

Antiplasticization. II. Characteristics of Antiplasticizers*

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Synopsis

By the incorporation of certain types of additives in bisphenol A polycarbonate, the modulus and tensile strength of the films are increased and the elongation is decreased. This effect is called antiplasticization, because the opposite results are obtained on plasticization—decreased modulus and tensile strength and increased elongation. A study of these additives indicated that antiplasticizers are compounds which are compatible with the polymer and which (1) contain polar atoms such as halogen, nitrogen, oxygen, or sulfur, (2) contain at least two nonbridged rings, (3) have a glass transition temperature greater than -50°C. , and (4) have one dimension less than about 5.5 Å. in at least 65% of the length of the molecules.

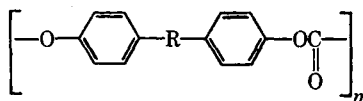
INTRODUCTION

The first paper¹ of this series reported that several classes of compounds antiplasticize bisphenol polycarbonates; that is, when present in concentrations up to 30% they increase the tensile modulus and tensile strength of films and decrease the elongation. Also, the glass transition temperatures of the polymers are depressed appreciably less by these antiplasticizers than by conventional plasticizers.

This paper discusses the characteristics of materials which act as antiplasticizers for bisphenol polycarbonates, and the next paper² of this series discusses the characteristics and properties of polymers which can be antiplasticized by these additives.

For convenience, most examples of this report are limited to the commercially available bisphenol A polycarbonate, which is prepared from 4,4'-isopropylidenediphenol. A few examples are given with the polycarbonate of 4,4'-(2-norbornylidene)diphenol.³ For simplicity, this polymer will be referred to as K-1 polycarbonate.

* Paper presented at the 152nd National Meeting of the American Chemical Society, New York, September 1966.



For bisphenol A, R = $(\text{CH}_3)_2\text{C} <$

For K-1, R =

EXPERIMENTAL

Materials

Bisphenol A polycarbonate, obtained from the General Electric Co. (trade name Lexan), had an inherent viscosity of 1.0 (measured at a concentration of 0.25 g./100 ml. in chloroform). K-1 polycarbonate³ had an inherent viscosity of 1.1.

Many of the additives were obtained from Distillation Products Industries. The Aroclors were obtained from Monsanto Chemical Co., poly(styrene glycol) from Dow Chemical Co., Abalyn (methyl abietate) from Hercules Powder Co., and H-1 Ketone and Dechlorane from Hooker Chemical Co. The other additives were synthesized by conventional procedures.

Films





Films containing the various additives were obtained by casting from methylene chloride. The dopes were coated with a doctor blade onto 9 × 18 in. glass plates by conventional techniques, and the solvent was allowed to evaporate into the air at room temperature. The films, from 1-3 mils in thickness, were dried at room temperature for 24 hr. Those with glass transition temperatures above 100°C. were then heated in an oven at 100 to 110°C. for 2 hr. to ensure the removal of all solvent. Films with lower transition temperatures were heated under reduced pressure in an oven at temperatures ranging from 40 to 65°C., depending upon the transition temperatures.

Tensile properties of the films (tensile strength, elongation, modulus) were measured on an Instron tensile tester (ASTM D882-64T Method A). The tensile modulus was the slope of the initial straight portion of the stress-strain diagram. The Elmendorf tear strength was measured in accordance with ASTM D689-44. The heat-distortion temperatures were measured in a forced-convection oven⁴ (ASTM D1637-61). The glass transition temperature was taken as the temperature at which the film distorted 0.25% at a load of 5 psi. when heated in the forced-convection oven.³

RESULTS

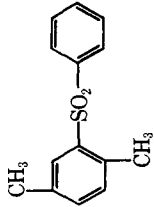
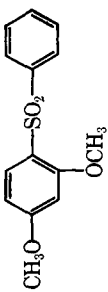
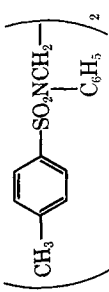
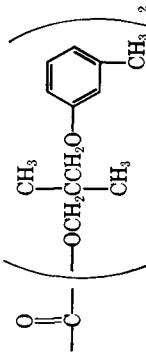
Properties of bisphenol A polycarbonate films containing various types of antiplasticizers are listed in Table I. The increase in modulus and tensile strength was considerable. Surprisingly, the tear strength of the

