



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<p>(21) International Application Number: PCT/US89/03966 (22) International Filing Date: 12 September 1989 (12.09.89) (30) Priority data: 243,426 12 September 1988 (12.09.88) US (71)(72) Applicants and Inventors: SMID, Johannes [NL/US]; 6059 Holcomb Hill Road, Lafayette, NY 13084 (US). DELAVIZ, Yadollah [IR/US]; Slocum Heights, B34 - Apt. 8, Syracuse, NY 13210 (US). CABASSO, Israel [US/US]; 131 Buckingham Avenue, Syracuse, NY 13210 (US). (74) Agent: MORGAN &amp; FINNEGAN; 345 Park Avenue, New York, NY 10154 (US).</p>		<p>(81) Designated States: AT (European patent), BE (European patent), CH (European patent), DE (European patent), DK, FR (European patent), GB (European patent), IT (European patent), LU (European patent), NL (European patent), NO, SE (European patent). <b>Published</b> <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>
<p>(54) Title: HOMOGENEOUS RADIOPAQUE POLYMER-ORGANOBI SMUTH COMPOSITES</p>		
<div style="text-align: center;"> <p style="margin-left: 400px;">( I )</p> </div>		
<p>(57) Abstract</p> <p>Novel radiopaque materials and a method for their preparation are described. The radiopaque materials comprise composites of polymers and heavy metal-containing organic compounds, which heavy metal containing compounds have formula (I), wherein X is a heavy metal; R<sub>1</sub>, R<sub>2</sub> and R<sub>3</sub> may be the same or different and are individually selected from the group consisting of phenyl, halogen substituted phenyls, alkyl substituted phenyls, aryl substituted phenyls, ester substituted phenyls, alkene substituted phenyls, silyl groups and methylmethacrylate and R<sub>3</sub> can additionally be selected from the group consisting of halogen, alkyl, alkene, ester and carboxylic acid when R<sub>3</sub> is not the same as R<sub>1</sub> and R<sub>2</sub>. The composites, which are permanent and nonleachable, do not adversely affect the mechanical and physical properties of compositions. They are useful as medical and dental resins, in fabricating medical and dental appliances, prosthetic devices, radiation shielding devices and radiopaque polyester fabrics for clothing.</p>		

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1           In medicine, it would be desirable to monitor the  
2     positioning of bone cement used in hip joint replacements  
3     without surgical procedure. Similarly, it would be desirable  
4     to use x-rays to monitor replacement heart valves, replacement  
5     arteries, or the path of catheters traversing blood vessels and  
6     organ systems. Hence, there is a need for polymeric materials  
7     with increased radiation absorption potentials which also  
8     possess the requisite nonleachable properties for safe and  
9     acceptable use in dentistry and medicine.

10           Heavy metal salts, such as, for example, those of  
11     bismuth or barium have been used as contrast medium in  
12     diagnostic radiography. They have properties which would  
13     suggest their suitability for increasing the radiation  
14     absorption potential of medical and dental resins. As a  
15     result, substantial effort has been made to incorporate barium  
16     sulfate and other radiopaque salts, such as, for example,  
17     bismuth bromide, bismuth chloride or bismuth subnitrate into  
18     polymers to render them opaque to x-rays. However, early  
19     radiopaque polymers containing heavy metal salts have not been  
20     totally satisfactory.

21           One type of known heavy metal-containing radiopaque  
22     materials are radiopaque glass containing embedded heavy  
23     metals. In these materials, the metal is not molecularly bound  
24     to the polymer matrix and, therefore, has a tendency to weaken  
25     the composite. Moreover, because glass filler based resins  
26     lack homogeneity a further weakening of regions in the matrix  
27     results. Those regions of a composite having little or no  
28     glass are radiolucent. In addition, a light scattering effect  
29     is produced by radiopaque glasses which alters optical  
30     properties and renders them optically opaque.

1           Polymers with added inorganic heavy metal salts in an  
2   essentially physical mixture, are also known. In these  
3   materials the heavy metal is present as fine powders locked in  
4   a matrix. Their preparation results in an uneven distribution  
5   of the salt, which has an adverse affect on the mechanical  
6   properties of the plastic material. The salt tends to  
7   gradually leach out of the matrix causing discoloration of the  
8   polymer and release of heavy metal toxins. The salt and  
9   polymer remain as separate distinct phases in these mixtures  
10   producing an opaque, cloudy, light scattering material. Mixing  
11   does not impart homogeneity between the salt and polymer.

