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S P E C I F I C A T I O N**TITLE****"ANTIMICROBIAL MATERIALS"****BACKGROUND OF THE INVENTION**

5 The present invention relates generally to disinfectants and products having same. More specifically, the present invention relates to materials having antimicrobial properties and products made therefrom.

10 In the medical industry, one of the principal concerns with respect to products that are introduced into the body or provide a pathway into the body is bacterial infection. The industry continually strives to reduce the incidence of bacterial infection caused by
15 bacteria contamination of medical apparatuses. This is particularly true in connection with medical apparatuses that cannot normally be sterilized in autoclaves or which when used encounter bacteria containing environments.

 For example, sutures, catheters, surgical tape,
20 tubings, sponges, gloves, pads, surgical covers, dialysis connectors, and certain medical instruments cannot be autoclaved to ensure sterility. They often must be used in areas where pathogenic bacteria are encountered. Accordingly, for such medical apparatuses, the art has
25 long sought means and methods of rendering those medical apparatuses antibacterial and, hopefully, antimicrobial.

 The general approach in the art has been that of coating the medical apparatuses, or a surface thereof, with a bactericide. However, since most bactericides are
30 partly water soluble, or at least require sufficient solubilization for effective antibacterial action, simple

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coatings of the bactericides have been proven unreliable. For this reason, the art has sought to incorporate the bactericides into the medical apparatus or at least provide a stabilized coating thereon.

5 With the increased use of polymeric materials for construction of medical apparatuses, utilizing an antimicrobial polymer has become even more desirable. The art, therefore, has sought various combinations of plastics and antibacterial agents. The antibacterial
10 agent could be fixedly attached to or incorporated in the plastic, so that the combination thereof could be used for the manufacture of these plastic medical apparatuses.

 This relatively recent effort in the art has taken a myriad of different approaches. For example, U.S.
15 Patent No. 3,401,005, in an attempt to create a product that functions satisfactorily, applies a complexed composition of polyvinylpyrrolidone and iodine to cotton gauze. When dried, the coated material would have a germicidal characteristic. In a similar effort, a
20 complexed composition of polyvinylpyrrolidone and iodine was placed in absorbable, gelatin foams to produce surgical sponges. In the '005 patent, iodine is complexed with polyvinylpyrrolidone. The complexed composition was found to release iodine under use
25 conditions.

 Solid polyvinylpyrrolidone complexed with iodine is disclosed in U.S. Patent No. 3,898,326 as useful as a disinfectant material. U.S. Patent No. 4,017,407 extends this complexed composition to include detergents.

30 U.S. Patent No. 4,381,380 relates to a polymeric bacteriocidal composition for use in antibacterial applications. The composition of the '380 patent contains a plastic, sparingly cross-linked polyurethane

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having -O-(CO)-NH- urethane linkages and iodine complexed with a sufficient number of the linkages to provide bacteriocidal properties to the composition. Iodine solutions having concentrations of from 1% to 15% were
5 utilized for complexing the iodine with the urethane linkages.

Utilizing a plastic completely complexed with iodine as a potential self-sterilizing material has disadvantages. Among other factors, the concentration
10 of the iodine in the solution and the solvent of the iodine solution limits the amount of iodine complexed with the polyurethane. Further, the rate of release of iodine from plastics complexed with iodine depends upon the affinity the plastic has for iodine. As a result,
15 these complexed plastics often do not provide an effective delivery of iodine into the atmosphere or a liquid for sufficient antimicrobial treatment.

Therefore, a need exists for an improved antimicrobial material containing not only increased
20 concentrations of a bacteriocidal substance, but also an effective and controlled delivery of the bacteriocidal substance.

SUMMARY OF THE INVENTION

The present invention provides an improved
25 antimicrobial material including a plastic material and a molecular halogen entrapped within the plastic material. The molecular halogen is primarily absorbed into the plastic material and only some, if any, is complexed with the plastic material.

30 In an embodiment, approximately 0 to 40% of the molecular halogen is entrapped in the plastic material.

In a preferred embodiment, the molecular halogen is iodine.

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The present invention also provides a directional release material that effectively allows for the control of the site and rate of halogen delivery. The directional release material includes a first plastic material having impregnated therein a halogen. The first plastic material and the halogen define an outer surface having a first release rate for the halogen. The directional release material also includes a second plastic material having impregnated therein the halogen. The second plastic material and the halogen define an inner surface having a second release rate for the halogen. This second release rate being faster than the first release rate to achieve directional release of the halogen.

In an embodiment, suitable plastic materials that may be used in the directional release material are: polycarbonate/polyester blend; polyethylene; polyurethane; polypropylene; polystyrene; copolyester; and styrene-ethylene-butylene-styrene copolymers.

Still further, the present invention provides a method for making a disinfectant material. The method includes the step of contacting a plastic material with a halogen gas that is absorbed in the plastic material.

In an embodiment, the method for making a disinfectant material includes the further step of forming the plastic material into a medical apparatus. Preferably, the plastic material is contacted with the halogen gas after being shaped into the medical apparatus.

The present invention also provides a method for impregnating a plastic material. The method includes the step of delivering iodine crystals in an enclosed vessel. Then, the plastic material to be impregnated is placed

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in the enclosed vessel for a time sufficient to allow iodine to absorb into the plastic material.

An advantage of the present invention is that it provides an improved antimicrobial material.

5 Another advantage of the present invention is that it provides the impregnation of halogen gases into a plastic material, resulting in an increased uptake of the molecular halogens.

10 Yet another advantage of the present invention is that it provides a directional release material that effectively allows for the control of the site and rate of halogen delivery.

15 Still further, an advantage of the present invention is that it provides an antimicrobial polymer that delivers a halogen for use as an antimicrobial substance in a controlled manner.

Moreover, an advantage of the present invention is that it provides a new method for impregnating a plastic material with iodine.

20 Additional features and advantages of the present invention are described in, and will be apparent from, the detailed description of the presently preferred embodiments and from the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

25 Figure 1 illustrates the absorption rate by weight percent for various plastic samples treated pursuant to the present invention.

30 Figure 2 illustrates the absorption rate by weight percent of various copolyesters and styrene-ethylene-butylene-styrene copolymers at room temperature.

Figure 3 illustrates the absorption rate by weight percent of a linear low density polyethylene at 60°C and room temperature.

5 Figure 4 illustrates the weight percentage of iodine absorbed and released from various plastic materials while placed under a lab hood.

Figures 5 and 6 illustrate the short term release rates by weight (g) versus time (hrs) of styrene-ethylene-butylene-styrene copolymer and copolyester,
10 respectively.

Figure 7 illustrates the iodine release rate in weight percent versus days for three plastic materials tested in the present invention.

Figures 8-10 illustrate the effects of iodine on
15 the elongation of various plastic materials.

Figure 11 illustrates a method of impregnating plastic samples pursuant to the present invention.

Figure 12 illustrates the absorption of iodine by weight percentage versus time into copolyester samples.

20 Figure 13 illustrates the release rate of iodine by weight percentage versus time for copolyester samples.

Figure 14 illustrates an iodine impregnated dialysis cap with a corresponding dialysis connector.

25 Figure 15 illustrates a dialysis cap including an impregnated disk with a corresponding dialysis connector.

Figure 16 illustrates the vapor rates by weight (g) versus time (min) of alcohol and iodine from an iodine solution.

30 Figure 17 illustrates the absorption of iodine into various samples in three testing jars by iodine weight percentage versus time.

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Figures 18A-18C illustrate the release of iodine from impregnated samples in testing Jar 1, Jar 2 and Jar 3, respectively, by iodine weight percentage versus time.

**DETAILED DESCRIPTION OF THE
PRESENTLY PREFERRED EMBODIMENTS**

5 The present invention provides improved methods and materials for producing an antimicrobial material. Pursuant to the present invention, a molecular halogen is impregnated in a plastic material. Utilizing a
10 halogen gas to impregnate plastic promotes the impregnation of larger amounts of molecular halogens than the amount that can be achieved using liquid halogens.

