

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
27 December 2007 (27.12.2007)

PCT

(10) International Publication Number
WO 2007/149783 A1

(51) International Patent Classification:

C08K 3/10 (2006.01) *C08L 81/04* (2006.01)
C08K 3/04 (2006.01) *C08K 3/40* (2006.01)

(21) International Application Number:

PCT/US2007/071362

(22) International Filing Date: 15 June 2007 (15.06.2007)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

60/805,239 20 June 2006 (20.06.2006) US

(71) Applicant (for all designated States except US): **POLY-ONE CORPORATION** [US/US]; 33587 Walker Road, Avon Lake, Ohio 44012 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **BARBER, Grant** [US/US]; 171 Somerset Lane, Apt. #7, Avon Lake, Ohio 44012 (US). **AVAKIAN, Roger, W.** [US/US]; 170 Cambridge Drive, Aurora, Ohio 44202 (US). **JARUS, David** [US/US]; 3008 Claremont Road, Shaker Heights, Ohio 44122 (US).

(74) Agents: **HORNICKEL, John, H.** et al.; Polyone Corporation, 33587 Walker Road, Avon Lake, Ohio 44012 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH,

CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))
- of inventorship (Rule 4.17(iv))

Published:

- with international search report
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: THERMALLY CONDUCTIVE POLYMER COMPOUNDS CONTAINING ZINC SULFIDE AND THERMAL CARBON BLACK

(57) Abstract: A thermally conductive polymer compound is disclosed. The compound can also range from being statically dissipative to electrically conductive. The compound comprises a thermoplastic polymer matrix and zinc sulfide and thermal carbon black particles dispersed in the matrix. Optionally, reinforcing filler or a second polymer or both is present. Optionally, colorant is also present to take advantage of the grayscale properties provided by the white zinc sulfide and the black thermal black particles. The compound can be extruded or molded into a heat dissipating article.

WO 2007/149783 A1

THERMALLY CONDUCTIVE POLYMER COMPOUNDS
CONTAINING ZINC SULFIDE AND THERMAL CARBON BLACK

CLAIM OF PRIORITY

[0001] This application claims priority from U.S. Provisional Patent Application Serial Number 60/805,239 bearing Attorney Docket Number 12006018 and filed on June 20, 2006, which is incorporated by reference.

FIELD OF THE INVENTION

[0002] This invention concerns thermoplastic polymer compositions which are thermally conductive because of the presence of zinc sulfide and optionally electrically conductive, dissipative, or insulative depending the amount of thermal carbon black present.

BACKGROUND OF THE INVENTION

[0003] Any energized product in modern society is not ideally efficient. Therefore, the consumption of energy is accompanied by the emission of heat. Dissipation of heat from an energized product is a common industrial engineering consideration. Electronic products are particularly susceptible to excessive heat. Personal computers contain fans for keeping sensitive electronic parts at or near the ambient temperature by dissipating the heat by convection.

[0004] Thermally conductive polymer compounds also exist to dissipate heat by conduction. These compounds are formed into parts to serve as heat sinks, radiators, etc. and other items more traditionally made of metal. Often aluminum oxide, or more commonly called alumina, is used as an additive to a thermoplastic polymer matrix to serve as the vehicle for dissipation of heat. But alumina is a particularly abrasive material which can degrade the internal surfaces of manufacturing equipment such as compounding extruders.

SUMMARY OF THE INVENTION

[0005] Therefore, what the art needs is a thermally conductive additive, for a thermoplastic polymer matrix material, that is not abrasive. What the art also needs is a thermally conductive compound that can be electrically conductive, electrically dissipative, or electrically insulative.

[0006] The present invention has solved that problem by using zinc sulfide as the thermally conductive additive and thermal carbon black as a secondary additive.

[0007] Zinc sulfide has a much lower Mohs hardness than alumina (3 vs. 9, respectively) with a comparable thermal conductivity (27 W/mK vs. 30W/mK, respectively).