TABLE I
Effect of Antiplasticizers on Film Properties of Bisphenol A Polycarbonate

Designation	Antiplasticizer ^a Formula or name	Tensile properties					Elmendorf tear strength, g./mil
		Modulus, 10 ⁶ psi	Yield strength, psi	Break strength, psi	Elongation at break, %		
—	—	3.0-3.3	8,500-9,000	9,000-9,500	20-90	15	
I	Chlorinated biphenyl, 42% Cl (Aroclor 1242) ^b	3.9	—	9,000	9	—	
II	Chlorinated biphenyl, 54% Cl (Aroclor 1254)	4.5	—	14,200	4	24	
III ^c	HO(-CHCH ₂ O-) _n H  C ₆ H ₅ (Mol. wt. 500)	4.6	—	13,500	4	22	
IV		3.7	—	9,800	4	20	
V		4.4	—	12,000	4	22	
VI		3.8	10,000	9,300	11	21	

(continued)

TABLE I (continued)

Designation	Antiplasticizer ^a Formula or name	Tensile properties					Elmendorf tear strength, g./mil
		Modulus, 10 ⁶ psi	Yield strength, psi	Break strength, psi	Elongation at break, %		
VII		4.2	9,500	9,700	15	21	
VIII		4.6	12,000	10,200	12	19	
IX		4.4	—	12,300	5	19	
X		4.3	—	10,100	3	—	

XI		4.3	—	12,700	5	24
XII		4.3	—	13,500	4	23
XIII ^d		4.7	—	12,700	4	23
XIV		4.3	—	12,700	5	27
XV		4.3	—	13,200	5	23

^a Concentration in film is 20%.
^b Registered trademark of Monsanto Chemical Co.
^c Polyglycol 174-500 from Dow Chemical Co.
^d Abalyn, obtained from Hercules Powder Co.

films was also increased. These films were transparent, and x-ray diffractometric curves gave no indication of crystallinity. Films with a thickness of 2 mils could be tightly creased without cracking, but thicker films with low elongations cracked on creasing. Similar results are obtained with K-1 polycarbonate and other bisphenol polycarbonates. The effect of several of these antiplasticizers on the glass transition and heat-distortion temperatures of bisphenol polycarbonates is described in our earlier publication.¹

Compound XII, incidentally, is an ultraviolet stabilizer, and a concentration of 20% increased the life (time to brittleness) of a 2.5-mil film in an Atlas XWR Weather-Ometer to 5500 hr. The film life was 500 hr. when 20% Aroclor 5460 was present.

Table II shows the action of several phthalates on the tensile properties of bisphenol A polycarbonate. The data are arranged in the order of increasing modulus. Dimethyl and dibutyl phthalates, it is apparent, are plasticizers whereas the other additives have an antiplasticizing effect.

The tensile properties of bisphenol A and K-1 polycarbonate films containing aromatic hydrocarbons are listed in Table III. Some of the hydrocarbons appreciably increased the modulus, but they did not significantly increase the tensile strength. Since antiplasticizers are materials which appreciably increase both the modulus and the tensile strength of a polymer, these hydrocarbons are not antiplasticizers. The hydrocarbons have the added disadvantage in that they are relatively volatile. Higher-boiling aromatic hydrocarbons would be less volatile, but they have low compatibility with the polymers. Even *p*-terphenyl is not sufficiently soluble in methylene chloride or benzene so that films containing it can be obtained.

Table IV shows the effect of a cage-type chloroketone on film properties of the two polycarbonates. This ketone, decachlorooctahydro-1,3,4-

TABLE II
Effect of Phthalates on Tensile Properties of Bisphenol A Polycarbonate Films*

Designation	R	Modulus, 10 ⁶ psi	Yield strength, psi	Break strength, psi	Elongation at break, %
—	—	3.0–3.3	8,500–9,000	9,000–9,500	20–90
XVI	Methyl	2.6	5,000	3,700	44
XVII	Butyl	3.0	7,500	7,100	21
XVIII	Cyclohexyl	3.6	9,300	8,200	8
XIX	$ \begin{array}{c} \text{CH}_3 \quad \text{CH}_3 \\ \quad \\ \text{p-C}_6\text{H}_4\text{—CCH}_2\text{CCH}_3 \\ \quad \\ \text{CH}_3 \quad \text{CH}_3 \end{array} $	3.7	11,000	9,700	11
XX	Phenyl	3.9	9,500	9,000	10

* Phthalate concentration in film is 20%.

