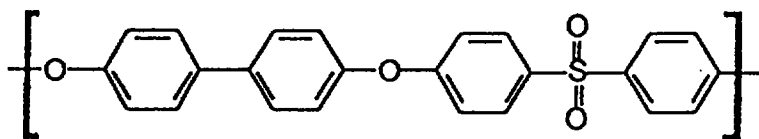
These compositions can include mineral fillers such as carbonates including chalk, calcite and dolomite; silicates including mica, talc, wollastonite, silicon dioxide, glass spheres, glass powders; aluminum; clay; quartz; and the like. Also, reinforcing fibers such as fiberglass, carbon fibers, and the like may be used. The compositions may also include additives such as titanium dioxide; thermal stabilizers, ultraviolet light stabilizers, plasticizers, and the like.

EXAMPLES

The following examples provide specific illustrations of the present invention and are not to be construed in any way as a limitation on its scope or generality.

Sample Preparations and Test Procedures

There were two types of polymeric materials used in all the preparations of this invention: polybiphenylsulfone and bisphenol-S based polysulfone. The polybiphenylsulfone is a polymer having the repeat unit



It is available commercially from Amoco Performance Products, Inc. under the trade name Radel R 5000. It has a reduced viscosity of approximately 0.60 dl/g as measured in N-methyl pyrrolidone at a concentration of 0.2 g/dl and 25°C. It has a number-average molecular weight of about 20,000 as measured by gel permeation chromatography using methylene chloride as a solvent and a polystyrene molecular weight calibration. This polymer is referred to hereafter as PSF-I.

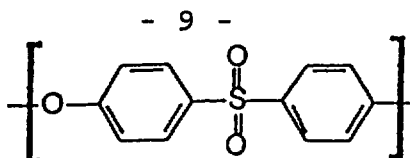
One bisphenol-S polysulfone used is the commercial product Victrex 4100 G available from Imperial Chemical Industries, PLC. It is a polymer having the formula repeat unit

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It has a reduced viscosity of about 0.50 g/dl in N-methylpyrrolidone at 25°C and a concentration of 0.2 g/dl. Its number-average molecular weight by gel permeation chromatography is about 17,000 using methylene chloride as solvent and a polystyrene molecular weight calibration. This polymer is referred to hereafter as PES-I. The polymers were used in pellet form and all are transparent, by virtue of their amorphous character, and have a slight amber color.

Controls A and B

Two neat polymers PSF-I and PES-I were dried overnight in a Lydon dehumidified recirculating air oven at a temperature of 300°F. Parts were then injection molded on a Battenfeld injection molding machine with a 3 oz injection capacity to produce standard ASTM test specimens. Mechanical properties and heat deflection temperatures (HDT) were measured per the ASTM procedures shown below. All tests were conducted on 1/8" thick specimens except HDT which was run on both 1/8" and 1/4" specimens.

Property	ASTM Method No.
Tensile Modulus	D-638
Tensile Strength	D-638
Elongation at Break	D-638
Notched Izod Impact Strength	D-256
Tensile Impact Strength	D-1822
Heat Deflection Temperature	D-648
Flexural Modulus	D-790
Flexural Strength	D-790

Examples 1 to 6

The compositions shown in Table I were mixed well as pellets and placed in a dehumidified air oven at 300°F for about 16 hrs (overnight) for drying. The dry blends were then extruded using a 25 mm twin screw double vented BErstorff extruder having an L/D ratio of 33/1

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according to the conditions profile shown in Table I. The first vent port was open to the atmosphere, the second was connected to a vacuum pump. The extruder was fitted with a double strand die. The polymer extrudate was pelletized after passing through a water trough for cooling. All blends were extruded and pelletized without incident at the throughput rates indicated in Table 1. Between successive blend compositions, two pounds of extrudate were designated as "transition" material and discarded. From past experience, this amount is sufficient to effectively displace the melt in the extruder so as the compositions of the final blends do not differ from those of the dry pellet mixes.

The six blends were dried again overnight in the Lydon oven at 300°F and injection molded the following day on the Battenfeld injection molding machine described above to generate the needed ASTM parts. All blends appeared translucent on molding and the magnitude of the translucency increased towards the middle of the composition scale and became progressively less at the compositions rich in one polymer or the other. The lack of clarity in these blends is an indication of immiscibility between the two homopolymers.

Mechanical Properties

ASTM mechanical properties for the controls and blends are shown in Table II. The strength and modulus values for all blends appear to vary linearly with respect to PSF-I content in the blend. As a measure of ductility, elongation at break of all the blends can be considered equivalent to that of PSF-I within the variability of this measurement. The tensile impact, a discriminating test of polymer unnotched toughness is likewise similar for all compositions. All these mechanical properties confirm the very good mechanical compatibility of the blends of this invention. For compositions rich in PSF-I (examples 1, 2, and 3), little or no loss in the high notched Izod of PSF-I is observed. Accordingly, compositions comprising from 60 to 99 weight percent PSF-I and correspondingly from 1 to 40 weight percent PES-I have many of the excellent physical properties of PSF-I.

Immiscible polymer blends which have poor mechanical compatibility are typically characterized by low strength for parts containing "weld lines" as a result of a multi-gated mold configuration. To ascertain the mechanical compatibility of these blends the weld-line strengths were measured against the base case with no weld line. ASTM

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tensile bars containing weld lines were produced on a Van Dorn injection molding machine fitted with a double gated tensile bar mold. Molding was performed at conditions similar to those used for the standard single gate case. Results are shown in Table III illustrating the retention of tensile strength over weld-line sections for all blends.

Steam Sterilization

To assess the steam sterilization resistance of the PSF-I/PES-I blend compositions, the following test was employed. 5"x1/2"x1/8" ASTM bars were mounted by fixing the bar horizontally from one end in a cantilever fashion, and a weight was suspended on the free end. The weight attached to the specimen was such that a maximum flexural stress of about 1000 psi was generated at the fixed end surface of the bar. The samples which were mounted side by side in a stainless steel drawer were then placed in a steam autoclave. The autoclave was operated at a steam pressure of 27 psig, and a temperature of 270°F, and the autoclave chamber was charged with water containing 50 part per million (ppm) morpholine. Each autoclave cycle consisted of a 5-minute heat-up and pressurization step followed by a hold at the set conditions for 30 minutes after which the autoclave was vented and allowed to cool down for 10 minutes. The samples were typically inspected at the completion of 15-25 cycles and all samples were tested in duplicates.

Table IV summarizes the results from the steam sterilization performance study. Quite unexpectedly, the performance of all blends except that of example 6 is comparable to that of PSF-I. None showed any evidence of stress cracking following 450 cycles of steam sterilization as described above. In comparison, PES-I experienced a rupture after only 45 cycles. The blend of example 6 had a rupture at 166 cycles - still significantly better than PES-I. The unbroken duplicate of example 6 and control B were cracked extensively and the test was not continued on them as they are also considered failures from the practical standpoint of the test. Accordingly, compositions comprising about 35 to 99 weight percent PSF-I and about 65 to 1 weight percent PES-I have improved resistance to steam containing amine stabilizers.

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Table I: Extrusion Conditions for Preparation of PSF-I/PES-I Blends of Examples 1-6.*

Example	1	2	3	4	5	6
Percent PSF-I	80	70	60	50	40	25
Percent PES-I	20	30	40	50	60	75
Temperatures (C)						
Zone 1	330	330	320	320	320	320
" 2	340	340	330	330	330	330
" 3	350	350	340	340	340	340
" 4	350	350	350	340	340	340
" 5	350	350	350	340	340	340
" 6	360	350	350	340	340	340
" 7 (Die)	350	340	340	340	340	340
Melt	388	382	378	374	371	371

* Conditions common to all runs were approximately as follows:

screw speed = 200 rpm

throughput rate = 29 lbs/hr

Vent 2 vacuum reading = 30 in Hg

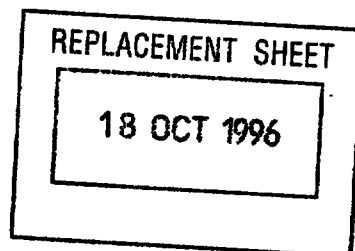
Vent 1 open to the atmosphere

Table II: Mechanical Properties of PSF-I, PES-I and 6 Blend Compositions of the Two Polymers.

Example	PSF-I (%)	Tensile Strength (kpsi)	Tensile Modulus (kpsi)	Elongation at Break (%)	Flexural Strength (kpsi)	Flexural Modulus (kpsi)
Control A	100	10.3	337	109	12.8	339
1	80	10.6	335	99	13.5	361
2	70	10.8	341	117	14.1	374
3	60	10.9	344	107	14.4	382
4	50	11.0	346	107	14.9	386
5	40	11.4	345	115	15.3	398
6	25	11.6	355	101	15.5	393
Control B	0	12.1	402	36	16.2	409

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Example	PSF-I (%)	Notched Izod (ft-lb/in)	Tensile Impact (ft-lb/in ²)	Heat Deflection Temp.	
				[1/8"] (C)	[1/4"] (C)
Control A	100	16.0	235	193	203
1	80	15.2	207	196	199
2	70	15.7	179	196	198
3	60	8.5	226	194	198
4	50	2.5	222	195	212
5	40	2.2	195	192	211
6	25	1.8	181	193	207
Control B	0	1.3	175	193	205

Table III: Weld Line Strengths of PSF-I/PES-I Blends Compared with the Strength of Non-weld Line Specimens.

Example	PSF-I (%)	Tensile Strengths	
		No Weld Line (kpsi)	Weld Line (kpsi)
Control A	100	10.3	10.0
1	80	10.6	10.4
2	70	10.8	10.5
3	60	10.9	10.8
4	50	11.0	11.0
5	40	11.4	11.2
6	25	11.6	11.5

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Table IV: Steam Sterilization* Performance of PSF-I, PES-I and 6 Blend Compositions of the Two Polymers.

Example	PSF-I (%)	Number of Cycles Steam Sterilization	Observations
Control A	100	450	No Changes
1	80	450	No Changes
2	70	450	No Changes
3	60	450	No Changes
4	50	450	No Changes
5	40	450	No Changes
6	25	166	Cracks/Rupture
Control B	0	45	Cracks Rupture

* Steam Sterilization Conditions: 1000 psi flexural stress, 27 psig steam with 50 ppm morpholine, 270 deg F steam, 30-minute autoclaving cycle.

Essentially the same results can be obtained by replacing PES-I with Radel A-200 sold by Amoco Performance Products, Inc., which is the condensation product of dichlorodiphenyl sulfone with a 3:1 molar ratio of Bisphenol S to hydroquinone.

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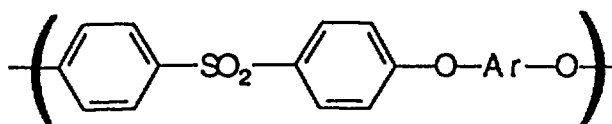


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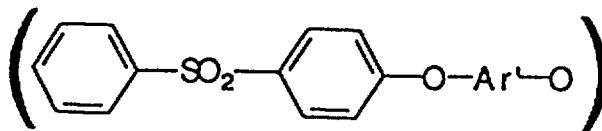
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CLAIMS:

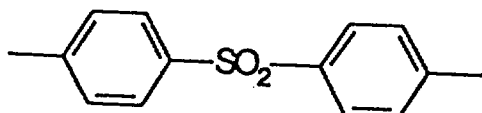
1. A composition comprising a blend of (a) poly(biphenyl ether sulfone) consisting essentially of the repeating unit:



and (b) a second poly(aryl ether sulfone) consisting essentially of the repeating unit:

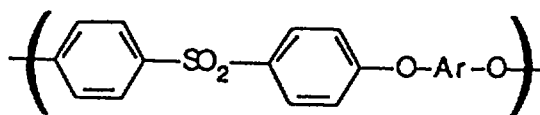


wherein Ar is a divalent group comprising at least 50 mole percent p-biphenylene and Ar' is a divalent group comprising at least 50 mole percent



and the weight ratio of (a) to (b) is from about 25 to 99 to 75 to 1.