[0008] Thus, one aspect of the invention is a thermally conductive polymer compound, comprising a thermoplastic polymer matrix and zinc sulfide and thermal carbon black dispersed in the matrix.

[0009] Features of the invention will be explored below.

EMBODIMENTS OF THE INVENTION

[00010] Thermoplastic Polymer Matrix

[00011] Any conventional thermoplastic polymer is a candidate to serve as the matrix for the compound of the present invention. Without undue experimentation, one of ordinary skill in the art can select a matrix based on considerations of cost, manufacturing technique, physical properties, chemical properties, etc.

[00012] Non-limiting examples of suitable thermoplastic polymers are polyolefins, poly halo-olefins, polyamides, polyesters, polyurethanes, polycarbonates, polyarylenes (sulfides, ethers, etc.), and mixtures thereof. The polymers can be homopolymers or copolymers of any structure.

[00013] Preferably, among these many candidates, polyphenylene sulfide is used because of its durability, high temperature tolerance, existence of suitable thermal conductivity, and heat distortion temperature. Polyphenylene

sulfides are polymers containing a phenyl moiety and one or more sulfides bonded thereto. Those skilled in the art will recognize the variety of commercially available polyphenylene sulfides are suitable for use in the present invention. Non-limiting examples of such commercially available polyphenylene sulfides ("PPS") include Ryton brand PPS powders in various grades from Chevron Phillips Chemical Co. of The Woodlands, Texas. Any of the patents in the literature known to those skilled in the art are appropriate for determining a suitable choice, without undue experimentation.

[00014] Zinc Sulfide

[00015] Thermal conductivity of PPS is greatly enhanced in the present compound by the addition of zinc sulfide (ZnS).

[00016] ZnS can be structured in any form, such as powder, flake, fiber, and others. Powdered ZnS is preferred because of its ability to disperse into the polymer matrix. Powdered ZnS can have a particle size ranging from about 0.5 nm to about 100 micrometers, and preferably from about 5 micrometers to about 50 micrometers.

[00017] Optional Filler Reinforcement

[00018] Structural integrity of parts, made of compounds of the present invention, is enhanced by the use of reinforcing fillers. Preferably, those fillers are chemically inert and fibrous in shape.

[00019] Non-limiting examples of reinforcing fillers are silica, carbon black, glass fiber, carbon fiber, carbon nanotubes, aramid, mineral fiber, and the like. Preferably glass fiber is used because of its available and low cost compared to other types of fillers. If any electrical conductivity is desired in the compound, one can use carbon black, carbon fiber, or carbon nanotubes as the reinforcing filler. Without undue experimentation, one skilled in the art can formulate a thermally conductive and electrically conductive compound. An example of an electrically conductive PPS compound is disclosed in co-pending international patent application PCT/US2007/061,403, which is incorporated by reference herein.

[00020] Secondary Additive

[00021] As mentioned above with respect to reinforcement fillers, carbon black, carbon fibers, and carbon nanotubes can be added if one desires electrically conductivity.

[00022] However, this invention has unexpectedly found that the addition of a special secondary additive, thermal carbon black particles (also called "thermal black"), introduces two advantages to the compound of the present invention.

[00023] The first advantage is that thermal carbon black, depending on its concentration in the compound, can range from having the compound be essentially electrically insulative to static dissipative to semi-electrically conductive to electrically conductive.

[00024] The second advantage is the thermal carbon black is black on the grayscale while zinc sulfide is white on the grayscale, permitting the presence of both to contribute to coloration of the compound at any location in color space.

[00025] Thermal carbon black is one in a family of "pigment blacks", particularly in the Aroperse product line of Degussa, A.G. as sold as Aroperse 15 thermal black, CAS No 1333-86-4, the preferred secondary additive for this invention.