 For illustrative purposes only, the detailed description focuses on the use of molecular iodine as a
15 suitable halogen that may be used in the present invention. Iodine is a known microbicide, with a broad spectrum of action. However, as those skilled in the art will appreciate, other halogens, such as chlorine and bromine, are also suitable anti-bacterial agents.
20 Therefore, the present invention encompasses the use of all such halogens.

 The antimicrobial material of the present invention consists of a plastic material having a molecular halogen absorbed therein. To entrap the molecular halogen in the
25 plastic material, a halogen gas, such as gaseous iodine, is contacted with the plastic material.

 In one embodiment, elemental iodine is contacted with the plastic material. After the elemental iodine sublimates into iodine gas, molecular iodine is absorbed
30 in the plastic material. Iodine is able to enter and leave the plastic material without losing its microbicidal activity.

Absorbing iodine gases into the plastic material differs from the prior treatments utilizing iodine solutions and, in fact, provides advantages over same. Pursuant to the present invention, molecular iodine is
5 largely entrapped in the plastic material and only some, if any, of the iodine forms a chemical complex with such plastic material. The gradual release of such iodine depends on the mobility of molecular iodine gas in the plastic material.

10 A physical barrier, as opposed to the chemical barriers of prior treatments, prevents iodine's rapid release into the atmosphere or a liquid. Previously, researchers have focused on forming a chemical complex between iodine and the particular plastic material to
15 achieve a disinfecting type apparatus. With these prior treatments, iodine is bound as a result of a specific affinity due to the molecular structure of the plastic material. This binding results from a bonding action that is unique to the specific plastic material and not
20 based on iodine's solubility properties.

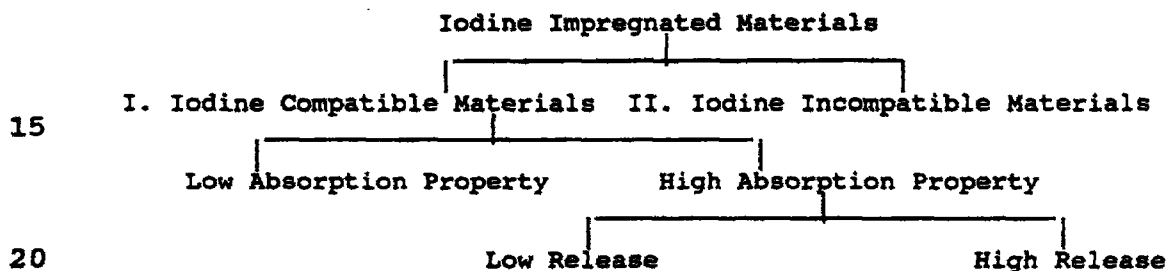
In contrast, the present invention takes advantage of the lipophilic nature of molecular iodine. This lipophilic nature allows molecular iodine to permeate into plastics in a reversible manner. The iodine
25 embedded plastic allows the sustained delivery of iodine.

The rate of iodine delivery depends upon several factors. For example, such factors include, among others, iodine concentration, temperature, pressure, materials, surface area. Manipulation of these factors
30 provides a basis for controlling iodine delivery to materials to be disinfected. For example, adding potassium iodide to aqueous solutions increases the rate at which iodine is released from the plastic material.

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The selection of polymer or polymer formulations making up the plastic material allows control of the iodine uptake and release properties. The inventors have discovered that different plastics have different solubility properties for iodine. Some plastics will take up larger amounts of iodine than other plastics (e.g. polypropylene versus polystyrene) to create a larger reservoir for sustained delivery of iodine.

Plastic materials suitable in the present invention can be classified according to the following hierarchy:



Examples of iodine incompatible materials include highly unsaturated materials (e.g., natural rubber), whereas saturated plastics or plastics with low levels of unsaturation are iodine compatible. Examples of plastics that are iodine compatible and have low uptake are polypropylene and polystyrene. Plastics which have high uptake of iodine have unexpectedly been found to differ, significantly, in their release rate of iodine. An example of plastics that have high uptake and low release is copolyesters. Plastics which have high uptake and high release are styrene-ethylene-butylene-styrene copolymers. The mechanical properties of these various plastic materials do not significantly change with high iodine impregnation.

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Due to the recognized variety of materials that respond differently to iodine impregnation, the present invention also provides a directional release material that controls the site and rate of iodine delivery. To this end, plastics of different compositions can be layered to create barriers for iodine release. Further, plastics can be impregnated with iodine at different times in the manufacturing process of useful products to confer an anti-microbial (bacteriocidal, virucidal, and fungicidal) property to the material.

Naturally, the selection of a suitable plastic material depends largely on the intended use of such material. For example, a particular plastic material may be selected because it has a fast halogen release rate, as opposed to another that has a slow halogen release rate. Among others, the following plastic materials may be utilized pursuant to the present invention: polyurethane; polypropylene; polystyrene; copolyester; polyethylene; polycarbonate/polyester blend and styrene-ethylene-butylene-styrene copolymer.

Because of the diversity of plastics and the potent activity of iodine as microbicidal agent, iodine impregnated plastics have a broad application for medical, industrial, food and water treatments. Examples of iodine impregnating materials that can be generated are: leukocyte filter pads; dialysis membranes; plastic beads to make a column for treating aqueous solutions; plastic balls used in water baths; blood bags; blood tubing; medical gloves; peritoneal dialysis catheters; and peritoneal dialysis connectors. Examples of materials to be disinfected with iodine impregnated plastics include: blood and its components including whole blood, red cell concentrates, plasma, platelet

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concentrates, plasma fractionation products including gamma globulin, coagulation products (e.g., Factor VIII, Factor IX, protein C, etc.), and albumin; recombinant products generated in tissue culture media; animal sera
5 used in tissue culture media preparation (fetal calf, newborn calf, human sera); dairy products including milk; swimming pool water; industrial water (e.g. cooling tower water); sewage treatment water; tooth brush bristles; telephone handpieces; and bench tops.

10 By way of example, and not limitation, an experiment illustrating the impregnation of molecular iodine into a plastic material will now be given.

Experiment No. 1

15 This experiment determined the ability to impregnate polypropylene test tubes with iodine in various fluid vehicles. In addition, the experiment evaluated the ability of the impregnated test tubes to release iodine.

20 To impregnate polypropylene, 0.25 grams of elemental iodine (dark gray crystals) were placed in filter paper. The filter paper was then folded and taped shut so as to securely contain the iodine crystals. The filter paper containing the iodine was then placed in a 50 ml polypropylene centrifuge tube.

25 As the iodine gas was released from the solid phase iodine, it was taken up by the polypropylene. The color of polypropylene turned a light brown initially and progressively became a dark chocolate brown. A total of 24 tubes were treated in this manner. The tubes were
30 allowed to incubate at room temperature for about two days. After the two days, the tubes were observed to be a uniform, dark chocolate brown color. This result indicated a substantial uptake of iodine had occurred.

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However, the iodine in one of the envelopes was opened and 0.2 grams of iodine could be recovered, demonstrating that a large amount of iodine was still present as solid crystals.

5 To demonstrate that iodine could be released by the iodine impregnated polypropylene tube, the following experiment was conducted using the preparations 1-3 below as extraction solutions.

10 (1) A saline solution (0.9% NaCl) was used. Iodine is known to be only slightly soluble in saline.

 (2) A 10% solution of potassium iodide (KI) was used. Iodine is known to be highly soluble in aqueous solutions containing potassium iodide.

15 (3) A 200 mg/ml suspension of amylose in saline was used. The presence of elemental iodine can be detected using the characteristic color reaction of amylose going from a white material to a tan, violet and purple color in the presence of increasing concentrations of iodine.

20 The following steps were conducted to determine whether iodine could be recovered and also the rate of release of such iodine. Forty ml of an extraction solution (1-3 above) was added into separate iodine impregnated 50 ml polypropylene centrifuge tubes. The
25 tubes were then placed on an end-over-end mixer. One ml samples were collected for all tubes after 45 minutes, 7.5 hours, 18 hours and 30 hours of rotation.