2. A composition comprising a blend of (a) from about 60 to about 99 percent by weight of a poly(biphenyl ether sulfone) comprising the repeating unit



and (b) from about 1 to 40 percent by weight of a second poly(aryl ether sulfone) comprising the repeating unit

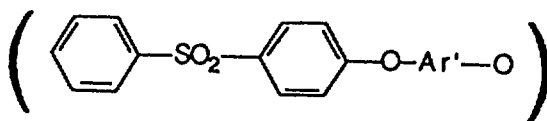
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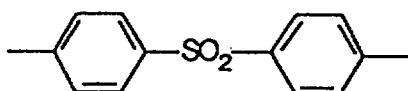
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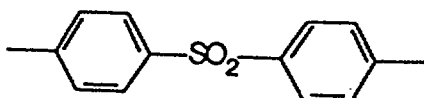
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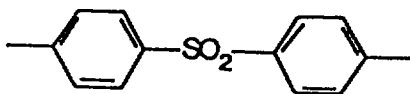
wherein Ar comprises biphenylene and Ar' comprises



3. A composition as claimed in claim 2 wherein Ar comprises at least 50 mole percent biphenylene and Ar' comprises at least 50 mole percent



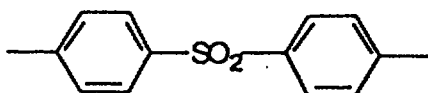
4. A composition as claimed in claim 3 wherein from 0 to 50 mole percent of Ar is at least one member selected from the group consisting of p-phenylene and



from 0 to 50 mole percent of Ar' is p-phenylene.

5. A composition as claimed in claim 2 wherein Ar consists essentially of biphenylene.

6. A composition as claimed in claim 2 wherein Ar' consists essentially of



* C L M S *

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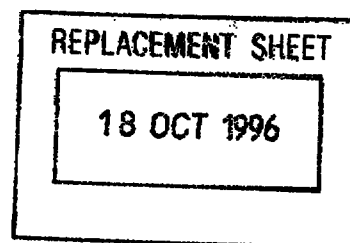
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7. A composition as claimed in claim 1 wherein said blend comprises at least 50 weight percent poly(biphenyl ether sulfone) and up to 50 weight percent poly(phenylene ether sulfone).

8. A composition as claimed in claim 1 wherein the poly(biphenyl ether sulfone) comprises from 50 to 99 weight percent.

9. A process which comprises steam sterilizing an article formed from a composition as claimed in any one of the preceding claims.

10. Use of a composition as claimed in any one of claims 1 to 8 in making articles for medical use or electrical insulation for electrical conductors.



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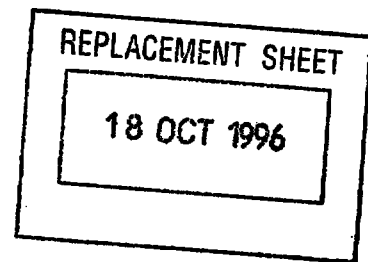
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ABSTRACT

POLY(ARYL ETHER SULFONE) COMPOSITIONS
COMPRISING POLY(PHENYLENE ETHER SULFONE)

A poly(aryl ether sulfone) blend comprising (a) from about 25 to about 99 percent by weight of a poly(biphenyl ether sulfone) and (b) from about 1 to about 75 percent by weight of a second poly(phenylene ether sulfone).

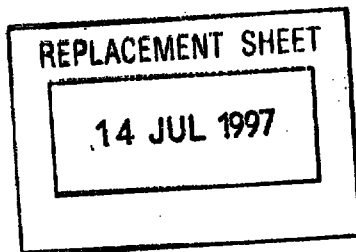


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REPLACED SHEETS		SG
☒ Description	: paged 1 to paged 9	
☒ Claim(s)	: paged 10 to paged 14	
☐ Drawing(s)	: paged to paged	
☒ Abstract	: paged to paged	
DATE OF RECEIPT		14/7/97

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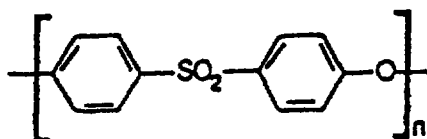
POLY(ARYL ETHER SULFONE) COMPOSITIONS
COMPRISING POLY(PHENYLENE ETHER SULFONE)

Description

This invention is directed to immiscible poly(aryl ether sulfone) blends possessing improved properties comprising (a) a poly(aryl ether sulfone) and (b) a second poly(aryl ether sulfone) other than said first poly(aryl ether sulfone) in a weight ratio of (a) to (b) which is in the range of from 70/30 to 99/1. The compositions described herein, particularly the preferred compositions, retain the very attractive characteristics of their constituents, and display excellent mechanical properties and heat resistance.

Articles made from these poly(aryl ether sulfones) can be steam-sterilized while under stresses of 3,448KN/m² (500 psi) or greater; moreover they are not affected by corrosion-reducing additives such as morpholine, for example. Also, the above materials demonstrate good chemical resistance in contact with commonly used hospital cleaners and detergents.

Poly(aryl ether sulfones) have been known for about two decades. They are tough linear polymers that possess a number of attractive features such as excellent high temperature resistance, good electrical properties, and very good hydrolytic stability. At least three poly(aryl ether sulfones) are commercially available. A poly(aryl ether sulfone) referred to herein as poly(phenylene ether sulfone) is available from Imperial chemical industries, Ltd. It has the formula (1)



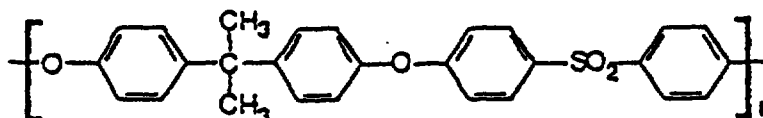
(1)

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and is produced by the polycondensation of 4,4'-dihydroxydiphenyl sulfone with 4,4'-dichlorodiphenyl sulfone as described in, for example, Canadian Patent No. 847,963. The polymer contains no aliphatic moieties and has a Tg of approximately 220°C.

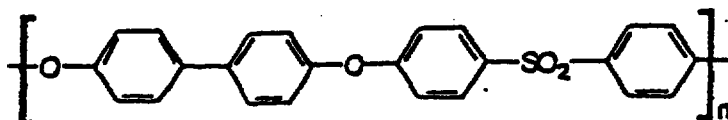
Another commercial poly(aryl ether sulfone) is available from Amoco Performance Products, Inc., under the trademark of UDEL®. It corresponds to formula (2).



(2)

has a Tg of about 190°C, and is made via the nucleophilic polycondensation of bisphenol-A di-sodium salt with 4,4'-dichlorodiphenyl sulfone, as described in U.S. Patent No. 4,108,837.

A third commercial poly(aryl ether sulfone) is also available from Amoco Performance Products, Inc., under the trademark of Radel® F. It corresponds to formula (3) has a Tg of about 220°C, and is produced by the polycondensation of biphenol with 4,4'-dichlorodiphenyl sulfone as described in, for example, Canadian Patent No. 847,963.



(3)

Over the years, there has developed a substantial body of patent and other literature directed to the formation and properties of poly(aryl ether sulfones and other poly(aryl ethers) (all hereinafter called "PAE"). A broad range of PAE's was achieved by Johnson et al., J. of Polymer Science, A-1, Vol. 5, 1967, pp. 2415-2427; Johnson et al., U.S. Patent Nos. 4,108,837 and 4,175,175. Johnson et al. show that a very broad range of PAE's can be formed by the nucleophilic aromatic substitution (condensation) reaction of an activated aromatic dihalide and an aromatic diol. By this method, Johnson et al. created a host of new PAE's.

Because of their excellent mechanical and thermal properties, coupled with outstanding hydrolytic stability, the

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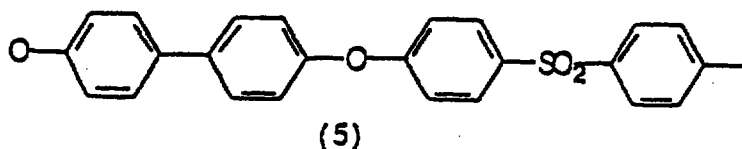
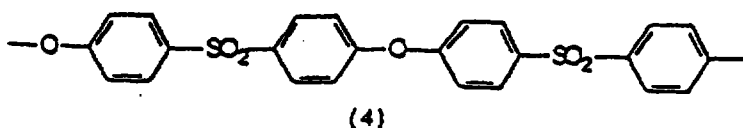
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poly(aryl ether sulfones) have been utilized in the medical market for a variety of purposes for at least ten years. These medical devices constitute a wide variety of articles. Obviously, one of the major attributes of the poly(aryl ether sulfones) is their ability to be steam autoclaved repeatedly without loss of properties. Steam autoclaving is a very severe test, requiring both high temperature and hydrolytic stability, and involving cyclical effects - wet/dry, hot/cold.

The poly(aryl ether sulfones) (1) and (2) show some important deficiencies, however. Indeed, parts molded from these materials, stress-crack when steam sterilized under stresses of say 3,448KN/m² (500 psi) or greater especially when excessive concentration of boiler additives, such as morpholine are employed to reduce corrosion in the steam generating system; or, when in contact with commonly used hospital cleaners and detergents.

While poly(biphenyl ether sulfone) (3) and parts molded therefrom have substantially better properties than poly(aryl ether sulfones) (1) and (2) it is substantially more expensive than (1) and (2) due to the high cost of biphenol.

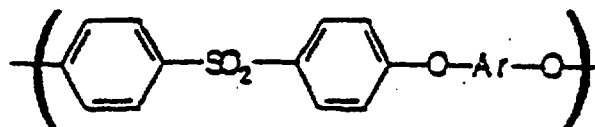
British Patent Application No. 2,088,396 describes copolymers containing units (4) and (5):



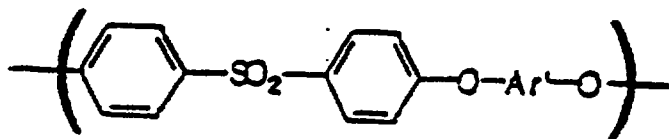
The claimed copolymers comprise about 80 to 10 mole percent of repeat units (4), and correspondingly about 20 to 90 mole percent of repeat units (5). The application states that the incorporation of (5) into the poly(aryl ether sulfone) (1) yields materials with improved resistance to hot water crazing. The application does not mention steam-sterilizability under load; nor does it teach that the copolymers show resistance to stress-cracking in the presence of boiler additives such as morpholine.

The general object of this invention is to provide blends of poly(aryl ether sulfones) having many of the base properties of the poly(biphenyl ether sulfone). Another object of this invention is to provide medical articles from blends of poly(aryl ether sulfones) which can be steam-sterilized while under stresses of 3,448KN/m² (500 psi) or greater without stress-cracking even in the presence of morpholine. Other objects appear hereinafter.