TABLE III
Effect of Aromatic Hydrocarbons on Tensile Properties of Polycarbonate Films

Polycarbonate	Hydrocarbon ^a	Modulus, 10 ⁶ psi	Yield strength, psi	Break strength, psi	Elongation at break, %
Bisphenol A	—	3.0-3.3	8,500-	9,000-	20-90
			9,000	9,500	
	Biphenyl, C ₁₂ H ₁₀	3.7	8,000	7,200	20
	Fluorene, C ₁₃ H ₁₀	3.8	—	8,300	4
	Phenanthrene, C ₁₄ H ₁₀	3.6	9,500	9,000	118
	Fluoranthene, C ₁₆ H ₁₀	3.8	8,500	7,500	29
	<i>o</i> -Terphenyl, C ₁₈ H ₁₄	4.2	8,700	8,000	14
	<i>m</i> -Terphenyl, C ₁₈ H ₁₄	4.5	9,500	8,300	4
K-1	—	3.4	9,800	10,700	40
	Fluorene, C ₁₃ H ₁₀	3.6	10,000	10,200	5
	Phenanthrene, C ₁₄ H ₁₀	3.8	9,700	8,800	13
	Fluoranthene, C ₁₆ H ₁₀	3.6	10,700	9,500	6
	<i>o</i> -Terphenyl, C ₁₈ H ₁₄	4.0	—	10,800	6
	<i>m</i> -Terphenyl, C ₁₈ H ₁₄	3.9	—	10,700	7

^a Concentration in film is 20%.

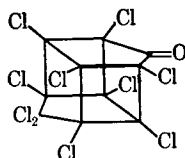
TABLE IV
Effect of H-1 Ketone on Film Properties of Polycarbonates

Polycarbonate	H-1 Ketone concn., % ^a	Tensile properties				Heat- dis- tortion temp., °C.
		Modulus, 10 ⁶ psi	Yield strength, psi	Break strength, psi	Elonga- tion at break, %	
Bisphenol A	0	3.0-3.3	8,500-	9,000-	20-90	154
			9,000	9,500		
	20	3.1	10,200	9,000	40	146
	30 ^b	2.9	8,400	8,000	17	143
K-1	0	3.4	9,800	10,700	40	230
	20	3.4	10,500	10,200	21	200
	30	3.4	10,700	10,000	8	188
	40 ^b	3.1	—	10,200	5	174

^a Trade name of Hooker Chemical Co. This compound, decachlorooctahydro-1,3,4-metheno-2H-cyclobuta[cd]pentalen-2-one (XXI), was obtained as the monohydrate and converted to the anhydrous ketone in refluxing toluene by azeotropically removing the water.

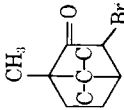

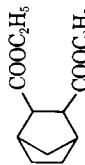
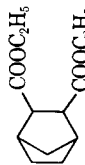
^b A small amount of the additive crystallized.


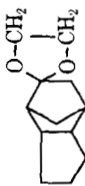
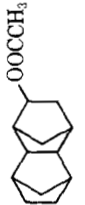
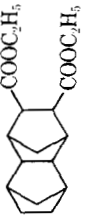
metheno-2H-cyclobuta[cd]pentalen-2-one⁵ (XXI), is commercially available under the trade name of H-1 Ketone. Unlike other additives, this



XXI

TABLE V
Effect of Polycyclic Additives on Film Properties of Bisphenol A Polycarbonate