12           More recently, heavy metal salts have been complexed  
13   with a polymer. Such composites require that the complexing  
14   polymer contain at least one monomer which is capable of  
15   donating a pair of electrons, i.e., acting as a Lewis base.  
16   These materials are, therefore, limited in structure since only  
17   polymers containing appropriate interaction sites, especially  
18   carbonyl moieties, are useful. These heavy metal-salt-polymer  
19   complexes are usually moisture sensitive. That is, an  
20   initially clear complex will cloud or turn milky upon exposure  
21   to moisture, making them inappropriate for certain  
22   applications. These heavy metal salt-polymer complexes may  
23   also be heat sensitive, and interfere with room temperature  
24   curing accelerators used in dental and other applications.

#### 25                           OBJECTS OF THE INVENTION

26  
27           It is therefore an object of this invention to provide  
28   a means for imparting radiopaque characteristics to a wide  
29   range of polymers.

30

1           It is a further objective of this invention to provide  
2 radiopaque composites containing heavy metal atoms which are  
3 evenly distributed within a polymer.

4           A further objective of this invention is to provide  
5 radiopaque composites wherein a heavy metal containing organic  
6 compound is incorporated into the polymer chain thereby  
7 imparting radiopaque characteristics to the polymer.

8           It is also an objective of this invention to provide  
9 non-leachable, moisture insensitive and heat insensitive  
10 radiopaque composites which do not interfere with room  
11 temperature curing accelerators of the types used in dental  
12 applications.

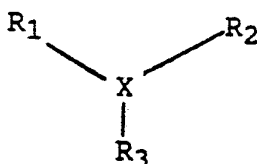
13           It is also an objective of this invention to provide  
14 composites which are non-toxic and non-carcinogenic.

15           A still further objective of this invention is to  
16 provide composites in which the radiopacifying or x-ray  
17 contrast additive may also act as a bactericide, fungicide,  
18 antioxidant or stabilizer.

19           These and other benefits will be apparent to those  
20 skilled in the art from the following description and Examples.

21                           DETAILED DESCRIPTION OF THE INVENTION

22  
23           It has now been found that these objectives can be  
24 attained by carrying out polymerization of a monomer or mixture  
25 of monomers in the presence of a heavy metal containing organic  
26 compound. The heavy metal containing organic compound has the  
27 general formula:



1

2 wherein X is a heavy metal; R<sub>1</sub>, R<sub>2</sub> and R<sub>3</sub> may be the same or  
3 different and are individually selected from the group  
4 consisting of phenyl, halogen substituted phenyls, alkyl  
5 substituted phenyls, aryl substituted phenyls, ester  
6 substituted phenyls, alkene substituted phenyls, silyl groups  
7 and methacrylate and R<sub>3</sub> can additionally be selected from  
8 the group consisting of halogen, alkyl, alkene, ester and  
9 carboxylic acid when R<sub>3</sub> is not the same as R<sub>1</sub> and R<sub>2</sub>.

10 Heavy metals useful in this invention have atomic  
11 numbers of 50 to 92, and more preferably, atomic numbers of 72  
12 to 92. Lanthanide series metals having atomic numbers of 57 to  
13 71, although satisfactory, are less preferred than the higher  
14 atomic weight metals like mercury, lead and bismuth. Rare  
15 transition metals with atomic numbers of 72 to 77 are also  
16 acceptable, but are less preferred because of lower atomic  
17 weights, high cost and their ability to form multinuclear  
18 complexes. Most preferred heavy metals include barium,  
19 bismuth, lead, mercury and uranium.

20 The heavy metal containing organic compounds useful in  
21 the present invention are relatively non-polar and are thus  
22 hydrophobic. This provides radiopaque composites that are  
23 moisture insensitive. These organometallic compounds are also  
24 miscible up to 70 weight percent with many polymers.

25 A preferred organometallic compound useful in this  
26 invention is triphenyl bismuth. Known uses for triphenyl  
27 bismuth include bactericide, fungicide, antioxidant and  
28 stabilizer. While the addition of triphenyl bismuth to  
29 polymers to form composites having radiopaque characteristics  
30 is a novel aspect of the present invention, the triphenyl

1 bismuth component of the novel composite may also impart some  
2 bactericide, fungicide, antioxidant or stabilizing  
3 characteristics to the composite.

4 In one aspect, the present invention provides  
5 radiopaque materials which comprise a heavy metal containing  
6 organic compound as a radiopacifying agent miscible with a  
7 polymer at the molecular level. That is, instead of a  
8 physical, incompatible mixture of radiopacifying agent and  
9 polymer resulting in uneven distributions of radiopacifying  
10 agent which adversely affect mechanical and physical  
11 properties, according to the present invention a heavy metal  
12 containing organic compound, such as an organobismuth compound,  
13 is homogeneously solubilized into a polymer during  
14 polymerization of the corresponding monomer in which the  
15 radiopacifying compound is also soluble. The hydrophobic  
16 nature of the compound prevents its leaching out from a polymer  
17 matrix of the polymer into an aqueous environment.