30 The following observations demonstrated that iodine could be recovered from the plastic and that the rate of release depends, among other factors, upon the solubility of iodine in the extraction media. First, only slight yellow discoloration of the saline solution was observed after 30 hours of rotation, indicating a slight amount

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of iodine was present in the saline. The potassium iodide solution extracted out more iodine as indicated by a strong yellow color after 30 hours of rotation. The yellow color intensity was detectable after 45 minutes of rotation and became progressively stronger with time. This result demonstrated a sustained delivery of iodine into the solution. Still further, the amylose extraction solution became slightly discolored with yellow color after 45 minutes of incubation, violet/brown after 7 hours, dark purple after 8 hours and thereafter. This result demonstrates that elemental iodine was being released from the tubes into the saline media, and then captured by the amylose to produce the characteristic change in color of amylose caused by iodine.

By way of example, and not limitation, experiments illustrating the ability of the antimicrobial material of the present invention to inactivate viruses will now be given.

Experiment No. 2

This experiment determined the rate of vesicular stomatitis virus (VSV) inactivation by iodine impregnated polyurethane beads in tissue culture medium (RPMI 1640) at room temperature. The iodine impregnated polyurethane beads were prepared by incubating 100 grams of polyurethane pellets with 2 grams of crystal iodine at room temperature for 3-4 days.

TESTING PROCEDURE:

30 ml of RPMI 1640 medium was placed into a 50 ml test tube. VSV (Indiana strain) was added to the media at 1/500 dilution.

Three (3) 50 ml test tubes were utilized for testing. 2.5 g of I₂-PU beads was added to the first

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test tube. 1 g of I₂-PU beads was added to the second test tube. 2.5 g of PU beads (PU bead control) was added to the third test tube. Each test tube was washed twice with 20 ml PBS each time. (Each gram of polyurethane beads contains about 30 pellets.)

10 ml of virus medium was added to each tube. The reaction incubation was carried out in end-over-end rotation at approximately 20 rpm speed. Untreated virus samples were collected as process control.

At 30 min, 1 hr, 2 hr and overnight (18 hr) intervals, one sample was collected from each group. The process control was collected at the 1 hr interval. The samples were quenched with 1.5% sodium thiosulfate to chemically neutralize iodine present in the sample.

The controls and samples were all then tested in Vero cells by a limiting dilution assay. The virus input, based on the untreated process control, was $10^{6.55}$ TCID₅₀/ml. Table 1 below details the assay results.

TABLE 1

Sample	Virus Titer Input = $10^{6.55}$ TCID ₅₀ /ml				Log Reduction			
	0.5 hr.	1 hr.	2 hr.	18 hr.	0.5 hr.	1 hr.	2 hr.	18 hr.
Bead Preparation								
Bead Control	7.25	7.08	4.28	5.33	0	0	2.27	1.22
0.25 g/ml	4.63	1.83	<1.83*	<1.83	1.92	4.72	>4.72	>4.72
0.1 g/ml	6.55	6.20	<1.83	<1.83	0	0.35	>4.72	>4.72

* = below the detection limit, no recoverable virus.

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Experiment No. 3

This experiment determined the rate of VSV inactivation by iodine impregnated polyurethane beads in normal human plasma at room temperature. The iodine impregnated polyurethane beads were prepared by incubating 100 grams of polyurethane pellets with 2 grams of crystal iodine at room temperature for 3-4 days.

TESTING PROCEDURE:

40 ml of normal human plasma was placed into a 50 ml test tube. VSV (Indiana strain) was added to the media.

Three (3) 50 ml test tubes were utilized for testing. 2.5 g of I₂-PU beads was added to the first test tube. 1 g of I₂-PU beads was added to the second test tube. 2.5 g of PU beads (PU bead control) was added to the third test tube. Each test tube was washed twice with 20 ml PBS each time. (Each gram of polyurethane beads contains about 30 pellets.)

10 ml of virus plasma was added to each tube. The reaction incubation was carried out in end-over-end rotation at approximately 20 rpm speed. 2ml of untreated virus plasma was placed in a sterile tube and was used as process control (no end-over-end rotation).

At 30 min, 1 hr, 2 hr and overnight (18 hr) intervals, one sample was collected from each group. The process control was collected at the 1 hr interval. The samples were quenched with 1.5% sodium thiosulfate to chemically neutralize iodine present in the sample.

The controls and samples were all then tested in Vero cells by a limiting dilution assay. The virus input, based on the untreated process control, was 10^{6.73} TCID 50/ml. Table 2 below details the assay results.

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TABLE 2

Sample	Virus Titer Input = 10 ^{6.73} TCID 50/ml					Log Reduction				
	0.5 hr.	1 hr.	2 hr.	4 hr.	18 hr.	0.5 hr.	1 hr.	2 hr.	4 hr.	18 hr.
Bead Preparation										
Bead Control	6.90	6.55	6.73	6.73	6.73	0	0.18	0	0	0
0.25 g/ml	5.15	5.15	4.80	4.98	2.0	1.58	1.58	1.93	1.75	4.73
0.10 g/ml	5.33	4.98	4.98	4.28	3.57	1.4	1.75	1.75	2.45	3.16

Experiment No. 4

This experiment determined the rate of HIV inactivation by iodine impregnated polyurethane beads in tissue culture medium (RPMI 1640) at room temperature. The iodine impregnated polyurethane beads were prepared by incubating 100 grams of polyurethane pellets with 2 grams of crystal iodine at room temperature for 3-4 days.

TESTING PROCEDURE:

18 ml of RPMI 1640 medium was placed into a 50 ml test tube. HIV (III_B) was added to the media.

Nine (9) 15 ml test tubes were separated into three groups. To the first group, 0.5 g of I₂-PU beads was added to each test tube. 0.1 g of I₂-PU beads was added to each test tube in the second group. 0.5 g of PU beads (PU bead control) was added to each test tube in the third group. Each test tube was washed twice with 20 ml PBS each time. (Each gram of polyurethane beads contains about 30 pellets.)

2 ml of virus medium was added to each tube. The reaction incubation was carried out in end-over-end rotation at approximately 20 rpm speed. 2 ml of

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untreated virus medium was placed in a sterile tube and used as the process control.

At 1 hr, 2 hr and overnight (18 hr) intervals, one sample from each group was collected. The process control was collected at the 1 hr interval. The samples were quenched with 1.5% sodium thiosulfate to chemically neutralize iodine present in the sample.

The controls and samples were all then tested in MT-2 cells by a syncytial formation assay. This virus input, based on the untreated process control, was $10^{4.85}$ TCID 50/ml. Table 3 below details the assay results.

TABLE 3

Sample	Virus Titer Input = $10^{4.85}$ TCID 50/ml			Log Reduction		
	1 hr.	2 hr.	18 hr.	1 hr.	2 hr.	18 hr.
Bead Preparation						
Bead Control	4.7	4.7	4.7	0.15	0.3	0
0.25 g/ml	<1.7*	<1.7*	<1.7*	>3.15	>3.15	>3.15
0.05 g/ml	2.6	<1.7*	<1.7*	2.25	>3.15	>3.15

* = below detection limit, no recoverable virus.

Experiment No. 5

This experiment determined the rate of HIV inactivation by iodine impregnated polyurethane beads in 100% normal human plasma at room temperature. The iodine impregnated polyurethane beads were prepared by incubating 100 grams of polyurethane pellets with 2 grams of crystal iodine at room temperature for 3-4 days.

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TESTING PROCEDURE:

18 ml of normal human plasma was placed into a 50 ml test tube. HIV (III_B) was added to the media.

5 Nine (9) 15 ml test tubes were separated into three groups. To the first group, 0.5 g of I₂-PU beads was added to each test tube. 0.1 g of I₂-PU beads was added to each test tube in the second group. 0.5 g of PU beads (PU bead control) was added to each test tube in the third group. Each test tube was washed twice with
10 20 ml PBS each time. (Each gram of polyurethane beads contains about 30 pellets.)

2 ml of virus plasma was added to each tube. The reaction incubation was carried out in end-over-end rotation at approximately 20 rpm speed. 2 ml of
15 untreated virus plasma was placed in a sterile tube and used as the process control.