The invention provides a composition comprising a blend of (a) a first poly(aryl ether sulfone) consisting of the repeating unit:



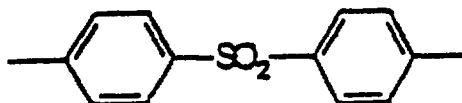
and (b) a second poly(aryl ether sulfone) other than said first poly(aryl ether sulfone) consisting essentially of the repeating unit:



in a weight ratio of (a) to (b) which is in the range of from 70/30 to 99/1 wherein at least 50 mole % of said Ar groups are p-biphenylene and wherein at least 50 mole % of said Ar' groups are

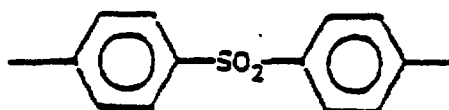


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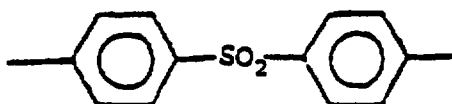
The poly(aryl ether sulfone) blends of the invention have substantially the same properties as the more expensive poly(aryl ether sulfone) (3).

According to an embodiment of the invention, the composition comprises the blend of poly(aryl ether sulfones) in which the remainder of the Ar groups (0 to 50 mole percent) are other than



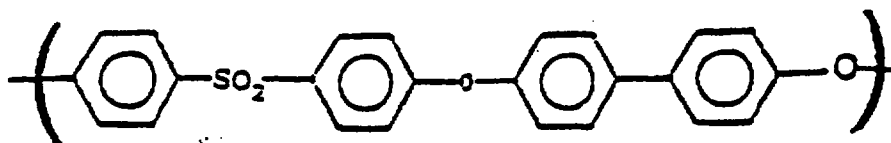
Furthermore, the remainder of the Ar' groups (0 to 50 mole percent) may be other than p-biphenylene.

According to a further embodiment of the invention, a composition is provided in which the remaining Ar groups (0 to 50 mole percent) in poly(aryl ether sulfone) (a) are selected from p-phenylene and



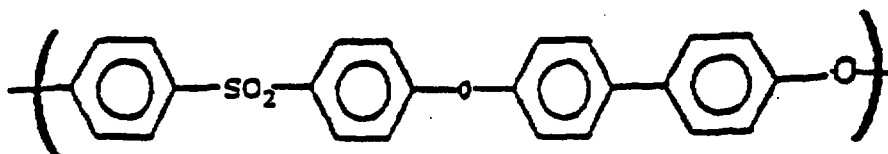
and the remaining Ar' groups (0 to 50 mole percent) in poly(aryl ether sulfone) (b) are p-phenylene.

According to a further embodiment, the invention provides a composition in which the poly(aryl ether sulfone) (a) is a polybiphenyl ether sulfone having the repeating unit:



preferably, the remaining Ar' groups (0 to 50 mole percent) of poly(aryl ether sulfone) (b) being p-phenylene.

The invention further provides a composition in which poly(aryl ether sulfone) (a) is a poly(biphenyl ether sulfone) having the repeating unit:

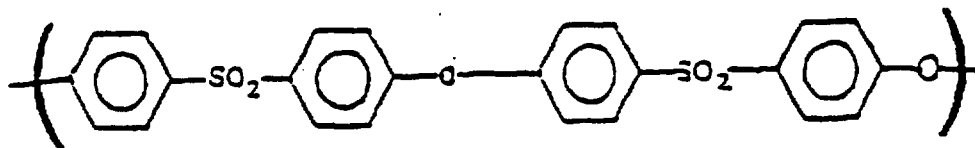


and a poly(aryl ether sulfone) (b) having the repeating unit:



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In general, the higher the concentration of biphenyl or biphenylene groups the better the properties of the polymer. The poly(aryl ether sulfones) can be prepared by either of two methods, i.e., the carbonate method or the alkali metal hydroxide method.

In the carbonate method, the polymers are prepared by contacting substantially equimolar amounts of the hydroxy-containing compounds and dihalodiarylsulfones, e.g., 4,4'-dichlorodiphenyl sulfone or 4,4'-difluorodiphenyl sulfone, with from about 0.5 to about 1.0 mole of an alkali metal carbonate per mole of hydroxyl group in a solvent mixture comprising a solvent which forms an azeotrope with water in order to maintain the reaction medium at substantially anhydrous conditions during the polymerization.

The temperature of the reaction mixture is kept at about 170°C to about 250°C, preferably from about 210°C to about 235°C for about one to 15 hours.

The reaction is carried out in an inert atmosphere, e.g., nitrogen, at atmospheric pressure, although higher or lower pressures may also be used.

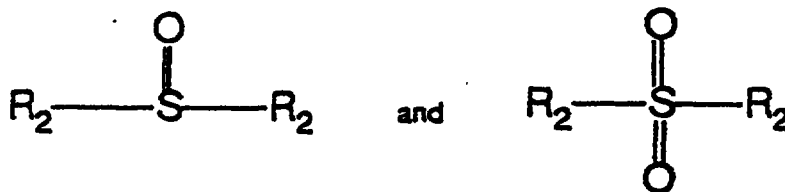
The polyarylethersulfone is then recovered by conventional techniques such as coagulation, solvent evaporation, and the like.

The solvent mixture comprises a solvent which forms an azeotrope with water and a polar aprotic solvent. The solvent which forms an azeotrope with water includes an aromatic hydrocarbon such as benzene, toluene, xylene, ethylbenzene, chlorobenzene, and the like.

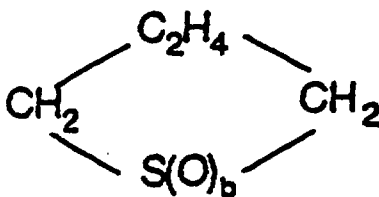
The polar aprotic solvents employed in this invention are those generally known in the art for the manufacture of polyarylether sulfones and include sulfur containing solvents such as those of the formula:



in which each R_1 represents a monovalent lower hydrocarbon group free of aliphatic unsaturation, which preferably contains less than about 3 carbon atoms or when connected together represents a divalent alkylene group with b being an integer from 1 to 2 inclusive. Thus, in all of these solvents, all oxygens and two carbon atoms are bonded to the sulfur atom. Contemplated for use in this invention are such solvents as those having the formula:



where the R_2 groups are independently lower alkyl, such as methyl, ethyl, propyl, butyl, and like groups, and aryl groups such as phenyl and alkylphenyl groups such as the tolyl group, as well as those where the R_2 groups are interconnected as in a divalent alkylene bridge such as



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in tetrahydrothiophene oxides and dioxides. Specifically, these solvents include dimethylsulfoxide, dimethylsulfone, diphenylsulfone, diethylsulfoxide, diethylsulfone, diisopropylsulfone, tetrahydrothiophene 1,1-dioxide (commonly called tetramethylene sulfone or sulfolane) and tetrahydrothiophene-1 monoxide.

Additionally, nitrogen containing solvents may be used. These include dimethylacetamide, dimethylformamide and N-methylpyrrolidone.

The azeotrope forming solvent and polar aprotic solvent are used in a weight ratio of from about 1:10 to about 1:1, preferably from about 1:5 to about 1:3.

In the reaction, the hydroxy containing compound is slowly converted, *in situ*, to the alkali salt thereof by reacting with the alkali metal carbonate. The alkali metal carbonate is preferably potassium carbonate. As indicated before, mixtures of carbonates such as potassium and sodium carbonate may also be used.

Water is continuously removed from the reaction mass as an azeotrope with the azeotrope forming solvent so that substantially anhydrous conditions are maintained during the polymerization.

It is essential that the reaction medium be maintained substantially anhydrous during the polycondensation. While amounts of water up to about one percent can be tolerated, and are somewhat beneficial when employed with fluorinated dihalobenzenoid compounds, amounts of water substantially greater than this are desirably avoided as the reaction of water with the halo and/or nitro compound leads to formation of phenolic species and only low molecular weight products are secured. Consequently, in order to secure the high polymers, the system should be substantially anhydrous, and preferably contain less than 0.5 percent by weight water during the reaction.

Preferably, after the desired molecular weight has been attained, the polymer is treated with an activated aromatic halide or an aliphatic halide such as methyl chloride or benzyl chloride, and the like. Such treatment of the polymer converts the terminal hydroxyl groups into ether groups which stabilize the polymer. The polymer so treated has good melt and oxidative stability.

While the carbonate method for preparing the polymer of this invention is simple and convenient, in some cases products of higher molecular weight can be made by the alkali metal hydroxide method. In the alkali metal hydroxide method, described by Johnson et al., U.S. Patent Nos. 4,108,837 and 4,175,175, a double alkali metal salt of a dihydric phenol is contacted with a dihalobenzenoid compound in the presence of a sulfur containing solvent as herein above defined under substantially anhydrous conditions.

Additionally, the polymers of this invention can be prepared by other methods known in the prior art, in which at least one dihydric phenol and at least one dihalobenzenoid compound are heated, for example, with a mixture of sodium carbonate or bicarbonate and a second alkali metal carbonate or bicarbonate having a higher atomic number than that of sodium, as described in U.S. Patent No. 4,176,222.

The molecular weight of the poly(aryl ethers) utilized for manufacturing the devices of the instant invention is indicated by reduced viscosity data in an appropriate solvent such as methylene chloride, chloroform, N-methylpyrrolidone, and the like. The reduced viscosities of the materials, as measured at concentrations of 0.2g per 100 ml. at 25°C. are at least 0.3 dl/g, preferably at least 0.4 dl/g and, typically, not exceeding about 1.5 dl/g.

The compositions of this invention are prepared by any conventional mixing method. For example, a preferred method comprises mixing the two poly(aryl ether sulfones) in powder or pellets form in an extruder and extruding the mixture into strands, chopping the strands into pellets and molding the pellets into the desired article.

The poly(aryl ether sulfones) of the instant invention allow for the fabrication of medical devices having outstanding stress-crack resistance. These devices can be steam-sterilized under stresses of 3,448 kN/m² (500 psi) or greater and in the presence of a variety of steam boiler additives. Typical boiler additives designed to reduce corrosion in steam generating systems are amino compounds such as morpholine, hydrazine, N,N-diethylaminoethanol ("NALCO 359" or "BETZ NA-9"), and octadecylamine. Steam sterilization is also possible in the presence of various hospital cleaners and detergents, such as those sold under the tradenames of "Castle 7900" (a sonic cleaner), "Chem Crest 14" (an ultrasonic cleaner), "Tergitol Min Foam 2X" (a non ionic surfactant), and the like.

The materials of the instant invention can include pigments, thermal stabilizers, ultraviolet light stabilizers, and other additives.

The instant poly(aryl ether sulfones) blends are useful for the fabrication of a wide variety of medical devices. They are of particular interest for autoclavable storage trays such as the systems for storage and delivery of sterile surgical instruments (thus eliminating the costs associated with wrapping); in the medical supply industry for shipment and storage of implants, prostheses and other medical devices under sterile conditions; and in many other similar applications.

The compositions of this invention can also be fabricated into any desired shape, i.e., moldings, coatings, films, or fibers. They are particularly desirable for use as electrical insulation for electrical conductors.

These compositions can include mineral fillers such as carbonates including chalk, calcite and dolomite; silicates including mica, talc, wollastonite, silicon dioxide, glass spheres, glass powders; aluminum; clay; quartz; and the like. Also, reinforcing fibers such as fiberglass, carbon fibers, and the like may be used. The compositions may also include additives such as titanium dioxide; thermal stabilizers, ultraviolet light stabilizers, plasticizers, and the like.