18 In another aspect, this invention provides radiopaque  
19 materials comprising a heavy metal containing organic compound  
20 incorporated directly into a polymer chain. For example, by  
21 employing organometallic compounds in which one or more of the  
22  $R_1$ ,  $R_2$ ,  $R_3$  substituents is a polymerizable group, such as, for  
23 example, a styryl substituent, the polymerization of a monomer  
24 in the presence of such a compounds in accordance with this  
25 invention produces a material in which the organometallic  
26 compound is incorporated directly into the backbone of the  
27 polymer chain to provide distribution of the organobismuth  
28 compound on the molecular level, thereby producing a  
29 homogeneous composite. Since the organometallic compound is  
30



1 actually part of the polymer chain, the heavy metal  
2 radio-pacifying agent is non-leachable.

3 The polymer composite may be formed from any monomer  
4 or mixture of monomers into which the selected organometallic  
5 compound can be solubilized. It may also be formed by casting  
6 a homogeneous mixture of the polymer and the radiopacifying  
7 agent from an appropriate solvent. The method of imparting  
8 radiopaque characteristics of this invention has a much wider  
9 range of structures and applications than the heavy metal salts  
10 previously mentioned. The latter are essentially only useful  
11 with carbonyl-containing monomers and polymers, while the more  
12 hydrophobic organobismuth and related compounds are soluble in  
13 a much wider range of monomers and polymers. Useful polymers  
14 and mixtures of polymers include those derived from styrene,  
15 vinyl halides, alkenes, (e.g., polypropylene), dienes  
16 vinylpyridines, those derived from, acrylonitrile, vinyl  
17 acetate, acrylates and the like.

18 The organometallic compound can also be mixed, or  
19 incorporated into condensation polymers. They include linear  
20 and cross-linked types formed from dicarboxylic acids and diols  
21 or triols. Specific representative examples of polyesters  
22 include polyethylene terephthalate, poly (isophthalic  
23 acid-co-maleic anhydride), poly (lauric acid-co-glycerol), and  
24 the cross-linked resin poly (phthalic anhydride-co-glycerol)  
25 (glyptal). The polyester composite fibers of this invention  
26 are especially of interest for making fabrics for clothing to  
27 be worn by workers exposed to potentially harmful levels of  
28 radiation, such as radiologists and x-ray technicians.

29 The heavy metal containing organic compound should be  
30 present in an amount sufficient to impart a desired radiopacity

1 to the polymer. The relative amounts of the components of the  
2 composites of this invention depend largely upon the specific  
3 heavy metal containing organic compound utilized, the specific  
4 polymer or mixture of polymers, the dimensions of the final  
5 product and the amount of radiopacity to be imparted to the  
6 polymer.

7 As previously mentioned, the heavy metals of the  
8 present invention are homogeneously distributed in the polymer  
9 at the molecular level to form optically lucent radiopaque  
10 materials. The hydrophobic nature of the heavy metal compound  
11 renders them virtually nonleachable from the resin into an  
12 aqueous environment to which the composites of this invention  
13 may be exposed. Non-leachability into many other solvents may  
14 be achieved by incorporating a polymerizable radiopacifying  
15 agent into the polymer backbone, either by addition  
16 polymerization or by condensation polymerization.

17 The present invention also contemplates the addition  
18 of cross-linking agents. This will provide even greater  
19 resistance to leaching of the heavy metal compound from the  
20 polymer. Suitable representative examples of cross-linking  
21 agents include tetraethylene glycol dimethacrylate (TEG),  
22 divinylbenzene, bisphenol-A-glycidyl methacrylate (BisGMA), and  
23 the like.

24 The linear radiopaque polymeric materials have  
25 molecular weights generally ranging from 10,000 to about  
26 1,000,000, and more specifically, from about 25,000 to about  
27 500,000.

28 Generally, the methods for preparing the homogeneous  
29 radiopaque polymers of the present invention include: a) bulk  
30 polymerization at high temperatures; b) room temperature

1 polymerization; c) suspension or emulsion polymerization; d)  
2 solvent casting; and e) compounding followed by melt processing.

3 Bulk polymerization involves dissolving the heavy  
4 metal compound in the monomer(s) and polymerizing in the  
5 presence of an initiator like benzoyl peroxide,  
6 azobisisobutyronitrile (AIBN), etc. More specifically, in the  
7 preparation of radiopaque polymers having carbon to carbon  
8 unsaturation, such as a vinyl group, the heavy metal compound  
9 and an initiator are dissolved in the monomer, such as, for  
10 example, styrene, and bulk polymerized at elevated  
11 temperatures. This high temperature bulk method is especially  
12 adaptable for industrial uses. In polymerizations for molds or  
13 in vitro applications, for example, the heavy metal organic  
14 compounds can be dissolved in styrene and polymerized with AIBN  
15 at the desired temperature.