At 1 hr, 2 hr and overnight (18 hr) intervals, one sample from each group was collected. The process control was collected at the 1 hr interval. The samples
20 were quenched with 1.5% sodium thiosulfate to chemically neutralize iodine present in the sample.

The controls and samples were all then tested in MT-2 cells by a syncytial formation assay. The virus input, based on the untreated process control, was 10^{5.5}
25 TCID 50/ml. Table 4 below details the assay results.

TABLE 4

Sample	Virus Titer Input = 10 ^{5.5} TCID 50/ml			Log Reduction		
	1 hr.	2 hr.	18 hr.	1 hr.	2 hr.	18 hr.
Bead Preparation						
Bead Control	5.2	5.3	5.0	0.3	0.2	0.5
0.1 g/ml	5.2	5.3	4.1	0.3	0.2	1.4

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0.5 g/ml	<1.7'	<1.7'	<1.7'	>3.8	>3.8	>3.8
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* = below detection limit, no recoverable virus.

By way of example, and not limitation, the results from experiments determining the differing absorption and release properties of various iodine impregnated plastics will now be given.

Various plastics were tested to determine their respective absorption and release properties with respect to iodine. For example, the following plastics were tested: polyurethane; polypropylene; polystyrene; copolyester; polyethylene; polycarbonate/polyester blend and styrene-ethylene-butylene-styrene copolymer.

Based on such testing, copolyesters (Hytrel™) and styrene-ethylene-butylene-styrene copolymers (Kraton™) were found to be the most effective plastic materials. The copolyesters used in the present invention are sold under the trademark Hytrel™ and may be obtained from DuPont located in Wilmington, Delaware. The styrene-ethylene-butylene-styrene copolymers used in the present invention are sold under the trademark Kraton™ and may be obtained from Shell located in Houston, Texas.

The description below focuses on the use of these particular plastic materials. However, the invention is not intended to be restricted to these materials, but extends to the breadth of the foregoing specification and the following claims. As one skilled in the art will appreciate, selection of a suitable plastic material depends largely on the use of such material. Therefore, the experimental results below simply provide illustrative details and should be understood to not restrict the present invention.

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The absorption of iodine in plastics was first tracked by weight percentage. In various tests conducted, plastic samples were weighed before and after impregnation with iodine. Based on the difference in weight, the inventors were able to determine the amount of iodine absorbed into the plastic sample.

Based on the several studies that were initially evaluated, copolyesters (Hytrel™) and styrene-ethylene-butylene-styrene copolymers (Kraton™) both absorb high amounts of iodine. Continuous monitoring also showed that these two materials have different release rates. Styrene-ethylene-butylene-styrene copolymer quickly loses the iodine; copolyester retains iodine even under a well ventilated hood.

The next experiment determined the effect of iodine on the mechanical properties of various plastics. Iodine is an aggressive oxidative agent and readily attacks unsaturated polymers. Based on various tests, iodine was found to degrade polyisoprene, santoprene, silicone rubber, Ecdel, PCCE and even linear low density polyethylene (Insite CGCT).

Experiment No. 6 - ABSORPTION TESTS

Figures 1-3 are illustrative absorption curves of different plastic materials. Figure 1 is a graph of weight percent iodine absorbed versus time (hrs) samples of a linear, low density polyethylene (CGCT), a polypropylene (Escorene™), a copolyester (Hytrel™), a polycarbonate/polyester blend (Makroblend™), and a polystyrene. Figure 2 is a graph of weight percent iodine absorbed versus time (day) for various copolyesters (Hytrel™) and styrene-ethylene-butylene-styrene copolymers (Kraton™) at room temperature. The copolyesters absorbed a greater percentage of iodine and

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are graphically represented on the upper portion of the graph. Whereas, the styrene-ethylene-butylene-styrene copolymers absorbed a lesser percentage of iodine and are graphically represented on the lower portion of the graph. Notably, the absorption rates for the various materials differ.

Certain factors may affect the absorption rates of these materials. Factors such as part geometry, iodine vessel container, iodine content and temperature may likely affect the absorption mechanism. As illustrated in Figure 3, the effect of temperature is quite significant on the absorption rate. Figure 3 shows the absorption rate by weight percentage versus time (hrs) of CGCT (LLDPE) at 60°C and room temperature.

Experiment No. 7 - IODINE RELEASE TESTS

After materials have been treated with iodine and removed from the absorption process, the iodine will slowly evaporate from the sample. This evaporation or release of iodine provides the anti-microbial action needed to keep components sterile. The rate of release is material dependent.

Figure 4 illustrates the release properties of various materials while placed under a lab hood. Specifically, Figure 4 illustrates the weight percentage of iodine absorbed and released from various materials over an extended period of time (i.e. three plus months). The absorption levels indicated in Figure 4 are not the maximum absorbency levels. However, the absorption levels give an indication of the release rates of different materials.

Figures 5 and 6 illustrate the short term release rates of styrene-ethylene-butylene-styrene copolymer and copolyester, respectively at 25°C. Figure 6 illustrates

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how well the copolyester retains the absorbed iodine. Copolyester can retain at least 30% impregnated iodine after 6 months under a hood in an open vial.

Experiment No. 8 - MECHANICAL PROPERTIES

5 The effect of iodine on the mechanical properties of several polymers has also been studied. Experiments were conducted to evaluate whether iodine adversely affected the utility and performance of the impregnated plastic material for industrial and medical uses. While
10 iodine can readily degrade some polymers, others seem relatively unaffected. The following information details the experiments conducted to test the mechanical stability of the various treated plastics. Various plastics were tested in both an open as well as a closed
15 type system.

Preparation:

Samples, injection molded tensile bars, were placed in conical flasks sealed by glass stoppers. The iodine was weighed, at least 2g, and packaged in filter paper
20 pouches. The pouches were then placed in the glass containers. In order to accelerate the absorption, some samples were placed in an oven at 60°C.

Open system vs. Closed system:

In order to survive the shelf and service life, it
25 is desirable for the impregnated materials to be shrouded to minimize iodine diffusion. The open system represents the service life of the material after the product has been opened. The closed system represents the effect of iodine during the shelf life of the product. Testing
30 within a closed system is expected to be more severe on the mechanical properties since the iodine content remains high throughout the testing period.

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Tables 5A-6B set forth the resulting effects of iodine impregnation on the mechanical properties of the various plastics. The testing evaluates the effect of not only the storage conditions, eg. open system, but also the iodine content, temperature of impregnation, and the exposure period. For each plastic sample, the tensile strength and the elongation percentage were also determined.

Tables 5A and 5B illustrate mechanical testing conducted in an open system with a temperature of impregnation of 60°C. As these tables illustrate, Hytrel™ samples absorbed for 3 days to 8% iodine show no significant effect after 4 months. Whereas, Hytrel™ samples absorbed for 5 days to 14% iodine became immediately brittle. Kraton™ samples absorbed for 3 days to 5% iodine show no significant effect after 4 months. Polypropylene samples absorbed for 12 days to 2.6% iodine show a 30% decrease in percent elongation at break. Still further, linear low density polyethylene (LLDPE) samples absorbed for 12 days to 4.56% iodine show a 35% decrease in percent elongation at break.