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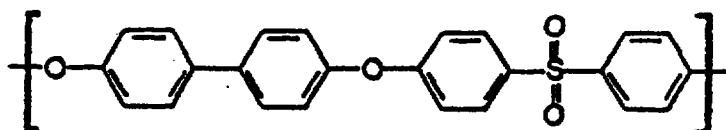
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EXAMPLES

The following examples provide specific illustrations of the present invention and are not to be construed in any way as a limitation on its scope or generality.

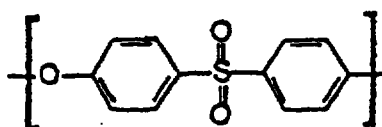
Sample Preparations and Test Procedures

There were two types of polymeric materials used in all the preparations of this invention: polybiphenylsulfone and bisphenol-S based polysulfone. The polybiphenylsulfone is a polymer having the repeat unit



It is available commercially from Amoco Performance Products, Inc. under the trade name Radel R 5000. It has a reduced viscosity of approximately 0.60 dl/g as measured in N-methyl pyrrolidone at a concentration of 0.2 g/dl and 25°C. It has a number-average molecular weight of about 20,000 as measured by gel permeation chromatography using methylene chloride as a solvent and a polystyrene molecular weight calibration. This polymer is referred to hereafter as PSF-I.

One bisphenol-S polysulfone used is the commercial product Victrex 4100 G available from Imperial Chemical Industries, PLC. It is a polymer having the formula repeat unit



It has a reduced viscosity of about 0.50 g/dl in N-methylpyrrolidone at 25°C and a concentration of 0.2 g/dl. Its number-average molecular weight by gel permeation chromatography is about 17,000 using methylene chloride as solvent and a polystyrene molecular weight calibration. This polymer is referred to hereafter as PES-I. The polymers were used in pellet form and all are transparent, by virtue of their amorphous character, and have a slight amber color.

Controls A and B

Two neat polymers PSF-I and PES-I were dried overnight in a Lydon dehumidified recirculating air oven at a temperature of 149°C (300°F). Parts were then injection molded on a Battenfeld injection molding machine with a 85g. (3 oz) injection capacity to produce standard ASTM test specimens. Mechanical properties and heat deflection temperatures (HDT) were measured per the ASTM procedures shown below. All tests were conducted on 3 mm (1/8") thick specimens except HDT which was run on both 3 mm (1/8") and 6 mm (1/4") specimens.

Property	ASTM Method No.
Tensile Modulus	D-638
Tensile Strength	D-638
Elongation at Break	D-638
Notched Izod Impact Strength	D-256
Tensile Impact Strength	D-1822
Heat Deflection Temperature	D-648
Flexural Modulus	D-790
Flexural Strength	D-790

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Examples 1 to 6

The compositions shown in Table I were mixed well as pellets and placed in a dehumidified air oven at 149°C (300°F) for about 16 hrs (overnight) for drying. The dry blends were then extruded using a 25 mm twin screw double vented BErstorff extruder having an L/D ratio of 33/1 according to the conditions profile shown in Table 1. The first vent port was open to the atmosphere, the second was connected to a vacuum pump. The extruder was fitted with a double strand die. The polymer extrudate was pelletized after passing through a water trough for cooling. All blends were extruded and pelletized without incident at the throughput rates indicated in Table 1. Between successive blend compositions, 1 kg (two pounds) of extrudate were designated as "transition" material and discarded. From past experience, this amount is sufficient to effectively displace the melt in the extruder so as the compositions of the final blends do not differ from those of the dry pellet mixes.

The six blends were dried again overnight in the Lydon oven at 149°C (300°F) and injection molded the following day on the Battenfeld injection molding machine described above to generate the needed ASTM parts. All blends appeared translucent on molding and the magnitude of the translucency increased towards the middle of the composition scale and became progressively less at the compositions rich in one polymer or the other. The lack of clarity in these blends is an indication of immiscibility between the two homopolymers.

Compositions comprising from 70 to 99 weight percent PSF-I and correspondingly from 1 to 30 weight percent PES-I are according to the invention.

Mechanical Properties

ASTM mechanical properties for the controls and blends are shown in Table II. The strength and modulus values for all blends appear to vary linearly with respect to PSF-I content in the blend. As a measure of ductility, elongation at break of all the blends can be considered equivalent to that of PSF-I within the variability of this measurement. The tensile impact, a discriminating test of polymer unnotched toughness is likewise similar for all compositions. All these mechanical properties confirm the very good mechanical compatibility of the blends of this invention. For compositions rich in PSF-I (examples 1, 2, and 3), little or no loss in the high notched Izod of PSF-I is observed. Accordingly, compositions comprising from 60 to 99 weight percent PSF-I and correspondingly from 1 to 40 weight percent PES-I have many of the excellent physical properties of PSF-I.

Immiscible polymer blends which have poor mechanical compatibility are typically characterized by low strength for parts containing "weld lines" as a result of a multi-gated mold configuration. To ascertain the mechanical compatibility of these blends the weld-line strengths were measured against the base case with no weld line. ASTM tensile bars containing weld lines were produced on a Van Dorn injection molding machine fitted with a double gated tensile bar mold. Molding was performed at conditions similar to those used for the standard single gate case. Results are shown in Table III illustrating the retention of tensile strength over weld-line sections for all blends.

Steam Sterilization

To assess the steam sterilization resistance of the PSF-I/PES-I blend compositions, the following test was employed. 127 mm x 13 mm x 3 mm (5"x1/2"x1/8") ASTM bars were mounted by fixing the bar horizontally from one end in a cantilever fashion, and a weight was suspended on the free end. The weight attached to the specimen was such that a maximum flexural stress of about 6.9×10^3 kN/m² (1000 psi) was generated at the fixed end surface of the bar. The samples which were mounted side by side in a stainless steel drawer were then placed in a steam autoclave. The autoclave was operated at a steam pressure of 186 kN/m² (27 psig), and a temperature of 132°C (270°F), and the autoclave chamber was charged with water containing 50 part per million (ppm) morpholine. Each autoclave cycle consisted of a 5-minute heat-up and pressurization step followed by a hold at the set conditions for 30 minutes after which the autoclave was vented and allowed to cool down for 10 minutes. The samples were typically inspected at the completion of 15-25 cycles and all samples were tested in duplicates.

Table IV summarizes the results from the steam sterilization performance study. Quite unexpectedly, the performance of all blends except that of example 6 is comparable to that of PSF-I. None showed any evidence of stress cracking following 450 cycles of steam sterilization as described above. In comparison, PES-I experienced a rupture after only 45 cycles. The blend of example 6 had a rupture at 166 cycles - still significantly better than PES-I. The unbroken duplicate of example 6 and control B were cracked extensively and the test was not continued on them as they are also considered failures from the practical standpoint of the test. Accordingly, compositions comprising about 35 to 99 weight percent PSF-I and about 65 to 1 weight percent PES-I have improved resistance to steam containing amine stabilizers.

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Table I:

Extrusion Conditions for Preparation of PSF-I/PES-I Blends of Examples 1-6.*						
Example	1	2	3 ^Δ	4 ^Δ	5 ^Δ	6 ^Δ
Percent PSF-I	80	70	60	50	40	25
Percent PES-I	20	30	40	50	60	75
Temperatures (C)						
Zone 1	330	330	320	320	320	320
" 2	340	340	330	330	330	330
" 3	350	350	340	340	340	340
" 4	350	350	350	340	340	340
" 5	350	350	350	340	340	340
" 6	360	350	350	340	340	340
" 7 (Die)	350	340	340	340	340	340
Melt	388	382	378	374	371	371

* Conditions common to all runs were approximately as follows:

screw speed = 200 rpm

throughput rate = 13 kg/hr (29 lbs/hr)

Vent 2 vacuum reading = 102 kN/m² (30 in Hg)

Vent 1 open to the atmosphere

^Δ comparative example

Table II: Mechanical Properties of PSF-I, PES-I and 6 Blend Compositions of the Two Polymers.

Example	PSF-I (%)	Tensile Strength 10 ³ × kN/m ² (kpsi)	Tensile Modulus 10 ³ × kN/m ² (kpsi)	Elongation at Break (%)	Flexural Strength 10 ³ × kN/m ² (kpsi)	Flexural Modulus 10 ³ × kN/m ² (kpsi)
Control A	100	71.0(10.3)	2.324(337)	109	88.3(12.8)	2.337(339)
1	80	73.1(10.6)	2.310(335)	99	93.1(13.5)	2.459(361)
2	70	74.5(10.8)	2.351(341)	117	97.2(14.1)	2.579(374)
3	60	75.2(10.9)	2.372(344)	107	99.3(14.4)	2.634(382)
4	50	75.9(11.0)	2.386(346)	107	102.7(14.9)	2.661(386)
5	40	78.6(11.4)	2.379(345)	115	105.5(15.3)	2.744(398)
6	25	80.0(11.6)	2.448(355)	101	106.9(15.5)	2.710(393)
Control B	0	83.4(12.1)	2.772(402)	36	111.7(16.2)	2.820(409)

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Example	PSF-I (%)	Notched Izod J/mm(ft-lb/in)	Tensile Impact kN/m ² (ft-lb/in ²)	Heat Deflection Temp. 3mm[1/8"]6mm[1/4"] (C) (C)	
Control A	100	551.0(16.0)	1.620(235)	193	203
1	80	523.5(15.2)	1.427(207)	196	199
2	70	540.7(15.7)	1.234(179)	196	198
3	60	292.7(8.5)	1.558(226)	194	198
4	50	86.1(2.5)	1.531(222)	195	212
5	40	75.8(2.2)	1.345(195)	192	211
6	25	62.0(1.8)	1.248(181)	193	207
Control B	0	44.8(1.3)	1.207(175)	193	205

Table III:

Weld Line Strengths of PSF-I/PES-I Blends Compared with the Strength of Non-weld Line Specimens.			
Example	PSF-I (%)	Tensile Strengths	
		No Weld Line 10 ³ x kN/m ² (kpsi)	Weld Line 10 ³ x kN/m ² (kpsi)
Control A	100	71.0 (10.3)	69.0 (10.0)
1	80	73.1 (10.6)	71.7 (10.4)
2	70	74.5 (10.8)	72.4 (10.5)
3	60	75.2 (10.9)	74.5 (10.8)
4	50	75.9 (11.0)	75.9 (11.0)
5	40	78.6 (11.4)	77.2 (11.2)
6	25	80.1 (11.6)	79.3 (11.5)

Table IV:

Steam Sterilization* Performance of PSF-I, PES-I and 6 Blend Compositions of the Two Polymers.			
Example	PSF-I (%)	Number of Cycles Steam Sterilization	Observations
Control A	100	450	No Changes
1	80	450	No Changes
2	70	450	No Changes
3	60	450	No Changes
4	50	450	No Changes
5	40	450	No Changes
6	25	166	Cracks/Rupture
Control B	0	45	Cracks Rupture

* Steam Sterilization Conditions: 6.9×10^3 kN/m² (1000 psi) flexural stress, 186 kN/m² (27 psig) steam with 50 ppm morpholine, 132°C (270 deg F) steam, 30-minute autoclaving cycle.

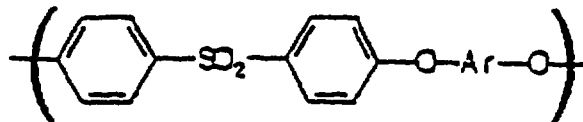
Essentially the same results can be obtained by replacing PES-I with Radel A-200 sold by Amoco Performance Products, Inc., which is the condensation product of dichlorodiphenyl sulfone with a 3:1 molar ratio of Bisphenol S to hydroquinone.