[00026] As explained in the IUPAC Gold Book, <http://goldbook.iupac.org/T06296.html>, thermal black is a special type of carbon black produced by pyrolysis of gaseous hydrocarbons in a preheated chamber in the absence of air. Thermal black consists of relatively large individual spheres (100 - 500 nm diameter) and aggregates of a small number of pseudospherical particles. The preferred alignment of the layer planes is parallel to the surface of the spheres.

[00027] The tailoring of electrical properties of the compound depends on the amount of thermal black present in the compound. Electrical properties are often characterized by surface resistivity. Generally, any amount of surface

resistivity less than 10^{12} Ohms/square provides at least static dissipation. As one proceeds toward 10^9 Ohms/square, one reaches a semi-conductive surface. If one reaches 10^5 Ohms/square, an electrically conductive surface is achieved.

[00028] It has been found that as much as 30 weight percent of thermal black in the compound results in static dissipative properties, but upon increasing the weight percentage of thermal black to 40 or 60 weight percent, one can achieve a semi-conductive surface and an electrically conductive surface, respectively. It can be surmised that a weight percentage of 50 percent would at least provide semi-conductive properties and probably electrically conductive properties.

[00029] Optional Other Polymers

[00030] The compound of the present invention can include additional polymer resins to alter the morphology or rheology of the compound. The other polymers can be compatible with PPS in order to form blends or incompatible with PPS in order to form a continuous/discontinuous two-phase polymeric system.

[00031] Non-limiting examples of other optional polymers include polyolefins, polyamides, polyesters, polyhalo-olefins, and polyurethanes. Presently preferred among these optional polymers are polyolefins such as polyethylenes, and more preferably high density polyethylenes (HDPE), in order to reduce brittleness of molded parts made from compounds of the present invention.

[00032] Optional Other Additives

[00033] The compound of the present invention can include conventional plastics additives in an amount that is sufficient to obtain a desired processing or performance property for the compound. The amount should not be wasteful of the additive nor detrimental to the processing or performance of the compound. Those skilled in the art of thermoplastics compounding, without undue experimentation but with reference to such treatises as Plastics Additives Database (2004) from Plastics Design Library (www.williamandrew.com), can

select from many different types of additives for inclusion into the compounds of the present invention.

[00034] Non-limiting examples of optional additives include adhesion promoters; biocides (antibacterials, fungicides, and mildewcides), anti-fogging agents; anti-static agents; bonding, blowing and foaming agents; dispersants; fillers and extenders; fire and flame retardants and smoke suppressants; impact modifiers; initiators; lubricants; micas; pigments, colorants and dyes; plasticizers; core/shell impact modifiers; processing aids; release agents; silanes, titanates and zirconates; slip and anti-blocking agents; stabilizers; stearates; ultraviolet light absorbers; viscosity regulators; waxes; catalyst deactivators, and combinations of them.

[00035] Optional Colorants

[00036] Of the optional other additives, colorants are useful to provide color to the thermoplastic compound. With the presence of both white zinc sulfide and black thermal black, the grayscale necessary in the establishment of a single location in color space is now possible.

[00037] Colorant can be a pigment, a dye, a combination of pigments, a combination of dyes, a combination of pigments and dye, a combination of pigment and dyes, or a combination of pigments and dyes. The choice of colorants depends on the ultimate color desired by the designer of the plastic article made from the compounds of the present invention. Pigments are preferred for durability to resist discoloration because of exposure to ultraviolet light.

[00038] The science of color is well known to those skilled in the art. Without undue experimentation, one can use color matching techniques to identify a particular location in spherical color space. For example, one skilled in the art can use the teachings of PCT Patent Application US2004/012233 to digitally map color space using specific polymer carriers and colorants as raw material ingredients. Alternatively, one can make small samples called plaques for visual review.