Table 5A

Material	Original Iodine Content %	Time to Test	Iodine content at test (%)	Tensile strength, PSI	Std. Dev.
Kraton G 2705	Control	-	-	817.5	14.85
	4.2	2 weeks	0.35	901	63.69
	7.99	2 weeks	0.66	944.33	51.64
	4.88	4 months	0.8	895.75	44.7
	4.2	4 months	0.27	910.6	19.73
Polystyrene	Control	-	-	7163.44	30.8
	4.21	4 months	1	6152.5	356.13

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Hytrel 4056	Control	-	-	4264.5	323.15
	7.55	2 weeks	4	4315	82.02
	14.27	2 weeks	11	1406.33	68.84
	7.55	4 months	3.88	4143.5	135.57
CGCT (LLDPE)	Control	-	-	2730.5	54.45
	4.56	2 weeks	4	2303	48.08
Escorene PD9214 (PP)	Control	-	-	5257.5	142.13
	1.4	4 months	0.9	5492.4	57.87
	2.6	4 months	1.5	5649.9	24.82

5

Table 5B

Material	Original iodine Content %	Time to Test	Iodine content at test (%)	Elongation %	Std. Dev.
Kraton G 2705	Control	-	-	179.95	21.43
	4.2	2 weeks	0.35	211.83	45.93
	7.99	2 weeks	0.66	167.53	23.05
	4.86	4 months	0.8	206.53	34.88
	4.2	4 months	0.27	194.8	17.67
Polystyrene	Control	-	-	13.28	0.88
	4.21	4 months	1	5.64	0.54
Hytrel 4056	Control	-	-	268.55	30.19
	7.55	2 weeks	4	314.7	6.65
	14.27	2 weeks	11	11.46	0.21
	7.55	4 months	3.88	316.4	24.58

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CGCT (LLDPE)	Control	-	-	376.85	2.33
	4.56	2 weeks	4	251	3.68
Escorene PD9214 (PP)	Control	-	-	46.75	1.48
	1.4	4 months	0.9	41.82	3.03
	2.6	4 months	1.5	34.33	3.64

5 Tables 6A and 6B illustrate mechanical testing conducted in an closed system with a temperature of impregnation of 25°C. Under such a closed system, Hytrel™ samples absorbed to 4.3% iodine did not show any effect after six days. Isoplast polyurethane (PU) samples absorbed to 0.08% iodine did not show any significant effect after nine weeks. In contrast, Prevail polyurethane samples absorbed to 14% iodine become brittle after nine weeks. Whereas, Pellethane polyurethane samples absorbed to 4.6% iodine did not show any significant effect.

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Table 6A

Material	Iodine Content (%)	Time to Test	Tensile strength, PSI	Std. Dev.
Hytrel 5555HS	Control	-	4737.28	268.21
	1.14	3 days	4486	335.93
	4.27	6 days	4685.22	438.98
Isoplast 2510 (PU)	Control	-	8505.8	139.56
	0.08	4 weeks	8472.33	6897

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	0.08	9 weeks	8315	0
LDPE	Control	-	1539.2	23.26
	0.6	3 weeks	1516	22.63
Prevail 3150 (PU)	Control		3904.5	12.02
	14	9 weeks	3484.5	68.59
Pellethane (PU)	Control	-	6061.32	296.18
	1.85	10 days	5595.9	182.93
	4.6	1 month	5591.81	199.99
PP/Kraton blend				
70% Escorene PD9214	Control	-	3507.46	55.47
30% Kraton G2705	1	10 days	4486	150.35
	4.27	1 month	4685.22	438.98
PP/Kraton blend	Control	-	2443.01	
50% Escorene PD9214	1.7	10 days	2600.7	119.16
50% Kraton G2705	2.6	1 month	2689.28	36.58
PP/Kraton blend				
30% Escorene PD9214	Control	-	1659.14	67.8
70% Kraton G2705	2.2	10 days	1668.48	71.5
	3.2	1 month	1748.48	-

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Table 6B

Material	Iodine Content (%)	Time to Test	% Elongation, %	Std. Dev.
Hytrel 5555HS	Control	-	335	20.811
	1.14	3 days	150.35	18.64
	4.27	6 days	351.5	50.2
Isoplast 2510	Control	-	127.89	47.15
PU	0.08	4 weeks	154.37	35.1
	0.08	9 weeks	98.9	30.12
LDPE	Control	-	108.48	12.26
	0.6	3 weeks	137.5	93.34
Prevail 3150	Control		90.6	1.23
PU	14	9 weeks	5.2	0.99
Pellethane TPU	Control	-	258.98	8.96
	1.85	10 days	269.32	11.96
	4.6	1 month	251.2	18.18
PP/Kraton blend				
70% Escorene PD9214	Control	-	372.44	16.23
30% G2705	1	10 days	335.93	18.64
	4.27	1 month	351.5	50.2
PP/Kraton blend	Control			
50% Escorene PD9214	1.7	10 days	308.48	39.85
50% G2705	2.6	1 month	325.3	10.45

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PD/Kraton blend				
30% Escorene PD9214	Control	-	248.98	29.94
70% G2705	2.2	10 days	232.45	4.45
	3.2	1 month	201.34	-

5 Tables 5A-6B illustrate that impregnating iodine
into various polymeric materials does not adversely
effect the mechanical properties of the various polymeric
materials. While mechanical properties and dimensions
changed after impregnation, they were still acceptable.
10 As a result thereof, various polymeric materials can be
impregnated with iodine and still be utilized to produce,
for example, medical and industrial apparatuses.

Impregnation results:

15 This experiment presents results from a
impregnation feasibility examination. The following
materials or blends were chosen for the iodine
impregnation study: (1) copolyester; (2) polyurethane;
(3) styrene-ethylene-butylene-styrene copolymer; (4)
PVP/copolyester; and (5) PVOH/styrene-ethylene-butylene-
20 styrene copolymer.

 Disks and mini tensile bars were cut from a
compression molded sheet. Iodine impregnation was done
in a vacuum (-15 to -25 psi) oven with a temperature of
116 +/- 3°F for about 24 hours. Samples were first kept
25 in a closed vial and then placed in the vacuum oven.

 After iodine treatment, the following three
parameters were monitored for a period of two months:
(1) iodine weight loss; (2) mechanical properties; and
(3) dimension. Figure 7 illustrates the iodine release

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rate for three polymeric materials while under a vented hood. Tables 7A, 7B and 7C set forth the percentage weight loss data collected over the two month study period. Figures 8-10 illustrate the effects of iodine on the elongation of a copolyester, a polyurethane, and a styrene-ethylene-butylene-styrene copolymer, respectively. Likewise, table 8 sets forth the mechanical elongation data collected over the two month period.

Table 7A

Sample ID	Material	% Iodine	% Thickness Change 0 day	% Thickness Change 19 days
98-1	Hytrel	15.65	3.47	1.93
98-2	Hytrel	15.86	0.88	1.75
98-3	Hytrel	18.74	1.72	
98-4	Hytrel	18.89	2.15	1.29
98-5	Hytrel	17.8	1.27	0.42
98-6	Hytrel	18.07	1.68	0.84
98-7	PU	34.03	0.81	0.81
98-8	PU	28.13	2.48	0.36
98-9	PU	32.23	1.61	0
98-10	PU	30.05	1.54	0
98-11	PU	32.57	0	-0.81
98-12	PU	28.1	3.7	0
98-13	Kraton	6.5	0	-1.37
98-14	Kraton	6.6	0	-0.68
98-15	Kraton	7.27	0	1.35
98-16	Kraton	7.38	0	0
98-17	Kraton	6.69	-0.69	0

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98-18	Kraton	7.37	-1.35	0
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Table 7B

Sample ID	Material	Dissipation System	%Iodine Day 1	%Iodine Day 5
98-1	Hytrel	Close	15.32	
98-2	Hytrel	Close		
98-3	Hytrel	Close		
98-4	Hytrel	Open	14.23	10.27
98-5	Hytrel	Open	13.75	10.19
98-6	Hytrel	Open	14.15	10.25
98-7	PU	Close		
98-8	PU	Close		
98-9	PU	Close		
98-10	PU	Open	21.91	13.45
98-11	PU	Open	22.32	13.80
98-12	PU	Open	20.71	12.38
98-13	Kraton	Close		
98-14	Kraton	Close		
98-15	Kraton	Close		
98-16	Kraton	Open	3.04	0.92
98-17	Kraton	Open	2.73	0.76
98-18	Kraton	Open	3.11	0.84

Table 7C

Sample ID	Material	%Iodine Day 19	%Iodine 54 Days	Average
98-1	Hytrel	15.18	15.03	~ 15%(closed)
98-2	Hytrel	15.44	15.45	
98-3	Hytrel	9.12*	9.20	
98-4	Hytrel	7.58	6.31	6.24 ± 0.07%(open)