16 Room temperature polymerization can be utilized in  
17 this invention since, unlike the bismuth salts previously used  
18 to impart radiopacity, the radiopacifying organometallic  
19 compounds of this invention do not interfere with the room  
20 temperature polymerizations in which a peroxide initiator is  
21 used jointly with amine accelerators such as  
22 dimethyl-p-toluidine. Room temperature polymerization can also  
23 be initiated without accelerators by using a strong visible  
24 light source.

25 As an alternative to dissolving the heavy metal  
26 organic compound in monomer(s) followed by polymerization, the  
27 homogeneous organometallic-polymer composites may be formed by  
28 film casting methods and solvent evaporation. Incorporation of  
29 triphenyl bismuth, for instance, in poly(methyl methacrylate)  
30 to form films or transparent radiopaque shields can be

1 performed by dissolving the polymer and heavy metal compound in  
2 a common solvent like THF. Thus, for example 40 percent by  
3 weight solution of triphenyl bismuth in THF containing  
4 dissolved poly(methyl methacrylate) can be cast as a film and  
5 the solvent allowed to slowly evaporate.

6 Another alternative for making homogeneous, radiopaque  
7 composites is by thoroughly mixing the heavy metal organic  
8 compound with the polymer, followed by melting processing of  
9 this mixture. For example, mixtures of triphenyl bismuth and  
10 powdered polypropylene, when heated above the melting point of  
11 the polymer produce homogeneous, radiopaque composites.

12 Radiopaque polyesters of the present invention may be  
13 prepared by dissolving the heavy metal organic compound in a  
14 polyol, such as, for example, ethylene glycol. The dissolved  
15 organometallic compound is then mixed with a dicarboxylic acid,  
16 such as terephthalic acid or phthalic anhydride, and  
17 polymerized at elevated temperatures in the presence of a known  
18 catalyst.

19 As previously mentioned, the radiopaque heavy metal  
20 compound polymer composites have a wide variety of applications  
21 especially in the dental and medical field. In the latter, the  
22 radiopaque polymers may be employed in resin systems having low  
23 levels of cross-linking which, for purposes of the present  
24 invention, range from 0 to about 5 percent, and denser more  
25 rigid structures having a higher degree of cross-linking  
26 ranging from more than 5 to about 15 percent. Such systems  
27 include "self-curing" type resins which react at ambient  
28 temperatures of between 25 and 30°C, and systems which cure at  
29 elevated temperatures with the application of heat.

30

1           Generally, for preparing radiopaque biomedical resins,  
2     i.e., polymer compositions having useful applications in  
3     restorative dentistry and medicine, the heavy metal-polymer  
4     composite would be ground to a fine powder and used as a  
5     component of a two-part system. More specifically, in the  
6     two-part system the composition is furnished in two separate  
7     containers. The first container would comprise a powder  
8     containing a mixture of the radiopaque polymer complex  
9     previously described, fillers and an initiator, such as benzoyl  
10    peroxide or AIBN. The second container comprises a liquid  
11    containing methyl methacrylate monomer, an amine acelerator and  
12    a cross-linking agent such as ethylene glycol dimethacrylate.  
13    When the solutions are mixed, or when in the absence of amine  
14    accelerator they are exposed to a strong visible light, the  
15    radiopaque polymer complex will swell in the methyl  
16    methacrylate monomer and polymerize into a solid homogeneous  
17    polymeric mass.

18           Applications for the radiopaque polymer composites  
19    having low levels of cross-linking include removable dental  
20    devices like dentures, bite splints, night guards, orthodontic  
21    space maintainers, maxillofacial devices and other nonfixed  
22    devices where there is a risk of accidental impaction into the  
23    respiratory or digestive tracts. These radiopaque polymer  
24    composites having low levels of cross-linking can also be  
25    formulated into bone cements for bonding implanted devices to  
26    bone tissues so as to permit monitoring by noninvasive methods.

27           The second category for biomedical resins include  
28    highly cross-linked structures where radiopacity is also a  
29    desirable property. They include fixed structures like  
30    restorative resins, veneering facings for dental crowns and

1 bridges, dental and surgical implants, root canal sealants and  
2 other dental, surgical and implants applications. These  
3 materials are generally provided to the user as a two-part  
4 system which upon mixing cures at ambient temperatures either  
5 by combining the initiator with a light source or with an amine  
6 accelerator. In the highly cross-linked structures, however,  
7 no preformed polymer is used. Instead, each component consists  
8 of a solution of monomers. Many of such applications can also  
9 employ a hard, inert reinforcing "filler" consisting of a  
10 finely divided material such as silica.

11 In addition to the foregoing medical/dental  
12 applications, the radiopaque polymer composites may be used  
13 with all body implants, prosthetic devices and appliances which  
14 are presently used with radiolucent plastics, such as, for  
15 example, catheters, bone implants, heart valves or arteries.