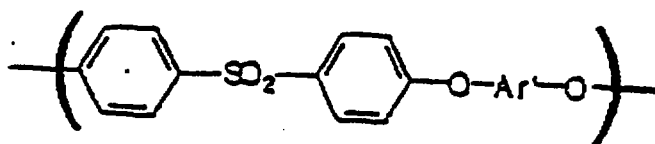
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Claims

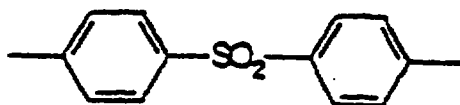
1. A composition comprising a blend of (a) a first poly(aryl ether sulfone) consisting of the repeating unit:



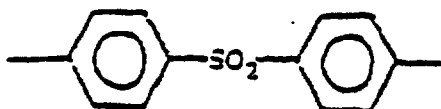
and (b) a second poly(aryl ether sulfone) other than said first poly(aryl ether sulfone) consisting essentially of the repeating unit:



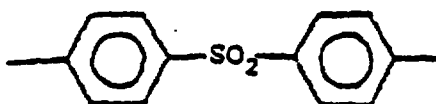
in a weight ratio of (a) to (b) which is in the range of from 70/30 to 99/1 wherein at least 50 mole % of said Ar groups are p-biphenylene and wherein at least 50 mole % of said Ar' groups are



2. A composition according to Claim 1, wherein the remainder of said Ar groups (0 to 50 mole per cent) are other than



3. A composition according to Claim 1 or Claim 2, wherein the remainder of said Ar' groups (0 to 50 mole percent) are other than p-biphenylene.
4. A composition according to Claim 1, in which the remaining Ar groups (0 to 50 mole percent) in component (a) are selected from p-phenylene and



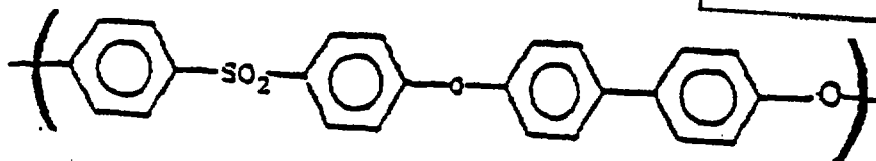
and the remaining Ar' groups (0 to 50 mole percent) in component (b) are p-phenylene.

5. A composition according to Claim 1, in which component (a) is a polybiphenyl ether sulfone having the repeating unit:

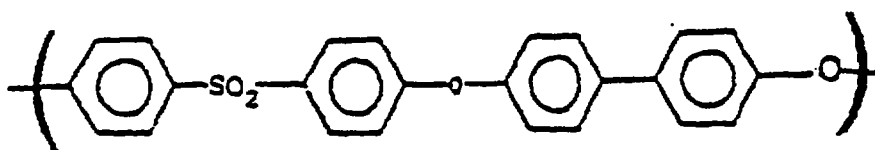




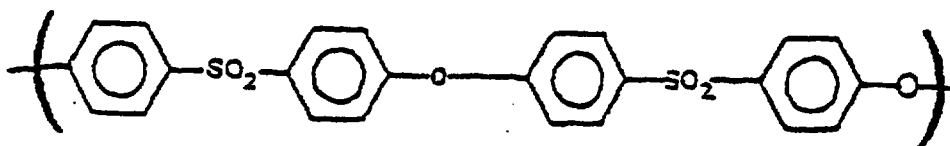
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6. A composition according to Claim 5, wherein the remaining Ar' groups in component (b) (0 to 50 mole percent) are p-phenylene.
7. A composition according to Claim 1, in which component (a) is a poly(biphenyl ether sulfone) having the repeating unit:

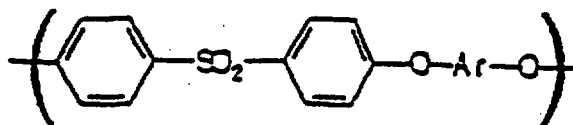


and component (b) is a poly(aryl ether sulfone) having the repeating unit:

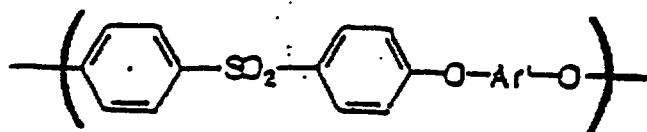


Patentansprüche

1. Zusammensetzung, die eine Mischung von (a) einem ersten Poly(arylethersulfon) umfaßt, bestehend aus der sich wiederholenden Einheit:



und (b) einem zweiten Poly(arylethersulfon), das sich von dem ersten Poly(arylethersulfon) unterscheidet, im wesentlichen bestehend aus der sich wiederholenden Einheit:

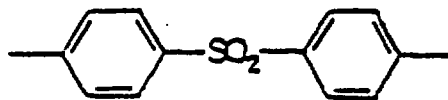


in einem Gewichtsverhältnis von (a) zu (b) im Bereich von 70/30 bis 99/1, wobei wenigstens 50 Mol-% der genannten Ar-Gruppen p-Biphenylen sind und wobei wenigstens 50 Mol-% der genannten Ar'-Gruppen



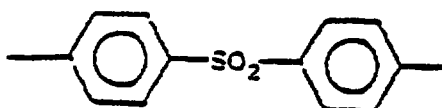


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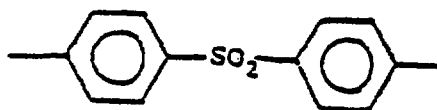
sind.

2. Zusammensetzung nach Anspruch 1, worin die übrigen genannten Ar-Gruppen (0 bis 50 Mol-%) sich von



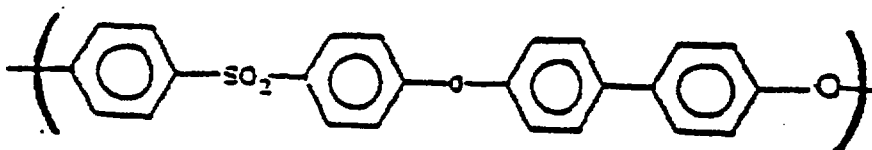
unterscheiden.

3. Zusammensetzung nach Anspruch 1 oder Anspruch 2, worin die übrigen genannten Ar'-Gruppen (0 - 50 Mol-%) sich von p-Biphenylen unterscheiden.
4. Zusammensetzung nach Anspruch 1, worin die übrigen Ar-Gruppen (0 bis 50 Mol-%) in der Komponente (a) ausgewählt wurden aus p-Phenylen und



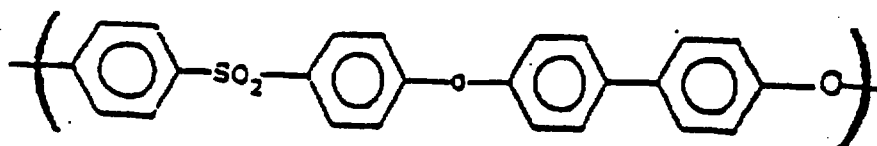
und die übrigen Ar'-Gruppen (0 bis 50 Mol-%) in der Komponente (b) p-Phenylen sind.

5. Zusammensetzung nach Anspruch 1, wobei die Komponente (a) ein Polybiphenylethersulfon mit der wiederkehrenden Einheit:



ist.

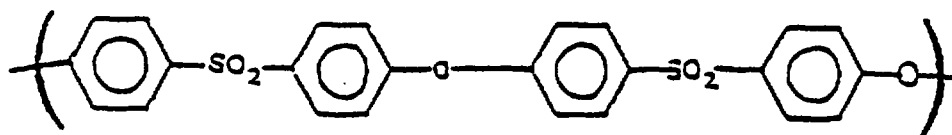
6. Zusammensetzung nach Anspruch 5, wobei die übrigen Ar'-Gruppen in der Komponente (b) (0 bis 50 Mol-%) p-Phenylen sind.
7. Zusammensetzung nach Anspruch 1, wobei die Komponente (a) ein Poly(biphenylethersulfon) mit der wiederkehrenden Einheit:



und Komponente (b) ein Poly(arylethersulfon) mit der wiederkehrenden Einheit:



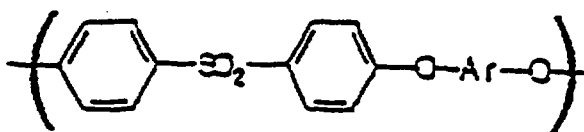
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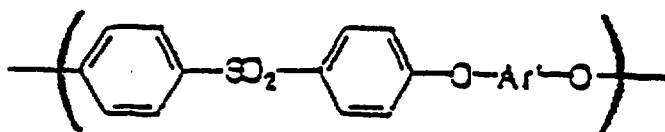
ist.

Revendications

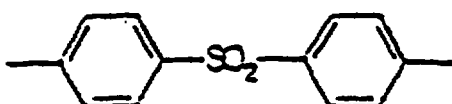
1. Composition comprenant un mélange de (a) une première poly(aryl éther sulfone) constituée de l'unité récurrente :



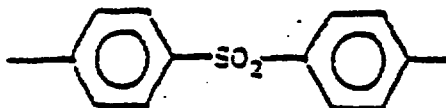
et de (b) une deuxième poly(aryl éther sulfone) autre que ladite première poly(aryl éther sulfone), constituée essentiellement de l'unité récurrente :



dans un rapport pondéral de (a) à (b) qui se situe dans la plage de 70/30 à 99/1, composition dans laquelle au moins 50 moles % desdits groupes Ar sont des groupes p-biphénylène et dans laquelle au moins 50 moles % desdits groupes Ar' sont les suivants :



2. Composition selon la revendication 1, dans laquelle le restant desdits groupes Ar (0 à 50 moles %) sont autres que :

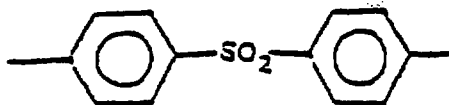


3. Composition selon la revendication 1 ou 2, dans laquelle le restant desdits groupes Ar' (0 à 50 moles %) sont autres que le p-biphénylène.
4. Composition selon la revendication 1, dans laquelle les groupes Ar restants (0 à 50 moles %) du composant (a) sont sélectionnés parmi le p-phénylène et le groupe suivant :

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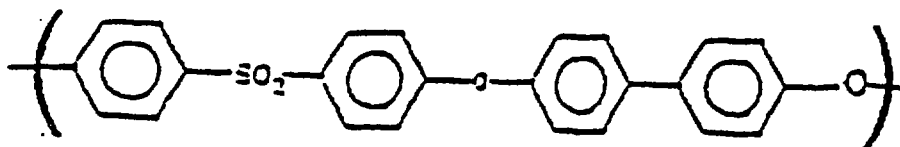


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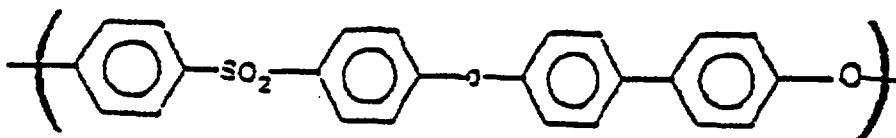


et les groupes Ar' restants (0 à 50 moles %) du composant (b) sont formés de p-phénylène.