[00039] Colorants are commercially available from a number of sources well known to those skilled in the art. Commercially available pigments are well known to those skilled in the art and include organic and inorganic colorant chemistries. Commercially available dyes are well known to those skilled in the art and include all organic chemistries. Commercial sources for pigments and dyes include multinational companies such as BASF, Bayer, Ciba-Geigy, Color-Chem International, Sun Chemical, Zhuhai Skyhigh Chemicals, and others identified at Internet Web Sites such as <http://www.colorpro.com/info/vendors/colorant.html> and http://dir.yahoo.com/Business_and_Economy/Business_to_Business/Chemicals_and_Allied_Products/Pigments_and_Dyes/

[00040] PolyOne Corporation provides a wide range of color concentrates (also called masterbatches) that can be used to make a standard color or a customized color in a compound to be extruded or molded into a plastic article, having thermal conductivity, a tailored amount of surface resistivity, and a specific color.

[00041] Ingredients

[00042] Table 1 shows the acceptable, desirable, and preferred amounts of each of the ingredients discussed above, recognizing that the optional ingredients need not be present at all. All amounts are expressed in weight percent of the total compound.

Table 1			
Range of Ingredients			
	Acceptable	Desirable	Preferable
Polymer Matrix	5 - 45	10 - 40	15 - 35
Zinc Sulfide	30 - 80	50 - 75	60 - 70
Thermal carbon black*	5-70	5-70	5-70
Optional Reinforcing Filler	0 - 20	0 - 15	2 - 7
Optional Other Polymer	0 - 20	0 - 15	5 - 10
Optional Other Additives	0 - 10	0 - 7	1 - 5

* The amount of thermal carbon black depends on whether one desires for the compound to be electrostatically dissipative, electrically conductive, or somewhere in between, as determined by surface resistivity properties.

[00043] Processing

[00044] The preparation of compounds of the present invention is uncomplicated. The compound of the present can be made in batch or continuous operations.

[00045] Mixing in a continuous process typically occurs in a single or twin screw extruder that is elevated to a temperature that is sufficient to melt the polymer matrix with addition of other ingredients either at the head of the extruder or downstream in the extruder. Extruder speeds can range from about 50 to about 500 revolutions per minute (rpm), and preferably from about 100 to about 300 rpm. Typically, the output from the extruder is pelletized for later extrusion or molding into polymeric articles.

[00046] Mixing in a batch process typically occurs in a Banbury mixer that is capable of operating at a temperature that is sufficient to melt the polymer matrix to permit addition of the solid ingredient additives. The mixing speeds range from 60 to 1000 rpm and temperature of mixing can be ambient. Also, the output from the mixer is chopped into smaller sizes for later extrusion or molding into polymeric articles.

[00047] Subsequent extrusion or molding techniques are well known to those skilled in the art of thermoplastics polymer engineering. Without undue experimentation but with such references as "Extrusion, The Definitive Processing Guide and Handbook"; "Handbook of Molded Part Shrinkage and Warpage"; "Specialized Molding Techniques"; "Rotational Molding Technology"; and "Handbook of Mold, Tool and Die Repair Welding", all published by Plastics Design Library (www.williamandrew.com), one can make articles of any conceivable shape and appearance using compounds of the present invention.

USEFULNESS OF THE INVENTION

[00048] Compounds of the present invention can dissipate heat quite efficiently, making them suitable for extruded or molded articles designed to contact a heated object and conduct that heat away from that object or contact a heated object and conduct that heat toward a second object that needs heat also. Either way, the compounds of the present invention can transport heat away from that source, whether to distribute to a remote location from that object (a radiator in a residential room) or to dissipate to a remote location from that object (a heat sink).

[00049] The physical properties of the polymer matrix determines the suitability of the compound for specific polymer engineering purposes; the use of the ZnS imparts thermally conductive where none or only a little thermal conductivity previously existed in the polymer matrix.

[00050] Examples provide data for evaluation.

EXAMPLES

[00051] Table 2 shows the ingredients chosen for Examples 1 and 2 and Comparative Example A.