16 Industrial applications for the radiopaque composites  
17 of the present invention include x-ray and other radiation  
18 shielding devices. Optionally, the transparent radiopaque  
19 polymers, which are also opaque to U/V radiation, can be used  
20 in such areas as aircraft windows and cabins for shielding  
21 pilots and astronauts from high energy U/V and x-radiation  
22 found at high altitudes. Transparent shielding devices made of  
23 sheets of radiopaque plastics for workers exposed to x-rays and  
24 other forms of potentially harmful radiation are also intended  
25 utilities. The radiopaque polyester fibers are especially  
26 useful in textiles and fabrics for making specialized  
27 radiopaque garments to be worn by workers exposed to radiation  
28 in the job place.

29 Additionally, the radiopaque polymers can be  
30 incorporated into any plastic device which requires detection

1 by x-rays. For example, the composites of this invention can  
2 be incorporated into plastic firearms to ensure detection by  
3 airport security x-ray devices.

4 The following specific examples demonstrate the  
5 radiopaque polymers and resin compositions, and are  
6 representative of the various methods for producing them.  
7 However, it is to be understood that these examples are for  
8 illustrative purposes only and do not purport to be wholly  
9 definitive as to conditions and scope.

10

#### 11 EXAMPLES I-VII

12

13 Seven samples of the composites of this invention were  
14 prepared by dissolving varying concentrations of  
15 triphenylbismuth in methyl methacrylate monomer. The  
16 compositions are reported in Table A. AIBN or BPO was added as  
17 an initiator in an amount of 0.5% by weight based on the  
18 monomer. Each sample was placed in a test tube with a serum  
19 cap, flushed with nitrogen, sealed and bulk polymerized for 48  
20 hours at 65°C. All samples of methyl methacrylate-  
21 triphenylbismuth formed a hard, transparent, colorless, clear  
22 and homogenous polymer.

23 The radiopaque polymers of Examples I-VII were tested  
24 to develop data on the possible presence of free  
25 triphenylbismuth and the effects of dissolved triphenyl bismuth  
26 on the glass transition temperature of poly(methyl  
27 methylacrylate) by differential scanning calorimetry using a  
28 Perkin-Elmer DSC-4 instrument. Scans were run from 50 to 150°C  
29 with a scan rate of 20°C per minute. A sample of poly(methyl  
30 methylacrylate) containing no triphenylbismuth was used as a  
control for comparison purposes. The results of the DSC

1 analyses are also reported in Table A.

2

3

TABLE A

4

5

	Triphenylbismuth Weight %	Tg °C
6 Control	0.0	
7 Example I	0.51	117
8 Example II	1.17	117
9 Example III	6.8	115
10 Example IV	10.6	106
11 Example V	17.9	101
12 Example VI	26.5	91
13 Example VII	32.1	85
14		75

10

11

12 The data in Table A show a gradual decrease in the glass  
13 transition temperature on increasing the triphenylbismuth  
14 content. The 78.5°C melt peak of triphenyl bismuth was not  
15 evident in any sample. Thus, a homogenous dispersion of  
16 triphenylbismuth in polymer was formed.

17 The radiopacity of the composites of EXAMPLES I-VII  
18 was tested as follows: Samples of EXAMPLES I-VII were cut in  
19 cylindrical pellets of 1 mm and 2 mm thickness. The pellets  
20 were polished and placed on a Kodak X-ray film along with an  
21 aluminum stepwedge with 1mm steps. The pellets were placed 22  
22 inches below the cathode ray tube of an X-ray apparatus and  
23 exposed to 90 kv 6 <sup>ma</sup>mas X-rays. Using a microfilm densitometer  
24 the X-ray absorption of the pellets was then compared with that  
25 of the aluminum stepwedge. It was found that 23 percent by  
26 weight triphenyl bismuth was required in a 2 mm pellet to  
27 provide the same radiopacity as a 2 mm pellet of aluminum, a  
28 radiopacity standard adopted for dental applications.

29 Studies were also performed to determine the  
30 leachability, heat stability, and air and moisture sensitivity



1 of the samples prepared in Examples I-VII. The composite  
2 samples were placed in a tube which was sealed. Vacuum was  
3 applied and the samples were heated up to 150-160°C, which  
4 temperature was maintained for several hours. No change in  
5 color, transparency or homogeneity was observed in the  
6 samples. In addition, samples of the composites of EXAMPLES  
7 I-VII were placed in water for more than 4 months. No change  
8 in color, transparency, homogeneity, radiopacity or weight of  
9 the samples was observed. No detectable amount of  
10 triphenylbismuth was found in the water. All the experiments  
11 show non-leachability, heat stability, moisture and air  
12 insensitivity of the polymer-triphenylbismuth system made in  
13 accordance with the present invention.