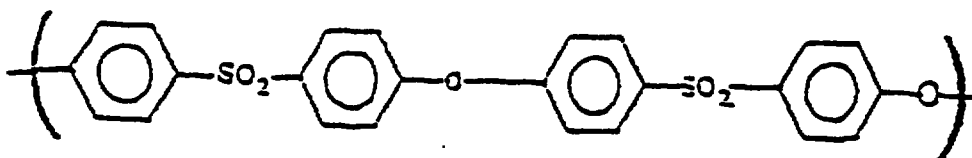
5. Composition selon la revendication 1, dans laquelle le composant (a) est une poly(biphényl éther sulfone) ayant l'unité récurrente :



6. Composition selon la revendication 5, dans laquelle les groupes Ar' restants du composant (b) (0 à 50 moles %) sont formés de p-phénylène.
7. Composition selon la revendication 1, dans laquelle le composant (a) est une poly(biphényl éther sulfone) ayant l'unité récurrente :



et le composant (b) est une poly(aryl éther sulfone) ayant l'unité récurrente :



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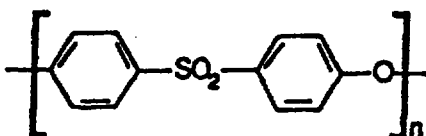
POLY(ARYL ETHER SULFONE) COMPOSITIONS COMPRISING POLY (PHENYLENE ETHER SULFONE)

Description

This invention is directed to immiscible poly(aryl ether sulfone) blends possessing improved properties comprising (a) a poly(aryl ether sulfone) and (b) a second poly(aryl ether sulfone) other than said first poly(aryl ether sulfone) in a weight ratio of (a) to (b) which is in the range of from 70/30 to 99/1. The compositions described herein, particularly the preferred compositions, retain the very attractive characteristics of their constituents, and display excellent mechanical properties and heat resistance.

Articles made from these poly(aryl ether sulfones) can be steam-sterilized while under stresses of 3,448KN/m² (500 psi) or greater; moreover they are not affected by corrosion-reducing additives such as morpholine, for example. Also, the above materials demonstrate good chemical resistance in contact with commonly used hospital cleaners and detergents.

Poly(aryl ether sulfones) have been known for about two decades. They are tough linear polymers that possess a number of attractive features such as excellent high temperature resistance, good electrical properties, and very good hydrolytic stability. At least three poly(aryl ether sulfones) are commercially available. A poly(aryl ether sulfone) referred to herein as poly(phenylene ether sulfone) is available from Imperial chemical Industries, Ltd. It has the formula (1)



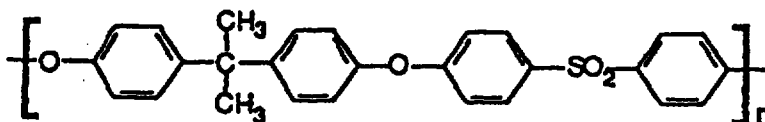
(1)

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and is produced by the polycondensation of 4,4'-dihydroxydiphenyl sulfone with 4,4'-dichlorodiphenyl sulfone as described in, for example, Canadian Patent No. 847,963. The polymer contains no aliphatic moieties and has a Tg of approximately 220°C.

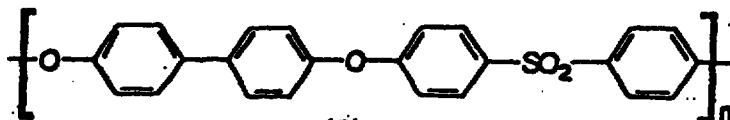
Another commercial poly(aryl ether sulfone) is available from Amoco Performance Products, Inc., under the trademark of UDEL®. It corresponds to formula (2),



(2)

has a Tg of about 190°C, and is made via the nucleophilic polycondensation of bisphenol-A di-sodium salt with 4,4'-dichlorodiphenyl sulfone, as described in U.S. Patent No. 4,108,837.

A third commercial poly(aryl ether sulfone) is also available from Amoco Performance Products, Inc., under the trademark of Radel® R. It corresponds to formula (3) has a Tg of about 220°C, and is produced by the polycondensation of biphenol with 4,4'-dichlorodiphenyl sulfone as described in, for example, Canadian Patent No. 847,963.



(3)

Over the years, there has developed a substantial body of patent and other literature directed to the formation and properties of poly(aryl ether sulfones and other poly(aryl ethers) (all hereinafter called "PAE"). A broad range of PAE's was achieved by Johnson et al., J. of Polymer Science, A-1, Vol. 5, 1967, pp. 2415-2427; Johnson et al., U.S. Patent Nos. 4,108,837 and 4,175,175. Johnson et al. show that a very broad range of PAE's can be formed by the nucleophilic aromatic substitution (condensation) reaction of an activated aromatic dihalide and an aromatic diol. By this method, Johnson et al. created a host of new PAE's.

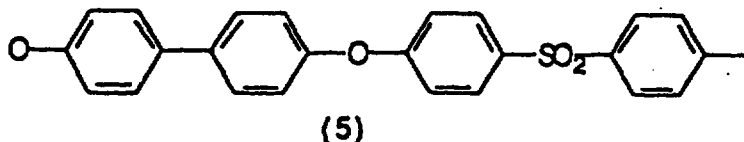
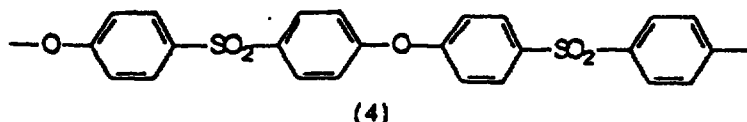
Because of their excellent mechanical and thermal properties, coupled with outstanding hydrolytic stability, the

poly(aryl ether sulfones) have been utilized in the medical market for a variety of purposes for at least ten years. These medical devices constitute a wide variety of articles. Obviously, one of the major attributes of the poly(aryl ether sulfones) is their ability to be steam autoclaved repeatedly without loss of properties. Steam autoclaving is a very severe test, requiring both high temperature and hydrolytic stability, and involving cyclical effects - wet/dry, hot/cold.

The poly(aryl ether sulfones) (1) and (2) show some important deficiencies, however. Indeed, parts molded from these materials, stress-crack when steam sterilized under stresses of say 3,448KN/m² (500 psi) or greater especially when excessive concentration of boiler additives, such as morpholine are employed to reduce corrosion in the steam generating system; or, when in contact with commonly used hospital cleaners and detergents.

While poly(biphenyl ether sulfone) (3) and parts molded therefrom have substantially better properties than poly(aryl ether sulfones) (1) and (2) it is substantially more expensive than (1) and (2) due to the high cost of biphenol.

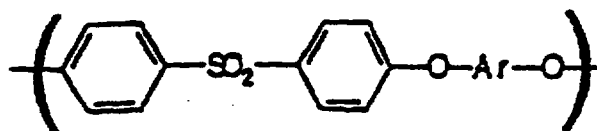
British Patent Application No. 2,088,396 describes copolymers containing units (4) and (5):



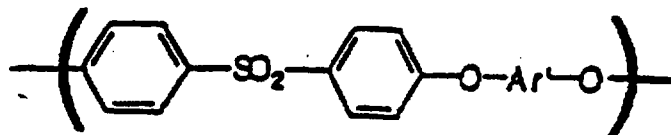
The claimed copolymers comprise about 80 to 10 mole percent of repeat units (4), and correspondingly about 20 to 90 mole percent of repeat units (5). The application states that the incorporation of (5) into the poly(aryl ether sulfone) (1) yields materials with improved resistance to hot water crazing. The application does not mention steam-sterilizability under load; nor does it teach that the copolymers show resistance to stress-cracking in the presence of boiler additives such as morpholine.

The general object of this invention is to provide blends of poly(aryl ether sulfones) having many of the base properties of the poly(biphenyl ether sulfone). Another object of this invention is to provide medical articles from blends of poly(aryl ether sulfones) which can be steam-sterilized while under stresses of 3,448KN/m² (500 psi) or greater without stress-cracking even in the presence of morpholine. Other objects appear hereinafter.

The invention provides a composition comprising a blend of (a) a first poly(aryl ether sulfone) consisting of the repeating unit:



and (b) a second poly(aryl ether sulfone) other than said first poly(aryl ether sulfone) consisting essentially of the repeating unit:

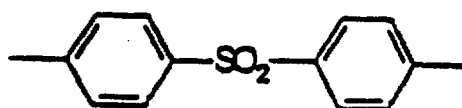


in a weight ratio of (a) to (b) which is in the range of from 70/30 to 99/1 wherein at least 50 mole % of said Ar groups are p-biphenylene and wherein at least 50 mole % of said Ar groups are

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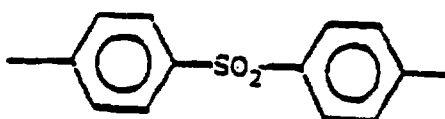
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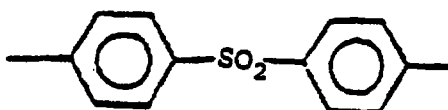
The poly(aryl ether sulfone) blends of the invention have substantially the same properties as the more expensive poly(aryl ether sulfone) (3).

According to an embodiment of the invention, the composition comprises the blend of poly(aryl ether sulfones) in which the remainder of the Ar groups (0 to 50 mole percent) are other than



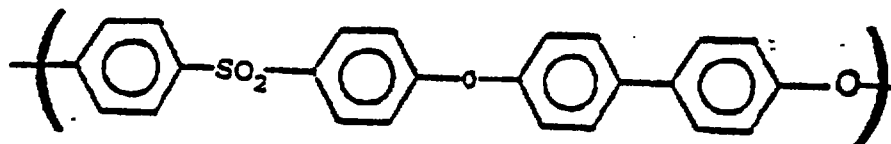
Furthermore, the remainder of the Ar' groups (0 to 50 mole percent) may be other than p-biphenylene.

According to a further embodiment of the invention, a composition is provided in which the remaining Ar groups (0 to 50 mole percent) in poly(aryl ether sulfone) (a) are selected from p-phenylene and



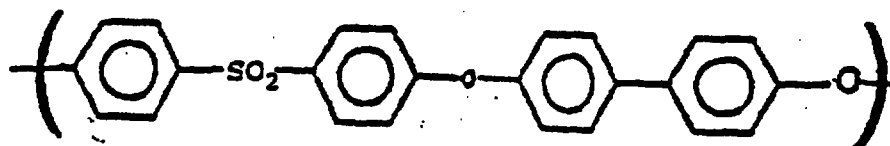
and the remaining Ar' groups (0 to 50 mole percent) in poly(aryl ether sulfone) (b) are p-phenylene.

According to a further embodiment, the invention provides a composition in which the poly(aryl ether sulfone) (a) is a polybiphenyl ether sulfone having the repeating unit:

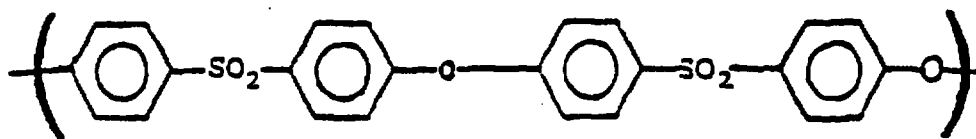


preferably, the remaining Ar' groups (0 to 50 mole percent) of poly(aryl ether sulfone) (b) being p-phenylene.

The invention further provides a composition in which poly(aryl ether sulfone) (a) is a poly(biphenyl ether sulfone) having the repeating unit:



and a poly(aryl ether sulfone) (b) having the repeating unit:



In general, the higher the concentration of biphenyl or biphenylene groups the better the properties of the polymer. The poly(aryl ether sulfones) can be prepared by either of two methods, i.e., the carbonate method or the alkali metal hydroxide method.