Table 2					
Recipes and Sources					
Ingredient Name	Brand Name	Commercial Source	A	1	2
ZnS Powder	Sachtolith HD	Sachtleben	0	65	65
PPS	Ryton PR26	Chevron Phillips	95	22.5	30
Fiberglass	Vetrotex 910	St. Gobain	5	5	5
High Density Polyethylene	No. R21-281	Solvay	0	7.5	0

[00052] Table 3 shows the mixing conditions in a Prism 16 mm twin screw extruder.

Table 3	
Extruder Conditions	
	Set
All Zones (°C)	300
Die (°C)	300
RPM	600

[00053] The extrudate was pelletized for later molding.

[00054] Using a 33 Cincinnati Millacron molding machine, the following settings were used to mold plaques and tensile test bars of the compound of the present invention.

Table 4 - Molding Conditions	
Drying Conditions:	
Temperature	100°C
Time (h)	3
Temperatures:	
Nozzle (°F)	580
Zone 1 (°F)	570
Zone 2 (°F)	570
Zone 3 (°F)	560
Mold (°F)	200
Oil Temp (°F)	100
Speeds:	
Screw RPM	65%
% Shot - Inj Vel Stg 1	10%
% Shot - Inj Vel Stg 2	25%
% Shot - Inj Vel Stg 3	20%
% Shot - Inj Vel Stg 4	25%
% Shot - Inj Vel Stg 5	10%
Pressures:	
Hold Stg 1 (PSI) - Time(sec)	600
Hold Stg 2 (PSI) - Time(sec)	1200
Timers:	
Injection Hold (sec)	10
Cooling Time (sec)	30

Table 4 - Molding Conditions	
Operation Settings:	
Shot Size	7.5
Cushion	0.3

[00055] Table 5 shows physical properties of the test plaques.

Table 5			
Physical Property (Average of 3 Samples, except for Thermal Conductivity)	Comparative A	1	2
Izod (ft./lb.)	0.30	0.40	0.40
Flexural Modulus (psi)	639.3	1243.3	1573.3
Tensile Modulus (ksi)	626.7	1390.0	1596.7
Stress at Break (psi)	7043.3	6610.0	10,633.3
Strain at Break %	1.2	0.6	0.8
Thermal Conductivity (Through Plane at 25°C) (W/mK)		1.052	1.070

[00056] Four more formulations, all without reinforcing fiber, were extruded, molded, and tested for physical properties under similar conditions as Comparative Example A and Examples 1 and 2. Table 6 shows the formulations and test results.

Table 6					
Example	3	4	5	6	7
ZnS (Sachtolith HD)	65.000	65.000	65.000	65.000	65.000
PPS (Ryton PR 26)	35.000	30.625	26.250	30.625	26.250
Fiberglass	0.000	0.000	0.000	0.000	0.000
HDPE (Solvay R21-281)	0.000	4.375	8.750	0.000	0.000
Impact Modifier (Arkema Lotader AX 8840 -- Ethylene/Glycidyl Methacrylate copolymer)	0.000	0.000	0.000	4.375	8.750

Table 6					
Example	3	4	5	6	7
Izod (ft./lb.)	0.60	0.50	0.40	0.73	0.77
Flexural Modulus (psi)	1193.3	1106.7	1036.7	830.3	577.7
Tensile Modulus (ksi)	1203.3	1196.7	1140.0	862.3	635.0
Stress at Break (psi)	8356.7	6856.7	7296.7	8006.7	6116.7
Strain at Break %	0.8	0.8	0.8	2.0	2.3

[00057] An understanding of the range of achievable electrical properties by the addition of the secondary additive, thermal carbon black, is possible with review of Examples 8-11 and Comparative Examples A and B. Table 7 shows the ingredients (maintaining a constant 60 weight percent of functional additives, but variable ingredients and variable volume percents accordingly) that were tested for surface resistivity using molded tensile test bars (wide flat surface) and a Pinion Products Voyager Model SRM-110 with big feet. Thermal conductivity was measured both "through plane" and "in plane" at 60°C.