14

15 EXAMPLE VIII

16

16 Room temperature polymerization in accordance with  
17 this invention was performed by dissolving the organometallic  
18 compound in the monomer, followed by addition of an initiator  
19 and an amine accelerator to form the polymer-organometallic  
20 composite. As a specific example, the composite of EXAMPLE  
21 VIII was prepared according to the following procedure: in a  
22 test tube 0.25 grams of triphenylbismuth was dissolved in 0.9  
23 grams of methyl methacrylate to form a clear, homogeneous and  
24 transparent solution. Benzoylperoxide, an initiator, was then  
25 added to the mixture in an amount of .025 grams or 2.5 weight  
26 percent based on the monomer. By adding 0.015 grams of an amine  
27 accelerator, specifically, N,N-dimethyl p-toluidine, a hard,  
28 polymerized, homogeneous, transparent product was formed after  
29 a few minutes. The composites of Examples VIII had the same

30

1 mechanical and thermal stability, and the same air and moisture  
2 insensitivity as the composites formed in Examples I-VII.

3

4

EXAMPLES IX and X

5 Another way of incorporating organometallic compounds  
6 into polymers is by solvent casting and formation of  
7 transparent and clear homogeneous films. In Examples IX and X  
8 the incorporation of triphenylbismuth into poly(vinyl chloride)  
9 was achieved by dissolving polyvinylchloride in hot THF  
10 (50-55°C) in a test tube. After complete dissolution,  
11 triphenylbismuth was added and the solution stirred for about 1  
12 hour. The colorless, clear, homogeneous solution formed was  
13 poured into a glass dish. The THF was removed first under a  
14 flow of N<sub>2</sub> for 48 hours and then in a vacuum oven until a  
15 constant weight for the film was achieved. PVC used in this  
16 experiment had a molecular weight of about 93,000.

17

Formulation of EXAMPLES IX and X

18

Example IX

19

Polyvinylchloride  
Triphenylbismuth  
THF

0.161 gm  
0.062 gm  
0.2 ml

Wt %

72  
28

20

21

Example X

22

Polyvinylchloride  
triphenyl bismuth  
THF

0.17 gm  
0.032 gm  
0.2 ml

Wt %

84.5  
15.5

23

24

25

The films formed by this method were transparent, clear and  
26 homogeneous. IR spectra of the samples of Examples IX and X  
27 show no trace of solvent (THF) left in the film.  
28

29

30

30

1           The solvent casting procedure may be used to  
2           incorporate organometallic compounds into many other polymers.  
3           The choice of solvents is dependent on the solubility of the  
4           polymers and organometallic compounds in the solvents. For  
5           example, an appropriate solvent for incorporating  
6           triphenylbismuth into polyacrylonitrile by solvent casting is  
7           dimethyl formamide (at 70°C), and for preparing  
8           polyethylene-triphenylbismuth composites hexane is an  
9           appropriate solvent.

10

#### 11                           EXAMPLES XI-XIV

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13           Radiopaque characteristics may also be imparted to  
14           polymers according to this invention by compounding polymer and  
15           an organometallic compound followed by melt processing to  
16           incorporate heavy metal organometallic compounds into  
17           polymers.

18           The composites of EXAMPLES XI-XIV were prepared by  
19           first mixing (compounding) the triphenylbismuth into isotactic  
20           polypropylene and then transferring the mixture to a test  
21           tube. The mixture is sealed and the test tube is evacuated.  
22           The mixture is heated above its melting point and kept at that  
23           temperature for a few hours to give a homogeneous, clear and  
24           transparent mixture. The mixture on cooling becomes opaque, as  
25           is pure isotactic polypropylene. The weight percent of  
26           triphenylbismuth in isotactic polypropylene for EXAMPLES XI-XIV  
27           are shown in TABLE B.

28           The isotactic polypropylene-triphenylbismuth samples  
29           of EXAMPLES XI-XIV were cut in cylindrical pellets of 1 mm and  
30           2 mm thickness. The radiopacity of the samples was measured  
          the same way as described above in regards to EXAMPLES I-VII of

1 this invention. It was found that 35 percent by weight  
2 triphenyl bismuth was required in a 2mm pellet to provide the  
3 same radiopacity as a 2mm pellet of aluminum.

4 The thermal properties of the samples of EXAMPLES  
5 XI-XIV were tested using the procedures described above in  
6 regard to EXAMPLES I-VII. The control in this case is pure  
7 isotactic polypropylene. The results are also shown in TABLE B.