In the carbonate method, the polymers are prepared by contacting substantially equimolar amounts of the hydroxy-containing compounds and dihalodiarlylsulfones, e.g., 4,4'-dichlorodiphenyl sulfone or 4,4'-difluorodiphenyl sulfone, with from about 0.5 to about 1.0 mole of an alkali metal carbonate per mole of hydroxyl group in a solvent mixture comprising a solvent which forms an azeotrope with water in order to maintain the reaction medium at substantially anhydrous conditions during the polymerization.

The temperature of the reaction mixture is kept at about 170°C to about 250°C, preferably from about 210°C to about 235°C for about one to 15 hours.

The reaction is carried out in an inert atmosphere, e.g., nitrogen, at atmospheric pressure, although higher or lower pressures may also be used.

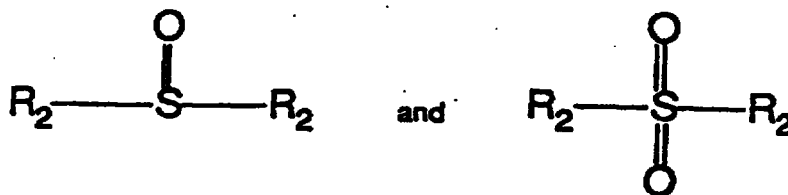
The polyarylethersulfone is then recovered by conventional techniques such as coagulation, solvent evaporation, and the like.

The solvent mixture comprises a solvent which forms an azeotrope with water and a polar aprotic solvent. The solvent which forms an azeotrope with water includes an aromatic hydrocarbon such as benzene, toluene, xylene, ethylbenzene, chlorobenzene, and the like.

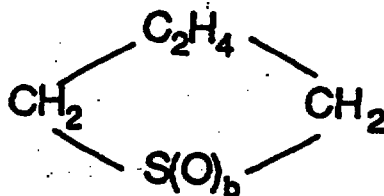
The polar aprotic solvents employed in this invention are those generally known in the art for the manufacture of polyarylether sulfones and include sulfur containing solvents such as those of the formula:



in which each R_1 represents a monovalent lower hydrocarbon group free of aliphatic unsaturation, which preferably contains less than about 8 carbon atoms or when connected together represents a divalent alkylene group with b being an integer from 1 to 2 inclusive. Thus, in all of these solvents, all oxygens and two carbon atoms are bonded to the sulfur atom. Contemplated for use in this invention are such solvents as those having the formula:



where the R_2 groups are independently lower alkyl, such as methyl, ethyl, propyl, butyl, and like groups, and aryl groups such as phenyl and alkylphenyl groups such as the tolyl group, as well as those where the R_2 groups are interconnected as in a divalent alkylene bridge such as



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in tetrahydrothiophene oxides and dioxides. Specifically, these solvents include dimethylsulfoxide, dimethylsulfone, diphenylsulfone, diethylsulfoxide, diethylsulfone, diisopropylsulfone, tetrahydrothiophene 1,1-dioxide (commonly called tetramethylene sulfone or sulfolane) and tetrahydrothiophene-1 monoxide.

Additionally, nitrogen containing solvents may be used. These include dimethylacetamide, dimethylformamide and N-methylpyrrolidone.

The azeotrope forming solvent and polar aprotic solvent are used in a weight ratio of from about 1:10 to about 1:1, preferably from about 1:5 to about 1:3.

In the reaction, the hydroxy containing compound is slowly converted, *in situ*, to the alkali salt thereof by reacting with the alkali metal carbonate. The alkali metal carbonate is preferably potassium carbonate. As indicated before, mixtures of carbonates such as potassium and sodium carbonate may also be used.

Water is continuously removed from the reaction mass as an azeotrope with the azeotrope forming solvent so that substantially anhydrous conditions are maintained during the polymerization.

It is essential that the reaction medium be maintained substantially anhydrous during the polycondensation. While amounts of water up to about one percent can be tolerated, and are somewhat beneficial when employed with fluorinated dihalobenzenoid compounds, amounts of water substantially greater than this are desirably avoided as the reaction of water with the halo and/or nitro compound leads to formation of phenolic species and only low molecular weight products are secured. Consequently, in order to secure the high polymers, the system should be substantially anhydrous, and preferably contain less than 0.5 percent by weight water during the reaction.

Preferably, after the desired molecular weight has been attained, the polymer is treated with an activated aromatic halide or an aliphatic halide such as methyl chloride or benzyl chloride, and the like. Such treatment of the polymer converts the terminal hydroxyl groups into ether groups which stabilize the polymer. The polymer so treated has good melt and oxidative stability.

While the carbonate method for preparing the polymer of this invention is simple and convenient, in some cases products of higher molecular weight can be made by the alkali metal hydroxide method. In the alkali metal hydroxide method, described by Johnson et al., U.S. Patent Nos. 4,108,837 and 4,175,175, a double alkali metal salt of a dihydric phenol is contacted with a dihalobenzenoid compound in the presence of a sulfur containing solvent as herein above defined under substantially anhydrous conditions.

Additionally, the polymers of this invention can be prepared by other methods known in the prior art, in which at least one dihydric phenol and at least one dihalobenzenoid compound are heated, for example, with a mixture of sodium carbonate or bicarbonate and a second alkali metal carbonate or bicarbonate having a higher atomic number than that of sodium, as described in U.S. Patent No. 4,176,222.

The molecular weight of the poly(aryl ethers) utilized for manufacturing the devices of the instant invention is indicated by reduced viscosity data in an appropriate solvent such as methylene chloride, chloroform, N-methylpyrrolidone, and the like. The reduced viscosities of the materials, as measured at concentrations of 0.2g per 100 ml. at 25°C, are at least 0.3 dl/g, preferably at least 0.4 dl/g and, typically, not exceeding about 1.5 dl/g.

The compositions of this invention are prepared by any conventional mixing method. For example, a preferred method comprises mixing the two poly(aryl ether sulfones) in powder or pellets form in an extruder and extruding the mixture into strands, chopping the strands into pellets and molding the pellets into the desired article.

The poly(aryl ether sulfones) of the instant invention allow for the fabrication of medical devices having outstanding stress-crack resistance. These devices can be steam-sterilized under stresses of 3,448 kN/m² (500 psi) or greater and in the presence of a variety of steam boiler additives. Typical boiler additives designed to reduce corrosion in steam generating systems are amino compounds such as morpholine, hydrazine, N,N-diethylaminoethanol ("NALCO 359" or "BETZ NA-9"), and octadecylamine. Steam sterilization is also possible in the presence of various hospital cleaners and detergents, such as those sold under the tradenames of "Castle 7900" (a sonic cleaner), "Chem Crest 14" (an ultrasonic cleaner), "Tergitol Min Foam 2X" (a non ionic surfactant), and the like.

The materials of the instant invention can include pigments, thermal stabilizers, ultraviolet light stabilizers, and other additives.

The instant poly(aryl ether sulfones) blends are useful for the fabrication of a wide variety of medical devices. They are of particular interest for autoclavable storage trays such as the systems for storage and delivery of sterile surgical instruments (thus eliminating the costs associated with wrapping); in the medical supply industry for shipment and storage of implants, prostheses and other medical devices under sterile conditions; and in many other similar applications.

The compositions of this invention can also be fabricated into any desired shape, i.e., moldings, coatings, films, or fibers. They are particularly desirable for use as electrical insulation for electrical conductors.

These compositions can include mineral fillers such as carbonates including chalk, calcite and dolomite; silicates including mica, talc, wollastonite, silicon dioxide, glass spheres, glass powders; aluminum; clay; quartz; and the like. Also, reinforcing fibers such as fiberglass, carbon fibers, and the like may be used. The compositions may also include additives such as titanium dioxide; thermal stabilizers, ultraviolet light stabilizers, plasticizers, and the like.

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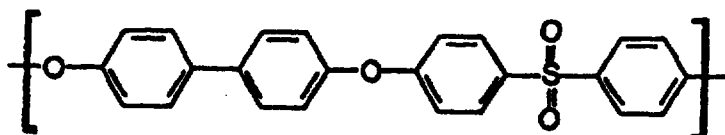
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EXAMPLES

The following examples provide specific illustrations of the present invention and are not to be construed in any way as a limitation on its scope or generality.

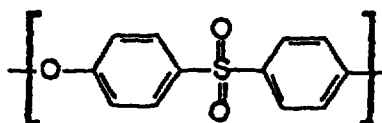
Sample Preparations and Test Procedures

There were two types of polymeric materials used in all the preparations of this invention: polybiphenylsulfone and bisphenol-S based polysulfone. The polybiphenylsulfone is a polymer having the repeat unit



It is available commercially from Amoco Performance Products, Inc. under the trade name Radel R 5000. It has a reduced viscosity of approximately 0.60 dl/g as measured in N-methyl pyrrolidone at a concentration of 0.2 g/dl and 25°C. It has a number-average molecular weight of about 20,000 as measured by gel permeation chromatography using methylene chloride as a solvent and a polystyrene molecular weight calibration. This polymer is referred to hereafter as PSF-I.

One bisphenol-S polysulfone used is the commercial product Victrex 4100 G available from Imperial Chemical Industries, PLC. It is a polymer having the formula repeat unit



It has a reduced viscosity of about 0.50 g/dl in N-methylpyrrolidone at 25°C and a concentration of 0.2 g/dl. Its number-average molecular weight by gel permeation chromatography is about 17,000 using methylene chloride as solvent and a polystyrene molecular weight calibration. This polymer is referred to hereafter as PES-I. The polymers were used in pellet form and all are transparent, by virtue of their amorphous character, and have a slight amber color.

Controls A and B

Two neat polymers PSF-I and PES-I were dried overnight in a Lydon dehumidified recirculating air oven at a temperature of 149°C (300°F). Parts were then injection molded on a Battenfeld injection molding machine with a 85g. (3 oz) injection capacity to produce standard ASTM test specimens. Mechanical properties and heat deflection temperatures (HDT) were measured per the ASTM procedures shown below. All tests were conducted on 3 mm (1/8") thick specimens except HDT which was run on both 3 mm (1/8") and 6 mm (1/4") specimens.

Property	ASTM Method No.
Tensile Modulus	D-638
Tensile Strength	D-638
Elongation at Break	D-638
Notched Izod Impact Strength	D-256
Tensile Impact Strength	D-1822
Heat Deflection Temperature	D-648
Flexural Modulus	D-790
Flexural Strength	D-790

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Examples 1 to 6

The compositions shown in Table I were mixed well as pellets and placed in a dehumidified air oven at 149°C (300°F) for about 16 hrs (overnight) for drying. The dry blends were then extruded using a 25 mm twin screw double vented BErstorff extruder having an L/D ratio of 33/1 according to the conditions profile shown in Table 1. The first vent port was open to the atmosphere, the second was connected to a vacuum pump. The extruder was fitted with a double strand die. The polymer extrudate was pelletized after passing through a water trough for cooling. All blends were extruded and pelletized without incident at the throughput rates indicated in Table 1. Between successive blend compositions, 1 kg (two pounds) of extrudate were designated as "transition" material and discarded. From past experience, this amount is sufficient to effectively displace the melt in the extruder so as the compositions of the final blends do not differ from those of the dry pellet mixes.

The six blends were dried again overnight in the Lydon oven at 149°C (300°F) and injection molded the following day on the Battenfeld injection molding machine described above to generate the needed ASTM parts. All blends appeared translucent on molding and the magnitude of the translucency increased towards the middle of the composition scale and became progressively less at the compositions rich in one polymer or the other. The lack of clarity in these blends is an indication of immiscibility between the two homopolymers.

Compositions comprising from 70 to 99 weight percent PSF-I and correspondingly from 1 to 30 weight percent PES-I are according to the invention.