Table 7						
Example	A	8	9	10	11	B
PPS - Ryton PR 26 powder	35	35	35	35	35	35
Sachtolith HDS (zinc sulfide)	60	50	40	30	20	
Lotader AX 8840	5	5	5	5	5	5
Carbon Black - Arosperse 15		10	20	30	40	60
Total (Wt. %)	100	100	100	100	100	100
Zinc Sulfide (volume %)	32	25	19	14	9	
Arosperse 15 black (volume %)		11	21	30	38	52
Total Filler (volume %)	32	37	40	44	47	52

Table 7						
Example	A	8	9	10	11	B
Surface Resistivity (Ohms/square)	$>10^{12.5}$	10^{12}	10^{12}	10^{12}	10^9	10^5
Thermal Conductivity (Through Plane) (W/mK)	0.74	0.71	0.69	0.85	0.75	0.72
Thermal Conductivity (In Plane) (W/mK)	0.85	0.92	0.89	0.88	0.79	0.82

[00058] Table 7 shows the extremes of no thermal black (Comparative Example A) creating an electrically insulative thermally conductive compound and no zinc sulfide (Comparative Example B) creating an electrically conductive thermally conductive compound. The thermal carbon black provides both types of conductivity in the case of Comparative Example B.

[00059] Between those extremes, Examples 8-11 demonstrate the ability to tailor the electrical conductivity properties while maintaining the thermally conductive properties. As the relative ratio of zinc sulfide to thermal carbon black moves from 5:1 (Ex. 8) to 3:3 (Ex. 10), there is both a consistent thermal conductivity property (both through-plane and in-plane) and a static dissipative electrical property. However, once the ratio moves from 3:3 (Ex. 10) to 2:4 (Ex. 11) to 0:6 (Comparative Ex. B), the thermally conductivity remains relatively consistent but the electrical property moves dramatically more conductive.

[00060] It is highly relevant to tailoring compounds of the present invention to note the replacement of 10 weight percent of zinc sulfide with thermal black causes a decrease in surface resistivity of three orders of magnitude to achieve a semi-conductive compound. It is surmised that another replacement of 10 weight percent of zinc sulfide with thermal black would

cause a decrease of at least another order of magnitude to achieve a conductive compound, because an actual replacement of 20 weight percent (to no zinc sulfide) yielded an electrically conductive compound.

[00061] The invention is not limited to the above embodiments. The claims follow.

What is claimed is:

1. A thermally conductive polymer compound, comprising a thermoplastic polymer matrix and zinc sulfide and thermal carbon black dispersed in the matrix.
2. The compound of Claim 1, further comprising reinforcing filler.
3. The compound of Claim 1, further comprising a second polymer different from the polymer matrix.
4. The compound of Claim 1, wherein the polymer matrix is polyphenylene sulfide.
5. The compound of Claim 2, wherein the polymer matrix is polyphenylene sulfide and wherein the filler is glass fiber.
6. The compound of Claim 3, wherein the polymer matrix is polyphenylene sulfide and wherein the second polymer is polyethylene.
7. The compound of any of Claims 1-3, wherein the thermoplastic polymer is selected from the group consisting of polyolefins, poly halo-olefins, polyamides, polyesters, polyurethanes, polycarbonates, polyarylene sulfides, polyarylene ethers, and mixtures thereof.
8. The compound of Claim 7, further comprising a polymeric impact modifier.