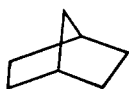
Polycyclic additive Formula	Concn., %	Tensile properties					Glass transition temp., °C.
		Modulus, 10 ⁶ psi	Yield strength, psi	Break strength, psi	Elongation at break, %		
—	0	3.0-3.3	8,500-9,000	9,000-9,500	20-90	150	
	20	3.5	9,300	8,300	71	94	
	20	3.5	8,200	6,700	35	69	
<i>trans</i> 	30	2.6	4,800	6,500	149	56	
<i>trans</i> 	20	3.4	8,700	7,200	35	89	

	20 30	3.3 3.7	8,700 8,800	7,800 7,300	12 41	79 62
<i>exo ring</i>						
	20	3.1	7,700	6,700	29	54
<i>exo ring</i>						
	20 30	3.0 2.4	7,000 4,500	6,500 6,200	51 143	82 48
<i>exo-endo rings and endo substituent</i>						
	20 30	4.0 3.6	— 9,000	9,300 7,800	23 80	— 86
<i>exo-endo rings and trans substituents</i>						

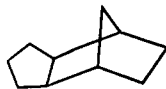
unusual compound had comparatively little effect on the modulus, tensile strength, and heat-distortion temperature of the polycarbonate films when 20 to 40% of the compound was present. The chloroketone also produces fire-retardant compositions. Two-mil films containing 30% of the ketone burn only about 5 sec. before extinguishing themselves; less chloroketone is required to make thicker objects self-extinguishing.

A similar compound in which the oxygen atom of the ketone is replaced by two chlorine atoms is also commercially available (trade name Dechlorane). At a concentration of 20%, this compound is less compatible with polycarbonates than the chloroketone, and it has a strong tendency to crystallize when films are cast. The tensile properties of the polycarbonates also are adversely affected by this additive.

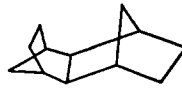
Since chloroketone XXI was not an antiplasticizer, the effects of other "thick" molecules on the film properties of bisphenol A polycarbonate were investigated. These compounds contained various polycyclic structures based on one or more norbornane rings (XXII), an *exo*-hexahydro-4,7-methanoindan ring (XXIII), or a decahydro-1,4-*exo*-5,8-*endo*-dimethanonaphthalene ring (XXIV).



XXII



XXIII



XXIV

The properties of bisphenol A polycarbonate films containing these polycyclic additives are listed in Table V. None of the additives are antiplasticizers. Most of the glass transition temperatures were not depressed as much by these additives as by conventional plasticizers,¹ but several of the additives are definitely plasticizers.

DISCUSSION

Polarity of Additive Molecules

Antiplasticizers (Table I) appreciably increase the modulus and tensile strength of the polycarbonate films and lower the elongation, whereas plasticizers (XVI and XVII in Table II) decrease the modulus and tensile strength and, when present in sufficient amounts, increase the elongation. By these definitions, the aromatic hydrocarbons in Table III are neither antiplasticizers nor plasticizers. Some of them appreciably increase the modulus, but they do not significantly increase the ultimate tensile strength. Biphenyl, for instance, increased the modulus of bisphenol A polycarbonate film to 3.7×10^5 psi, but the tensile strength was decreased to 8000 psi. The same amount of chlorinated biphenyl containing 54% chlorine (II in Table I), on the other hand, increased the modulus to 4.5×10^5 psi and the tensile strength to 14,200 psi. Similarly, 2,2'-dinitrobiphenyl (V) increased the modulus of bisphenol A polycarbonate film to 4.4×10^5 psi

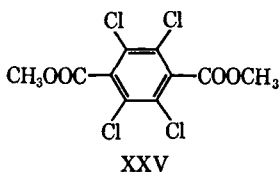
and the tensile strength to 12,000 psi. Addition of the polar chlorine and nitro groups to the biphenyl was necessary for antiplasticization to occur.

The antiplasticizers in Table I all contain polar atoms or groups. (Polarity is imparted by atoms such as halogen, nitrogen, oxygen, or sulfur.) Aroclor 1254 is a more effective antiplasticizer than Aroclor 1242 (which does not increase the tensile strength); an average of five chlorine atoms are present per biphenyl molecule in Aroclor 1254 (II), whereas only three are present in Aroclor 1242 (I). Sulfone VIII is more effective than sulfone VII; VIII is more polar because it contains methoxy groups instead of methyl groups.