Mechanical Properties

ASTM mechanical properties for the controls and blends are shown in Table II. The strength and modulus values for all blends appear to vary linearly with respect to PSF-I content in the blend. As a measure of ductility, elongation at break of all the blends can be considered equivalent to that of PSF-I within the variability of this measurement. The tensile impact, a discriminating test of polymer unnotched toughness is likewise similar for all compositions. All these mechanical properties confirm the very good mechanical compatibility of the blends of this invention. For compositions rich in PSF-I (examples 1, 2, and 3), little or no loss in the high notched Izod of PSF-I is observed. Accordingly, compositions comprising from 60 to 99 weight percent PSF-I and correspondingly from 1 to 40 weight percent PES-I have many of the excellent physical properties of PSF-I.

Immiscible polymer blends which have poor mechanical compatibility are typically characterized by low strength for parts containing "weld lines" as a result of a multi-gated mold configuration. To ascertain the mechanical compatibility of these blends the weld-line strengths were measured against the base case with no weld line. ASTM tensile bars containing weld lines were produced on a Van Dorn injection molding machine fitted with a double gated tensile bar mold. Molding was performed at conditions similar to those used for the standard single gate case. Results are shown in Table III illustrating the retention of tensile strength over weld-line sections for all blends.

Steam Sterilization

To assess the steam sterilization resistance of the PSF-I/PES-I blend compositions, the following test was employed. 127 mm x 13 mm x 3 mm (5"x1/2"x1/8") ASTM bars were mounted by fixing the bar horizontally from one end in a cantilever fashion, and a weight was suspended on the free end. The weight attached to the specimen was such that a maximum flexural stress of about 6.9×10^3 kN/m² (1000 psi) was generated at the fixed end surface of the bar. The samples which were mounted side by side in a stainless steel drawer were then placed in a steam autoclave. The autoclave was operated at a steam pressure of 186 kN/m² (27 psig), and a temperature of 132°C (270°F), and the autoclave chamber was charged with water containing 50 part per million (ppm) morpholine. Each autoclave cycle consisted of a 5-minute heat-up and pressurization step followed by a hold at the set conditions for 30 minutes after which the autoclave was vented and allowed to cool down for 10 minutes. The samples were typically inspected at the completion of 15-25 cycles and all samples were tested in duplicates.

Table IV summarizes the results from the steam sterilization performance study. Quite unexpectedly, the performance of all blends except that of example 6 is comparable to that of PSF-I. None showed any evidence of stress cracking following 450 cycles of steam sterilization as described above. In comparison, PES-I experienced a rupture after only 45 cycles. The blend of example 6 had a rupture at 166 cycles - still significantly better than PES-I. The unbroken duplicate of example 6 and control B were cracked extensively and the test was not continued on them as they are also considered failures from the practical standpoint of the test. Accordingly, compositions comprising about 35 to 99 weight percent PSF-I and about 65 to 1 weight percent PES-I have improved resistance to steam containing amine stabilizers.

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Table I:

Extrusion Conditions for Preparation of PSF-I/PES-I Blends of Examples 1-6.*						
Example	1	2	3 ^Δ	4 ^Δ	5 ^Δ	6 ^Δ
Percent PSF-I	80	70	60	50	40	25
Percent PES-I	20	30	40	50	60	75
Temperatures (C)						
Zone 1	330	330	320	320	320	320
• 2	340	340	330	330	330	330
• 3	350	350	340	340	340	340
• 4	350	350	350	340	340	340
• 5	350	350	350	340	340	340
• 6	360	350	350	340	340	340
• 7 (Die)	350	340	340	340	340	340
Melt	388	382	378	374	371	371

* Conditions common to all runs were approximately as follows:

screw speed = 200 rpm

throughput rate = 13 kg/hr (29 lbs/hr)

Vent 2 vacuum reading = 102 kN/m² (30 in Hg)

Vent 1 open to the atmosphere

^Δ comparative example

Table II: Mechanical Properties of PSF-I, PES-I and 6 Blend Compositions of the Two Polymers.

Example	PSF-I (%)	Tensile Strength 10 ³ x kN/m ² (kpsi)	Tensile Modulus 10 ³ x kN/m ² (kpsi)	Elongation at Break (%)	Flexural Strength 10 ³ x kN/m ² (kpsi)	Flexural Modulus 10 ³ x kN/m ² (kpsi)
Control A	100	71.0(10.3)	2.324(337)	109	88.3(12.8)	2,337(339)
1	80	73.1(10.6)	2,310(335)	99	93.1(13.5)	2,459(361)
2	70	74.5(10.8)	2,351(341)	117	97.2(14.1)	2,579(374)
3	60	75.2(10.9)	2,372(344)	107	99.3(14.4)	2,634(382)
4	50	75.9(11.0)	2,386(346)	107	102.7(14.9)	2,661(386)
5	40	78.6(11.4)	2,379(345)	115	105.5(15.3)	2,744(398)
6	25	80.0(11.6)	2,448(355)	101	106.9(15.5)	2,710(393)
Control B	0	83.4(12.1)	2,772(402)	36	111.7(16.2)	2,820(409)

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Example	PSF-I (%)	Notched Izod J/mm(ft-lb/in)	Tensile Impact kN/m ² (ft-lb/in ²)	Heat Deflection Temp. 3mm[1/8"]6mm[1/4"] (C) (C)	
Control A	100	551.0(16.0)	1,620(235)	193	203
1	80	523.5(15.2)	1,427(207)	196	199
2	70	540.7(15.7)	1,234(179)	196	198
3	60	292.7(8.5)	1,558(226)	194	198
4	50	86.1(2.5)	1,531(222)	195	212
5	40	75.8(2.2)	1,345(195)	192	211
6	25	62.0(1.8)	1,248(181)	193	207
Control B	0	44.8(1.3)	1,207(175)	193	205

Table III:

Weld Line Strengths of PSF-I/PES-I Blends Compared with the Strength of Non-weld Line Specimens.			
Example	PSF-I (%)	Tensile Strengths	
		No Weld Line 10 ³ x kN/m ² (kpsi)	Weld Line 10 ³ x kN/m ² (kpsi)
Control A	100	71.0 (10.3)	69.0 (10.0)
1	80	73.1 (10.6)	71.7 (10.4)
2	70	74.5 (10.8)	72.4 (10.5)
3	60	75.2 (10.9)	74.5 (10.8)
4	50	75.9 (11.0)	75.9 (11.0)
5	40	78.6 (11.4)	77.2 (11.2)
6	25	80.1 (11.6)	79.3 (11.5)

Table IV:

Steam Sterilization* Performance of PSF-I, PES-I and 6 Blend Compositions of the Two Polymers.			
Example	PSF-I (%)	Number of Cycles Steam Sterilization	Observations
Control A	100	450	No Changes
1	80	450	No Changes
2	70	450	No Changes
3	60	450	No Changes
4	50	450	No Changes
5	40	450	No Changes
6	25	166	Cracks/Rupture
Control B	0	45	Cracks Rupture

* Steam Sterilization Conditions: 6.9×10^3 kN/m² (1000 psi) flexural stress, 186 kN/m² (27 psig) steam with 50 ppm morpholine, 132°C (270 deg F) steam, 30-minute autoclaving cycle.

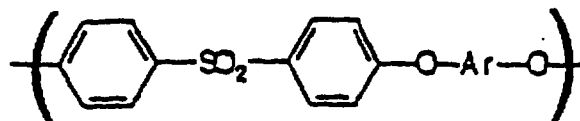
Essentially the same results can be obtained by replacing PES-I with Radel A-200 sold by Amoco Performance Products, Inc., which is the condensation product of dichlorodiphenyl sulfone with a 3:1 molar ratio of Bisphenol S to hydroquinone.

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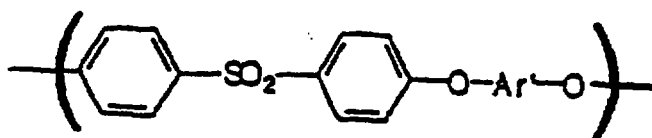
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Claims

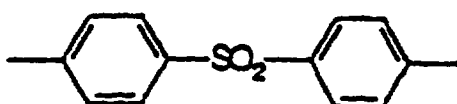
1. A composition comprising a blend of (a) a first poly(aryl ether sulfone) consisting of the repeating unit:



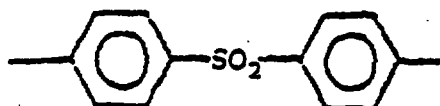
and (b) a second poly(aryl ether sulfone) other than said first poly(aryl ether sulfone) consisting essentially of the repeating unit:



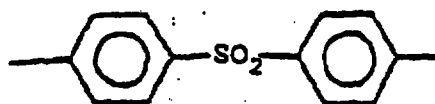
in a weight ratio of (a) to (b) which is in the range of from 70/30 to 99/1 wherein at least 50 mole % of said Ar groups are p-biphenylene and wherein at least 50 mole % of said Ar' groups are



2. A composition according to Claim 1, wherein the remainder of said Ar groups (0 to 50 mole per cent) are other than



3. A composition according to Claim 1 or Claim 2, wherein the remainder of said Ar' groups (0 to 50 mole percent) are other than p-biphenylene.
4. A composition according to Claim 1, in which the remaining Ar groups (0 to 50 mole percent) in component (a) are selected from p-phenylene and



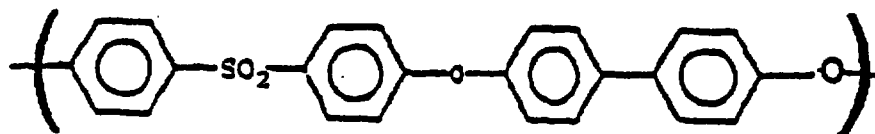
and the remaining Ar' groups (0 to 50 mole percent) in component (b) are p-phenylene.

5. A composition according to Claim 1, in which component (a) is a polybiphenyl ether sulfone having the repeating unit:

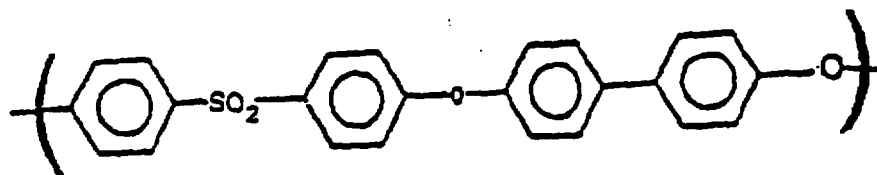


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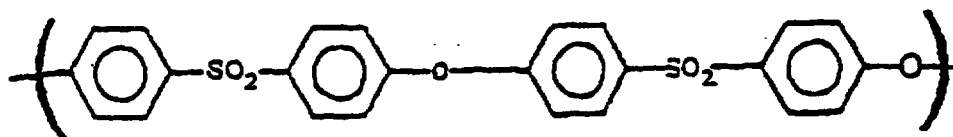
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6. A composition according to Claim 5, wherein the remaining Ar' groups in component (b) (0 to 50 mole percent) are p-phenylene.
7. A composition according to Claim 1, in which component (a) is a poly(biphenyl ether sulfone) having the repeating unit:



and component (b) is a poly(aryl ether sulfone) having the repeating unit:



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ABSTRACT

POLY(ARYL ETHER SULFONE) COMPOSITIONS
COMPRISING POLY(PHENYLENE ETHER SULFONE)

A poly(aryl ether sulfone) blend comprising (a) from about 25 to about 99 percent by weight of a poly(biphenyl ether sulfone) and (b) from about 1 to about 75 percent by weight of a second poly(phenylene ether sulfone).

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