9. The compound of any of Claims 1-8, further comprising one or more colorants, that when present with zinc sulfide which is white and thermal black which is black can cause the compound to be any color in spherical color space.
10. The compound of Claim 9, wherein the colorant comprises a pigment, a dye, a combination of pigments, a combination of dyes, a combination of pigments and dye, a combination of pigment and dyes, or a combination of pigments and dyes.
11. A method of using the compound of any of Claims 1-10, wherein the compound is extruded or molded into an article designed to contact a heated object and conduct that heat away from that object or contact a heated object and conduct that heat toward a second object that needs heat also.
12. The method of Claim 11, wherein the article has a surface that is statically dissipative if the amount of thermal carbon black in the compound is less than about 30 weight percent.
13. The method of Claim 11, wherein the article has a surface that is semi-conductive if the amount of thermal carbon black in the compound is between about 30 and about 50 weight percent.
14. The method of Claim 11, wherein the article has a surface that is electrically conductive if the amount of thermal carbon black in the compound is greater than about 50 weight percent.
15. An extruded or molded article made from the compound of any of Claims 1-10 above.

16. The article of Claim 15, wherein the article has a surface that is statically dissipative if the amount of thermal carbon black in the compound is less than about 30 weight percent.

17. The article of Claim 15, wherein the article has a surface that is semi-conductive if the amount of thermal carbon black in the compound is between about 30 and about 50 weight percent.

18. The article of Claim 15, wherein the article has a surface that is electrically conductive if the amount of thermal carbon black in the compound is greater than about 50 weight percent.

19. The article of Claim 15, wherein the article has a unique color in color space because of the presence of zinc sulfide, thermal black, and a colorant.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2007/071362**A. CLASSIFICATION OF SUBJECT MATTER***C08K 3/10(2006.01)i, C08K 3/04(2006.01)i, C08L 81/04(2006.01)i, C08K 3/40(2006.01)i*

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 8 : C08K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean Utility models and Applications for Utility models since 1975

Japanese Utility models and Applications for Utility models since 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKIPPASS(KIPO internal) "thermally conductive polymer", "polyphenylene sulfide", "polymer matrix"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6685855 B1(James Miller, Kevin McCullough, E. Mikhail Sagal) Feb. 3, 2004 See the abstract and claims 1-5	1-19
Y	US 2002/0058743 A1(Masayuki Tobita, Natsuko Ishihara et al) May. 16, 2002 See the abstract and claims 1, 6, 11	1-19
Y	US 2003/0236335 A1(James D. Miller, Kevin McCullough, E. Mikhail Saga) Dec. 25, 2003 See the abstract and claims 1-6	1-19
Y	US 6528572 B1(Niraj C. Patel, Kim G. Balfour) Mar. 4, 2003 See the Detailed Description(Col. 3, 4)	1-19



Further documents are listed in the continuation of Box C.



See patent family annex.

* 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 application or patent 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 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 when the document is taken alone

"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

"&" document member of the same patent family

Date of the actual completion of the international search

30 OCTOBER 2007 (30.10.2007)

Date of mailing of the international search report

30 OCTOBER 2007 (30.10.2007)

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
920 Dunsan-dong, Seo-gu, Daejeon 302-701,
Republic of Korea

Facsimile No. 82-42-472-7140

Authorized officer

CHOI, Cha Hee

Telephone No. 82-42-481-5546



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2007/071362**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

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

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
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, specifically:
3. ☒ Claims Nos.: 9, 11, 15
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

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

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ 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 claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2007/071362

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US06685855B1	03.02.2004	US2004207763A1 US2004207763AA US7268825BB	21.10.2004 21.10.2004 11.09.2007
US20020058743A1	16.05.2002	DE60108576C0 DE60108576T2 EP01186689A1 EP01186689B1 EP1186689A1 EP1186689B1 JP14088250 JP2002088250A2 US06730731 US6730731BB	03.03.2005 23.03.2006 13.03.2002 26.01.2005 13.03.2002 26.01.2005 27.03.2002 27.03.2002 04.05.2004 04.05.2004
US20030236335A1	25.12.2003	None	
US6528572B1	04.03.2003	None	