Stiffness of Additive Molecules

In addition to being polar compounds, antiplasticizer molecules have a relatively high degree of stiffness and rigidity. Cyclic structures introduce rigidity in a molecule, and all of the antiplasticizers in Table I contain cyclic structures. Compound V is a more effective antiplasticizer than IV, which is also a dinitro compound, but V is a more rigid molecule. Similarly, sulfones VII and VIII are more rigid than sulfonate VI and are more effective as antiplasticizers. Aromatic compounds are generally more effective antiplasticizers than saturated alicyclic structures, perhaps, as will be discussed later, because aromatic rings are thinner than alicyclic rings.

Molecules containing at least two rings normally are more effective antiplasticizers than molecules containing only one ring. Dialkyl phthalates (Table II), for instance, are plasticizers, whereas the diphenyl phthalate derivatives (XIX and XX) have an antiplasticizing effect. The antiplasticizers in Table I all contain at least two rings. Compound XXV, which contains six polar groups but only one ring, is not an antiplasticizer.



The modulus of a bisphenol A polycarbonate film containing 20% of this additive was 3.3×10^5 psi, the same as that of the polycarbonate alone, and the yield and break strengths were 8800 and 8100 psi, respectively. Another compound containing six polar groups but only one ring, pentachlorophenol, also was not an antiplasticizer. The modulus, yield strength, and break strength of a bisphenol A polycarbonate film containing 20% of this additive were 3.6×10^5 , 9000, and 8000 psi., respectively.

Sears and Darby⁶ reported that *N*-ethyl-*o/p*-toluenesulfonamide, a plasticizer when present in bisphenol A polycarbonate in high concentrations, increased the modulus and tensile strength at low concentrations. The maximum modulus and tensile strength occurred at an additive con-

centration of about 15%. In our study of the antiplasticization of polycarbonates with several additives containing more than one ring, the maximum stiffening action occurred at a concentration of about 30%.¹ This study included chlorinated compounds in which the rings were attached directly to, but not fused to, each other (Aroclors), low molecular weight polymers with phenyl groups periodically attached to the polymer chain (polystyrene glycols), and fused-ring compounds (abietic acid derivatives).

Not all polar compounds containing at least two rings are antiplasticizers. Some, in fact, are plasticizers, e.g., dibenzyl succinate and dibenzyl sebacate,¹ which contain flexible groups between the two phenyl rings. A more quantitative measure of the rigidity of a molecule, therefore, is required.

An indication of the rigidity of a molecule is given by its glass transition temperature. This may be determined for quenched, noncrystalline samples by differential thermal analysis.⁷ Quenching of the sample is achieved by heating above the melting point (if a solid) and then quickly cooling in liquid nitrogen. The glass transition temperatures of a number of additives are listed in Table VI, and it is significant that compounds with the lower glass transition temperatures are plasticizers whereas those with the higher glass transition temperatures are antiplasticizers. The most effective antiplasticizers are the compounds with transition temperatures above -50°C . The effectiveness of antiplasticization does not increase as the glass transition temperature increases, however, because other factors are involved, such as the polarity and thickness of the molecule.

TABLE VI
Glass Transition Temperatures of Additives

Additive	Glass transition temperature, $^{\circ}\text{C}$.
Dioctyl phthalate	-87 ^a
Diethyl phthalate	-85 ^a
Bis(2-ethylhexyl) phthalate	-82 ^a
Benzyl butyl phthalate	-70
Tri- <i>o</i> -cresyl phosphate	-61
Dibenzyl succinate	-58 ^a
Chlorinated biphenyl, 42% Cl (I) (Aroclor 1242 ^b)	-55
Methyl abietate (XIII) (Abalyn ^c)	-45
Dicyclohexyl phthalate	-33 ^a
Triethyleneglycol ester of hydrogenated abietic acid (Staybelite ester 3 ^e)	-28
Chlorinated biphenyl, 54% Cl (II) (Aroclor 1254 ^b)	-24 ^a
Diphenyl phthalate	-15 ^a
Poly(styrene glycol), mol. wt. 500 (III) (Polyglycol 174-500 ^d)	-10
Chlorinated terphenyl, 42% Cl (Aroclor 5442 ^b)	4
Chlorinated terphenyl, 60% Cl (Aroclor 5460 ^b)	55

^a Data of Garfield and Petrie.⁷

^b Monsanto Chemical Co.