8 TABLE B

9

	Weight percent of Triphenyl bismuth	T <sub>m</sub> °C
11 Control	0.0	152
12 EXAMPLE XI	10	151
13 EXAMPLE XII	15	150
14 EXAMPLE XIII	25	146
15 EXAMPLE XIV	30	146

16

17 DSC measurements of the blends show no melting point for  
18 triphenylbismuth indicating a homogeneous composite was  
19 achieved. Other than radiopacifying properties of these  
20 blends, the composites of EXAMPLES XI-XIV are heat stable,  
21 non-leachable and moisture and air insensitive.

22 EXAMPLE XV

23 Diphenyl p-styryl bismuth, synthesized according to  
24 known procedures, was copolymerized with methyl methacrylate in  
25 bulk with AIBN at 65°C to give a transparent, hard and clear  
26 copolymer. Because the monomer-containing heavy metal is part  
27 of the backbone of the product, it improves the thermal and  
28 mechanical properties of polymers in comparison to materials  
29 containing heavy metal components as additives only. Its  
30 permanent, chemical incorporation into the polymer structure  
prevents the leaching out of the heavy metal X-ray contrast

1 agent in any kind of solvent.

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3 Formulation of EXAMPLE XV

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4 Diphenyl p-styryl bismuth	0.54gram
Methyl methacrylate	1.26gram
AIBN	.009gram

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As should be apparent to those skilled in the art, the same procedure may be followed to achieve copolymerization with other monomers.

Other copolymers were formed using the same procedure given for EXAMPLE XV to yield poly(methylmethacrylate-co-diphenyl p-styryl bismuth) with different weight percent (or molar ratio) of heavy metal monomer. These copolymers were cut in cylindrical pellets of 1mm and 2mm thickness. The radiopacities of the pellets, were measured the same way as mentioned above in regard to Part C Examples I-VII of this invention. It was found that for this copolymer a 2mm thick pellet containing 26 wt% of the bismuth-containing monomer gave the same radiopacity as 2 mm thick aluminum. The Tg of this copolymer was 110°C, close to that of pure poly(methylmethacrylate), a considerable improvement of the Tg of 85°C (Table A, Example VI) for a composite of poly (methyl methacrylate) and ~~free~~ triphenylbismuth.

#### EXAMPLE XVI

The organometallic radiopacifying compounds including the radiopacifying monomers of this invention do not interfere with room cured polymerization procedures utilizing amine accelerators. EXAMPLE XVI was prepared by the room temperature polymerization of methyl methacrylate which contained 30 weight

1 percent of diphenyl p-styryl bismuth in accordance with the  
2 procedure described above with regard to EXAMPLE VIII of this  
3 invention.

4

5 Formulation of EXAMPLE XVI

6 Diphenyl p-styryl bismuth	0.54g
methyl methacrylate	1.26g
7 Benzoyl peroxide	0.045g
8 N,N-dimethyl p-toluidine	0.027g

9

10 The copolymer formed by this method has the same transparency,  
11 homogeneity, and mechanical and thermal properties as that  
12 formed in EXAMPLE XV of this invention.

13 Although particular illustrative embodiments of the  
14 present invention have been described herein, the present  
15 invention is not limited to these particular embodiments.  
16 Various changes and modifications may be made thereto by those  
17 skilled in the art without departing from the <sup>spirit</sup> ~~spirit~~ or scope  
18 of the invention, which is defined by the appended claims.

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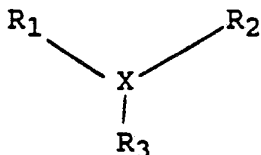
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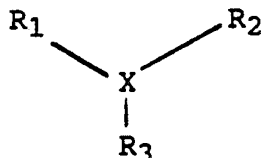
We claim:

1. A method for imparting radiopaque characteristics to a polymer, the method comprising polymerizing a monomer or mixture of monomers in the presence of a compound having the following formula:



wherein X is a heavy metal;  $R_1$ ,  $R_2$  and  $R_3$  may be the same or different and are individually selected from the group consisting of phenyl, halogen substituted phenyls, alkyl substituted phenyls, aryl substituted phenyls, ester substituted phenyls, alkene substituted phenyls, silyl groups and methacrylate and  $R_3$  can additionally be selected from the group consisting of halogen, alkyl, alkene, ester and carboxylic acid when  $R_3$  is not the same as  $R_1$  and  $R_2$ .

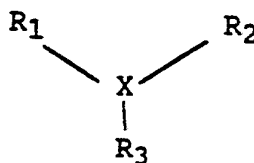
2. A method for imparting radiopaque characteristics to a polymer, the method comprising solvent casting the polymer from a solvent into which the polymer is dissolved, said solvent also having dissolved therein a compound having the following formula:



wherein X is a heavy metal;  $R_1$ ,  $R_2$  and  $R_3$  may be the same or different and are individually selected from the group consisting of phenyl, halogen substituted phenyls, alkyl substituted phenyls, aryl substituted phenyls, ester substituted phenyls, alkene substituted phenyls, silyl groups

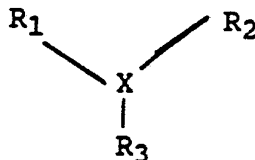
and methylmethacrylate and  $R_3$  can additionally be selected from the group consisting of halogen, alkyl, alkene, ester and carboxylic acid when  $R_3$  is not the same as  $R_1$  and  $R_2$ .