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98-5	Hytrel	7.49	6.18	"
98-6	Hytrel	7.54	6.24	"
98-7	PU	26.6*	22.03	~ 23%(closed)
98-8	PU	23.78	22.06	"
98-9	PU	27.45	24.06	"
98-10	PU	8.73	5.28	4.97% ± 0.53(open)
98-11	PU	8.91	5.26	"
98-12	PU	7.59	4.36	"
98-13	Kraton	5.59	5.36	5.57 ± 0.3(closed)
98-14	Kraton	5.41	5.43	"
98-15	Kraton	6.08	5.91	"
98-16	Kraton	0.38#	0.19	0.20 ± 0.04(open)
98-17	Kraton	0.24#	0.17	"
98-18	Kraton	0.33#	0.25	"

* Leak, aluminum rusted
Color back to clear (almost)

Table 8A

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Sample ID	Material	% Iodine
89-1T	PVOH/Kraton	37.4
89-2T	Hytrel	20.6
89-3T	PE192	N/A
89-4T	Kraton	6.7
89-5T	PVP/Hytrel	13.02
95-2	PE192	11.60
93-1	PU	0.83
93-2	PVOH/Kraton	0.66
93-3	PVP/Hytrel	0.87

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98-4	Hytrel	0.73
98-5	Kraton	0.66

Table 8B

Sample ID	Material	% Elongation w/o iodine	0th mon	1th mon	2nd mon
89-1T	PVOH/Kraton	1300	700	659	-
89-2T	Hytrel	784	800	448	468(n=4)
89-3T	PE192	-	-	-	-
89-4T	Kraton	1077	688	624	570(n=2)
89-5T	PVP/Hytrel	1000	44	12	-
95-2	PE192	>1000	-	294	212(n=2)
93-1	PU			835	994
93-2	PVOH/Kraton			>1000	-
93-3	PVP/Hytrel			847	-
98-4	Hytrel			0	-
98-5	Kraton			>1000	>1000

Based on the multitude of tests conducted, copolyester and styrene-ethylene-butylene-styrene copolymer proved to be the most effective materials. Table 9 below details the key properties of these materials as well as those of polyurethane.

Table 9

Material	Flexibility	%iodine capacity	Dissipation 0, 2, 6 months open system			seal	elongation retention 0, 1, 2 months		
Kraton-2705	Very flexible	7%	7%	0.2%	<0.1%	excellent	100%	56%	58%
Hytrel-5555	semi-flexible	>20%	18%	6.2%	>2%	poor-fair	84%	56%	53%
Polyurethane	flexible	>30%	30%	6%	>2%	Good			
Polyurethane							100%	20%	20%

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By way of example, and not limitation, test results illustrating the microbicidal activity of the present invention will now be given.

Experiment No. 9 - MICROBICIDAL RESULTS

5 This experiment presents results from a microbiology feasibility examination. The tests were performed on a range of plastic materials, varying concentrations of iodine, and several impregnation process parameters.

10 The test methods chosen were based on the requirement that any antimicrobial intended for use on the external areas of a certain medical device, namely continuous ambulatory peritoneal dialysis (CAPD) connectors, have the role of preventing bioburden
15 accumulation. For example, accidental contamination of the connector external areas during an exchange should be eliminated within the dwell time period to prevent bioborder accumulation.

 The initial testing of materials consisted of the
20 following test parameters: 1) direct surface contamination; 2) *Staphylococcus aureus* as the contaminating organism at a level of 10^5 colony forming units; and 3) exposure time of 15 minutes.

 These initial parameters were chosen for the
25 following reasons. The initial concept was to use an antimicrobial substance on areas prone to touch contamination. *Staphylococcus aureus* is the second most prevalent cause of CAPD peritonitis. It was chosen because it is comparable to *S. epidermidis* in sensitivity
30 to iodine but is less likely to be an extraneous contaminant that may result in false test failures. A five $\log_{10}$ reduction of viable contaminants was chosen to

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represent worst case touch or airborne contamination. Published literature and previous work show that povidone iodine can effectively disinfect surfaces in a fairly short exposure time (less than 10 min).

5 The test parameters for subsequent testing was modified slightly. First, the testing examined those scenarios where the impregnated material is not directly exposed to touch contamination but contacts other surfaces that may be exposed. To adequately evaluate
10 this scenario, non-impregnated materials were contaminated and then impregnated materials were placed on top of a "sandwich" configuration. Second, the exposure time was lengthened to one hour. Realistically, the CAPD dwell period is approximately four hours;
15 testing one hour instead of 15 minutes still gives a large safety factor.

 Tables 10A and 10B display the various materials evaluated for antimicrobial effectiveness. Copolyesters (Hytrel™) and styrene-ethylene-butylene-styrene
20 copolymers (Kraton™) materials were most extensively studied. These materials impregnated with even very low levels of iodine (approx. 1%) were effective. Copolyester samples with an original iodine concentration of 7.55% were still effective after 4 months of storage
25 in a container open to the atmosphere. Both copolyester and styrene-ethylene-butylene-styrene copolymer samples with original iodine concentrations of 1.25% and 1.21% respectively were effective after 6 weeks storage in a closed container.

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Table 10A

	Material	Original Iodine Content(%)	Temp. of Impregna- tion (C)	Storage Condition	Time to Test
5	Hytrel 4056	5.5	25	Closed	0
	Hytrel 4056	1.3	60	Closed	0
	Hytrel 4056	0.5	60	Closed	0
	Hytrel 4056	7.55	60	Open	20dys
	Hytrel 5555	10.0	25	Closed	2wks
10	Hytrel 5555	17.26	47(vacuum)	Closed	2wks
	Hytrel 5555	17.26	47(vacuum)	Closed	5wks
	Hytrel 5555	6.73	25	Closed	6wks
	Hytrel 4056	7.55	60	Open	4mos
	Hytrel 5555	1.23	47(vacuum)	Closed	6wks
15	Kraton 2705	3.4	25	Closed	0
	Kraton 2705	3.4	25	Closed	2mos
	Kraton 2705	3.4	25	Closed	4mos
	Kraton 2705	3.4	25	Closed	4mos
	Kraton 2705	0.3	60	Closed	0
20	Kraton 2705	0.788	60	Closed	0
	Kraton 2705	5.0	60	Open	2wks
	Kraton 2705	1.0	60	Open	2mos
	Kraton 2705	4.8	60	Open	2wks
	Kraton 2705	4.8	60	Open	10wks
25	Kraton 2705	4.8	60	Open	10wks
	Kraton 2705	2.5	25	Closed	1mo
	Kraton 2705	2.95	47(vacuum)	Closed	2wks
	Kraton 2705	2.95	47(vacuum)	Closed	5wks
	Kraton 2705	2.54	25	Closed	6wks
	Kraton 2705	1.21	47(vacuum)	Closed	6wks
	Kraton 2705	4.9	47(vacuum)	Closed	4wks

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CGCT (LLDPE)	1	60	Open	1mo
CGCT (LLDPE)	5.8	60	Open	42dys
CGCT (LLDPE)	5.8	60	Open	4mos
Escorene (PP)	1.4	60	Open	2wks
50%PP/50%Kraton	1.7	25	Closed	2wks
70%PP/30%Kraton	1.0	25	Closed	2wks
PE 192	18.85	47(vacuum)	Closed	2wks
PE 192	18.85	47(vacuum)	Closed	5wks
*ND = not determined				

Table 10B

Material	Iodine Content at Test (%)	Test Method	5log ₁₀ reduction of SA (Y/N)
Hytrel 4056	Same	Surface15min	Y
Hytrel 4056	Same	Surface15min	Y
Hytrel 4056	Same	Surface15min	Y
Hytrel 4056	4.1	Surface15min	Y
Hytrel 5555	ND*	Sandwich15min	Y
Hytrel 5555	ND	Sandwich15min	Y
Hytrel 5555	ND	Sandwich60min	Y
Hytrel 5555	ND	Sandwich60min	Y
Hytrel 4056	3.9	Sandwich60min	Y
Hytrel 5555	ND	Sandwich60min	Y
Kraton 2705	Same	Surface15min	Y
Kraton 2705	0.625	Surface15min	Y
Kraton 2705	ND	Surf + Oil15min	Y
Kraton 2705	ND	Surf/no oil 15min	Y
Kraton 2705	Same	Surface15min	Y