^c Hercules Powder Co.

^d Dow Chemical Co.

Garfield and Petrie,⁷ on the other hand, concluded that the lower the glass transition temperature of a diluent, the greater will be its plasticizing efficiency.

Thickness of Additive Molecules

The preceding examples suggest that antiplasticizers are polar polycyclic compounds with a relatively high degree of rigidity and a high glass transition temperature. We were surprised to find, however, that H-1 Ketone (XXI), which is a very polar, rigid, bulky polycyclic molecule with a melting point of 350°C.,⁵ is not an antiplasticizer (Table IV). To test a hypothesis that this was not an antiplasticizer because the molecule was too thick, we obtained properties on polycarbonate films containing various bulky, polar, thick molecules (Table V). The configurations of these molecules were based on norbornane (XXII), hexahydro-4,7-methanoindan (XXIII), and decahydro-1,4:5,8-dimethanonaphthalene (XXIV) rings. As mentioned previously, none of these additives were antiplasticizers, and several were plasticizers. The thickness of the molecule, therefore, is very important in determining whether a rigid, polar compound will be a plasticizer or an antiplasticizer.

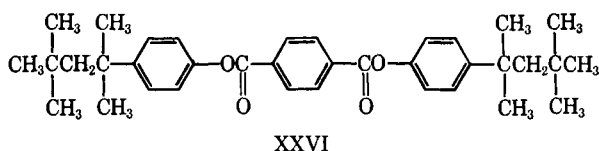
This concept explains why Aroclor 1268 (biphenyl containing nine chlorine atoms) is not as effective an antiplasticizer as Aroclor 1254 (biphenyl containing five chlorine atoms). Since Aroclor 1268 contains only one hydrogen atom per molecule, at least three of the chlorine atoms must be in *ortho* positions. According to a Fisher-Hirschfelder-Taylor model, the angle of the two phenyl rings to each other is at least 45° because of the steric effect of the *ortho* chlorine atoms. Consequently, the average thickness of an Aroclor 1268 molecule is greater than the average thickness of an Aroclor 1254 molecule, which can be completely planar. Similarly, the average thickness of Aroclor 5460 (terphenyl containing 9–10 chlorine atoms per molecule) is greater than that of Aroclor 5442 (terphenyl containing 4–5 chlorine atoms per molecule), and Aroclor 5460 is not as effective an antiplasticizer as Aroclor 5442. Comparative properties of bisphenol A polycarbonate films containing 20% of these Aroclors are shown in Table VII.

The importance of the size and thickness of an antiplasticizer molecule is also illustrated by phthalate esters (Table II). Dimethyl and dibutyl phthalates, which contain only one ring, are plasticizers, whereas dicyclo-

TABLE VII

Aroclor	Modulus, 10 ⁶ psi.	Break strength, psi.	Elongation, %
1254	4.5	14,200	4
1268	4.0	11,000	7
5442	4.6	12,800	4
5460	3.9	11,200	4

hexyl and diphenyl phthalates, which are larger molecules with three rings, have an antiplasticizing action. Dicyclohexyl phthalate is less effective as an antiplasticizer than diphenyl phthalate, and cyclohexyl groups are appreciably thicker than phenyl groups (5.1 A. compared to 2.7 A. according to Fisher-Hirschfelder-Taylor models in which 1 cm. = 1 A.). According to the film modulus, addition of tertiary octyl groups to the *para* position of the phenyl rings decreased the stiffening effect of the additive (XIX) somewhat. The thickness of the octyl groups is 6.2 A. The thick octyl groups had a greater effect on the modulus when they were at each end of the molecule in the terephthalate diester (XXVI) instead of



clustered on one side in the phthalate (XIX). The two octyl groups in the terephthalate constitute half the length of the molecule, and a bisphenol A polycarbonate film containing 20% of this additive had a modulus of only 3.2×10^5 psi.