3. A method for imparting radiopaque characteristics to a polymer, the method comprising melt processing a mixture of the polymer and a compound having the following formula:



wherein X is a heavy metal;  $R_1$ ,  $R_2$  and  $R_3$  may be the same or different and are individually selected from the group consisting of phenyl, halogen substituted phenyls, alkyl substituted phenyls, aryl substituted phenyls, ester substituted phenyls, alkene substituted phenyls, silyl groups and methylmethacrylate and  $R_3$  can additionally be selected from the group consisting of halogen, alkyl, alkene, ester and carboxylic acid when  $R_3$  is not the same as  $R_1$  and  $R_2$ .

4. A composition comprised of a radiopaque organic polymer resin and a sufficient amount of an organometallic compound having the structure:



wherein X is a heavy metal;  $R_1$ ,  $R_2$  and  $R_3$  may be the same or different and are individually selected from the group consisting of phenyl, halogen substituted phenyls, alkyl substituted phenyls, aryl substituted phenyls, ester substituted phenyls, alkene substituted phenyls, silyl groups and methylmethacrylate and  $R_3$  can additionally be selected from



the group consisting of halogen, alkyl, alkene, ester and carboxylic acid when  $R_3$  is not the same as  $R_1$  and  $R_2$ .

5. The composition of claim 4 wherein the amount of organometallic compound incorporated in the polymer chain is from .5 weight percent to 60 weight percent.

6. The composition of claim 4 wherein the organometallic compound is triphenylbismuth

7. The composition of claim 4 where the organometallic compound has a polymerizable substituent, for example, diphenyl-p-styrene bismuth.

8. The method of claim 1 wherein said polymerization is carried out in the presence<sup>ence</sup> of a cross-linking agent.

9. The method of claim 1 wherein said compound is dissolved in a polyol and said polymerization is carried out in said polyol.

# INTERNATIONAL SEARCH REPORT

International Application No. **PCT/US89/03966**

**I. CLASSIFICATION OF SUBJECT MATTER** (If several classification symbols apply, indicate all) <sup>6</sup>  
 According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5): G21F 1/10  
 U.S.C.: 252/478; 433/228.1

**II. FIELDS SEARCHED**

Minimum Documentation Searched <sup>7</sup>

Classification System	Classification Symbols
U.S.	252/478; 433/228.1

Documentation Searched other than Minimum Documentation  
 to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>

USPAT, MESSENGER Database Searched for "organometallic" and "polymer"

**III. DOCUMENTS CONSIDERED TO BE RELEVANT <sup>9</sup>**

Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
X	US, A, 3,577,346 (McKEOWN) 04 May 1971, see entire document.	Clms. 4,6,7
X	US, A, 2,833,741 (LAL) 06 May 1958, see entire document.	Clms. 4,6,7
A	US, A, 3,609,372 (VOGEL) 28 September 1971, see entire document.	Clms. 4,6,7

<sup>10</sup> Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"Δ" document member of the same patent family

**IV. CERTIFICATION**

Date of the Actual Completion of the International Search <b>05 JANUARY 1990</b>	Date of Mailing of this International Search Report <b>24 JAN 1990</b>
International Searching Authority <b>ISA/US</b>	Signature of Authorized Officer <b>C S K S Catherine S. Kilby Scalzo</b> CATHERINE S. KILBY SCALZO

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V.  OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

- 1.  Claim numbers \_\_\_\_\_, because they relate to subject matter <sup>(2)</sup> not required to be searched by this Authority, namely:
  
- 2.  Claim numbers \_\_\_\_\_, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out <sup>(2)</sup>, specifically:
  
- 3.  Claim numbers \_\_\_\_\_, because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI.  OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING

This International Searching Authority found multiple inventions in this international application as follows:

I. Composition of org-Bi + polymer (claims 4, 6, 7)  
Class 252/478

(See Attachment sheet 1)

- 1.  As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
- 2.  As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
- 3.  No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers: 4, 6 and 7
- 4.  As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

- The additional search fees were accompanied by applicant's protest.
- No protest accompanied the payment of additional search fees.

PCT/US89/03966  
Attachment sheet 1

- II. Composition of polymeric-org Bi (claims 4-7)  
Class 523/177
- III. Method of polymerizing (claims 1, 8, 9)  
Class 523/177
- IV. Method of solvent casting (claim 2)  
Class 523/177
- V. Method of melt processing (claim 3)  
Class 523/177