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5	Kraton 2705	Same	Surface15min	Y
	Kraton 2705	0.48	Surface15min	N (1log ₁₀ reduc)
	Kraton 2705	0.88	Surface15min	Y
	Kraton 2705	0.9	Surface15min	N (1log ₁₀ reduc)
	Kraton 2705	ND	Surf + Oil15min	N (.9log ₁₀ reduc)
10	Kraton 2705	ND	Surf/no oil 15 min	N (2log ₁₀ reduc)
	Kraton 2705	ND	Sandwich15min	Y
	Kraton 2705	ND	Sandwich15min	Y
	Kraton 2705	ND	Sandwich60min	Y
	Kraton 2705	ND	Sandwich60min	Y
15	Kraton 2705	ND	Sandwich60min	Y
	CGCT (LLDPE)	0.26	Surface15min	N (.2log ₁₀ reduc)
	CGCT (LLDPE)	1.78	Surface15min	N (1.5log ₁₀ reduc)
	CGCT (LLDPE)	1.19	Sandwich15min	Y
	Escorene (PP)	1.4	Surface15min	N (.6log ₁₀ reduc)
20	50%PP/ 50% Kraton	ND	Sandwich15min	Y
	70%PP/ 30% Kraton	ND	Sandwich15min	Y
	PE 192	ND	Sandwich15min	Y
	PE 192	ND	Sandwich60min	Y
	*ND = not determined			

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A few samples of polypropylene-kraton blends and polyurethane also showed effectiveness. The two materials that did not show consistent 5 log₁₀ reduction of *S. aureus* were linear low density polyethylene (CGCT) and polypropylene (Escorene™).

In addition to the above test parameters, preliminary testing on the effects of glycerol (simulating body oil) on antibacterial activity as well as the effect of temperature was evaluated. An evaluation of the effects of glycerol on antibacterial activity of impregnated material showed that oils can reduce the effectiveness. However, reduction of effectiveness is not observed when the iodine level is high, presumably in excess of the necessary bactericidal concentration. The inventors believe that the temperature used in the iodine impregnation process may impact either effectiveness and/or longevity.

The present invention also provides a method for making an antimicrobial material. The method includes the step of contacting a plastic material with a halogen gas that is thereby absorbed in the plastic material.

As set forth above, iodine impregnated plastics have a broad application for medical, industrial, food and water treatments. In an embodiment, the plastic material may be formed into a medical apparatus prior to contacting same with the halogen gas.

Likewise, the present invention provides a method for impregnating a plastic material. Pursuant to this method, iodine crystals are initially delivered in an enclosed vessel. Then, the plastic material to be impregnated is placed in the enclosed vessel for a time sufficient to allow the iodine to absorb into the plastic material.

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By way of example, and not limitation, different conceptual methods of impregnating iodine into a plastic material pursuant to the present invention will now be given. While the following examples focus on the
5 impregnation of a dialysis connector for use in a dialysis system, the present invention is not intended to be limited by these examples.

Concept 1 - Iodine Impregnated Cap

As illustrated in Figure 11, exposing plastic caps
10 14 to elemental iodine in an enclosed vessel 12 impregnates the caps 14 with iodine. Initially, a source of gaseous iodine 10, such as dry iodine crystals, is placed in an enclosed vessel 12. Then, plastic caps 14 are placed in the enclosed vessel 12 for a time
15 sufficient to allow the iodine to absorb into the plastic caps 14. Effectively, the elemental iodine sublimates into the enclosed vessel 12 and then absorbs into the plastic caps 14.

The iodine is absorbed into the plastic caps 14
20 over time at a rate that is dependent on temperature, the amount of iodine in the vessel 12, and the type of plastic. Figure 12 illustrates iodine absorption by weight percentage versus time into Hytrel® caps at 25°C. Release of iodine from the cap occurs when the cap is
25 removed from the iodine source and open to the atmosphere. The rate of iodine release is dependent on iodine concentration in the plastic, temperature and the type of plastic. Figure 13 shows the iodine release rate by weight percentage versus time for Hytrel® caps at
30 25°C.

Antimicrobial testing conducted on samples produced in this manner exhibited a 5 log₁₀ reduction of *S. aureus*

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at iodine concentrations as low as .43%. This test proved preliminary feasibility of this conceptual method.

5 In an embodiment, as illustrated in Figure 14, a disconnect cap 16 for peritoneal dialysis can be impregnated with iodine. The iodine is slowly released from the disconnect cap 16 and disinfects the dialysis connector 18 upon insertion of the connector 18 into the cap 16.

Concept 2: Pre-impregnated Disk in a Cap

10 For most applications, blocking iodine release from unwanted areas, such as onto the user's fingers or clothing, and concentrating the released iodine at the disinfection site is desirable. For example, releasing iodine from the inside of a cap and not the outside would
15 be beneficial.

In this concept, a plastic disk is impregnated with iodine by the same method that the cap is impregnated in Concept 1. As illustrated in Figure 15, after the disk 20 is impregnated, the disk 20 is placed inside the bottom of an iodine resistant cap 22 and sealed inside
20 an iodine barrier package. The disk 20 contains the iodine and the cap 22 serves as a barrier to prevent the iodine from escaping while the product is in use, thus eliminating any staining problem and concentrating iodine
25 inside the cap.

Concept 3: Post assembly impregnation process

Here, the cap disk concept is used as before, but instead of preimpregnation of the disk, elemental iodine is added to the system at the point of assembly. A small
30 amount of iodine is dispensed into the cap and a disk is placed on top of the iodine capturing the iodine between the two components. The assembly is then packaged and the iodine impregnates the disk while in the package

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prior to reaching the customer. (Impregnation would probably be complete within one week.) This assembly method eliminates the need for impregnation equipment, and eliminates the inventory of disks that are held up during an impregnation process. Also, iodine gas containment is greatly simplified. Antimicrobial effectiveness of this configuration was tested and proved to be effective.

Concept 4: Solvent dispensed iodine impregnation

The assembly process from concept 3 is used except that the elemental iodine is dissolved in a solvent, such as isopropyl alcohol (IPA), and volumetrically dispensed into the cap. The disk is then placed over the iodine solution and the assembly is packaged. The alcohol quickly evaporates into the package and the iodine, now dry, begins to diffuse into the disk. Figure 16 illustrates the two distinct vaporation rates by weight versus time of alcohol and the iodine from the solution.

Incorporating the iodine solution into the manufacturing process allows for the dispensing of small amounts of iodine at production speeds. Moreover, it utilizes much of the current manufacturing equipment and technology in standard plants, thereby decreasing the capital costs of producing the product. Over time, the disconnect cap will release iodine gas to disinfect mating components. This design advantageously eliminates the liquid medium and maintains antimicrobial effectiveness.

By way of example, and not limitation, experiments demonstrating the feasibility of impregnating a plastic component of a dialysis disconnect cap with iodine as well as the effectiveness of same to kill viruses will now be given.

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Experiment No. 10

This experiment demonstrated the ability to impregnate Hytrel® cap samples with iodine. The experiment also examined the rate of release of iodine from the samples. Still further, this experiment evaluated the mechanical stability of the iodine impregnated caps and the effectiveness of same to inactivate viruses.

Iodine Absorption study:

Hytrel® samples were utilized for testing in this experiment. Specifically, three sample jars with nine samples in each jar were utilized.

Prior to placing the samples in the three jars, the weight of each sample was recorded. Approximately 2.5g of iodine was placed in a small filter paper pouches. Next, nine weighed samples were placed in each jar and an iodine pouch was placed in the neck of each jar. The cover on each jar was then tightly closed to create an enclosed vessel.

The time and temperature of exposure was recorded for each sample in each jar. To determine the amount of iodine content, each sample was periodically weighed and changes were recorded. Tables 11A-13 detail the results from this absorption study. Figure 17 illustrates the iodine absorption for the samples in the three jars by iodine weight percentage versus time. The samples in jar 1 were exposed to iodine for 72 hours at approximately 60°C and absorbed 2.29% iodine by weight. The samples in jars 2 and 3 were exposed at approximately 27°C for 72 hours and 13 hours, absorbing 1.06% and 0.43% iodine, respectively.