Fisher-Hirschfelder-Taylor models indicated that the antiplasticizers included only compounds which had one dimension less than about 5.5 A. in at least 65% of the length of the molecule. This dimension is measured perpendicular to the axis (length) of the molecule in the direction which will give the minimum thickness at that portion of the molecule. In methyl abietate (XIII in Table I), for instance, a small portion of the molecule is about 6.5 A. in thickness, but most of the molecule is less than 5.5 A. and over half of it is less than 5.0 A. thick. An exact model could not be made of a norbornane ring (XXII) because of the strain involved, but the thickness is estimated to be about 6.5 A.; a substituent in the *endo* position in-

TABLE VIII
Thicknesses of Groups and Molecules*

Component	Thickness, A.
Phenyl ring	2.7
Chlorine atom	3.0
Poly(styrene glycol)	5.0
Cyclohexane ring	5.1
Dicyclohexyl phthalate	5.4
$\begin{array}{c} \text{CH}_3 \quad \text{CH}_3 \\ \quad \\ \text{CH}_3\text{CCH}_2\text{C}- \\ \quad \\ \text{CH}_3 \quad \text{CH}_3 \end{array}$	6.2
Norbornane ring	6.5

* Measured with Fisher-Hirschfelder-Taylor models.

creases the thickness. The thicknesses of several groups and molecules are listed in Table VIII.

Perhaps thick molecules, such as norbornane derivatives (Table V), push the polymer chains so far apart that the attractive forces between the chains are appreciably reduced. Consequently, the stiffness and tensile strength of the polymer are decreased and the elongation is increased.

Compatibility of Additive

In addition to the foregoing characteristics of antiplasticizers, it is obvious that the antiplasticizer should be compatible with the polymer. Some incompatible compounds make the films cloudy or even white, whereas others, particularly high-melting compounds, tend to crystallize. Crystallization can sometimes be avoided if thin films (1 mil or less) are cast so that the solvent can evaporate quickly.

CONCLUSIONS

Antiplasticizers are thin, polar, stiff molecules. More specifically, the data suggest that antiplasticizers are compounds which are compatible with the polymer and which (1) contain polar atoms such as halogen, nitrogen, oxygen, or sulfur, (2) contain at least two nonbridged rings, (3) have a glass transition temperature greater than -50°C ., and (4) have one dimension less than about 5.5 Å. in at least 65% of the length of the molecules. Two of the most effective antiplasticizers are Aroclor 1254 and Aroclor 5442.

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Résumé

Par l'incorporation de certains types d'additifs dans le polycarbonate de bisphénol-A, on augmente le module et la force à la tension des films et on décroît l'élongation. Cet effet est appelé l'antiplastification, parce que les résultats opposés sont obtenus par plastification, c'est-à-dire diminution du module et de force à la tension et élongation accrue. Une étude de ces additifs indique que les antiplastifiants sont des composés qui sont compatibles avec le polymère et qui (1) contiennent des atomes polaires tels que des halogènes, des azotes, oxygènes, ou soufres, (2) au moins deux cycles non pontés,

(3) ont une température de transition vitreuse plus élevée que -50°C ., et (4) ont une dimension inférieure à environ 5.5 \AA dans au moins 65% de la longueur des molécules.

Zusammenfassung

Durch Einbau bestimmter Additivtypen in Bisphenol-A-Polykarbonat werden Modul und Zugfestigkeit der Filme gesteigert und die Dehnung herabgesetzt. Dieser Effekt wird Antiweichmachung genannt, da bei der Weichmachung entgegengesetzte Wirkungen—verringertes Modul und Zugfestigkeit und erhöhte Dehnung—erhalten werden. Eine Untersuchung dieser Additive zeigte, dass die Antiweichmacher mit dem Polymeren verträgliche Verbindungen sind, welche (1) polare Atome, wie Halogen, Stickstoff, Sauerstoff oder Schwefel und (2) mindestens zwei nicht überbrückte Ringe enthalten, (3) eine Glasumwandlungstemperatur höher als -50°C und (4) eine Dimension geringer als etwa $5,5 \text{ \AA}$ in mindestens 65% der Moleküllänge besitzen.

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