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TABLE 11A

Jar #1	Time (hrs)	0.0	Time (hrs)	1.5	Time (hrs)	17.7	Time (hrs)	22.9
	Temp.	60°C	Temp.	27°C	Temp.	27°C	Temp.	27°C
Sample #	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %
28	1.9125	0.00%	1.9263	0.72%	1.9300	0.92%	1.9316	1.00%
16	1.9165	0.00%	1.9274	0.57%	1.9325	0.83%	1.9340	0.91%
4	1.9101	0.00%	1.9183	0.43%	1.9232	0.69%	1.9251	0.79%
18	1.9111	0.00%	1.9213	0.53%	1.9278	0.87%	1.9288	0.93%
12	1.9128	0.00%	1.9248	0.63%	1.9303	0.91%	1.9311	0.96%
13	1.9115	0.00%	1.9205	0.47%	1.9256	0.74%	1.9270	0.81%
20	1.9125	0.00%	1.9215	0.47%	1.9282	0.82%	1.9300	0.92%
31	1.9095	0.00%	1.9172	0.40%	1.9242	0.40%	1.9255	0.84%
19	1.9095	0.00%	1.9226	0.69%	1.9265	0.89%	1.9288	1.01%
Average		0.00%		0.55%		0.83%		0.91%
Std. Dev.		0.0000		0.0011		0.0008		0.0007

TABLE 11B

Jar #1	Time (hrs)	46.4	Time (hrs)	49.5	Time (hrs)	71.6
	Temp.	27°C	Temp.	60°C	Temp.	27°C
Sample #	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %
28	1.9343	1.14%	1.9508	2.00%	1.9551	2.23%
16	1.9372	1.08%	1.9598	2.26%	1.9630	2.43%
4	1.9284	0.98%	1.9475	1.96%	1.9522	2.21%
18	1.9328	1.13%	1.9498	2.02%	1.9556	2.33%
12	1.9349	1.15%	1.9503	1.96%	1.9563	2.27%
13	1.9312	1.03%	1.9464	1.83%	1.9518	2.11%
20	1.9336	1.10%	1.9508	2.00%	1.9569	2.32%
31	1.9288	1.01%	1.9475	1.99%	1.9536	2.31%

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19	1.9325	1.21%	1.9470	1.96%	1.9547	2.37%
Average		1.09%		2.00%		2.29%
Std. Dev.		0.0007		0.0011		0.0008

TABLE 12A

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Jar #2	Time (hrs)	0.0	Time (hrs)	1.5	Time (hrs)	17.7	Time (hrs)	22.9
	Temp.	27°C	Temp.	27°C	Temp.	27°C	Temp.	27°C
Sample #	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %
20	1.9112	0.00%	1.9125	0.07%	1.9161	0.26%	1.9192	0.42%
14	1.9095	0.00%	1.9108	0.06%	1.9157	0.32%	1.9177	0.43%
15	1.9173	0.00%	1.9188	0.08%	1.9233	0.31%	1.9266	0.48%
11	1.9180	0.00%	1.9191	0.06%	1.9236	0.29%	1.9264	0.44%
2	1.9153	0.00%	1.9166	0.07%	1.9218	0.34%	1.9245	0.48%
8	1.9121	0.00%	1.9128	0.04%	1.9168	0.25%	1.9196	0.39%
13	1.9124	0.00%	1.9137	0.07%	1.9185	0.32%	1.9210	0.45%
31	1.9089	0.00%	1.9101	0.06%	1.9139	0.26%	1.9161	0.38%
23	1.9133	0.00%	1.9144	0.06%	1.9192	0.31%	1.9216	0.43%
Average		0.00%		0.06%		0.30%		0.43%
Std. Dev.		0.0000		0.0001		0.0003		0.0003

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TABLE 12B

Jar #2	Time (hrs)	46.3	Time (hrs)	49.2	Time (hrs)	71.4
	Temp.	27°C	Temp.	27°C	Temp.	27°C
Sample #	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %
20	1.9239	0.66%	1.9244	0.69%	1.9316	1.07%
14	1.9237	0.74%	1.9245	0.78%	1.9312	1.14%
15	1.9311	0.72%	1.9322	0.78%	1.9371	1.03%
11	1.9317	0.72%	1.9321	0.74%	1.9376	1.02%
2	1.9310	0.82%	1.9316	0.85%	1.9366	1.11%

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8	1.9244	0.64%	1.9251	0.68%	1.9305	0.86%
13	1.9269	0.76%	1.9266	0.74%	1.9326	1.06%
31	1.9231	0.74%	1.9238	0.78%	1.9298	1.09%
23	1.9256	0.64%	1.9271	0.72%	1.9340	1.08%
Average		0.72%		0.75%		1.06%
Std. Dev.		0.0006		0.0005		0.0005

TABLE 13

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Jar #3	Time (hrs)	0.0	Time (hrs)	2.8	Time (hrs)	13.3
	Temp.	27°C	Temp.	27°C	Temp.	27°C
Sample #	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %
12	1.9137	0.00%	1.9161	0.13%	1.9213	0.40%
21	1.9219	0.00%	1.9245	0.13%	1.9300	0.42%
18	1.9128	0.00%	1.9149	0.11%	1.9229	0.53%
30	1.9111	0.00%	1.9127	0.08%	1.9200	0.47%
31	1.9089	0.00%	1.9111	0.11%	1.9171	0.43%
28	1.9124	0.00%	1.9144	0.11%	1.9225	0.53%
8	1.9122	0.00%	1.9144	0.11%	1.9192	0.37%
19	1.9098	0.00%	1.9118	0.10%	1.9170	0.38%
15	1.9172	0.00%	1.9188	0.08%	1.9244	0.38%
Average		0.00%		0.11%		0.43%
Std. Dev.		0.0000		0.0002		0.0006

Iodine Release Study:

25

This study measured the rate of release of iodine from the samples prepared in the previous absorption study. To measure the iodine release, the samples were stored in an open plastic beaker under a fume hood to allow the iodine to escape from the Hytrel® material. The samples were weighed over time to determine the

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release rate. Tables 14A - 16B detail the results of this study. Figures 18A-18C illustrate the release of iodine from the samples in Jar 1, Jar 2 and Jar 3, respectively, by iodine weight percentage versus time.

TABLE 14A

Jar #1	Time (hrs)	0.0	Time (hrs)	31.0	Time (hrs)	99.5
	Temp.	27°C	Temp.	27°C	Temp.	27°C
Sample #	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %
20	1.9562	0.00%	1.9530	-0.16%	1.9473	-0.45%
19	1.9533	0.00%	1.9505	-0.14%	1.9442	-0.47%
18	1.9546	0.00%	1.9520	-0.13%	1.9448	-0.50%
4	1.9526	0.00%	1.9496	-0.15%	1.9446	-0.41%
16	1.9621	0.00%	1.9596	-0.13%	1.9526	-0.48%
13	1.9508	0.00%	1.9479	-0.15%	1.9420	-0.45%
12	1.9552	0.00%	1.9517	-0.18%	1.9450	-0.52%
28	1.9554	0.00%	1.9520	-0.17%	1.9460	-0.48%
31	1.9524	0.00%	1.9499	-0.13%	1.9441	-0.43%
Average		0.00%		-0.15%		-0.47%
Std. Dev.		0.0000		0.0002		0.0003

TABLE 14B

Jar #1	Time (hrs)	147.8	Time (hrs)	622.0
	Temp.	27°C	Temp.	27°C
Sample #	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %
20	1.9435	-0.65%	1.9373	-0.97%
19	1.9406	-0.65%	1.9344	-0.97%
18	1.9413	-0.68%	1.9355	-0.98%
4	1.9414	-0.58%	1.9346	-0.92%

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16	1.9492	-0.66%	1.9430	-0.97%
13	1.9391	-0.60%	1.9339	-0.87%
12	1.9419	-0.68%	1.9366	-0.95%
28	1.9429	-0.64%	1.9332	-1.14%
31	1.9405	-0.61%	1.9331	-0.99%
Average		-0.64%		-0.97%
Std. Dev.		0.0003		0.0007

TABLE 15A

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Jar #2	Time (hrs)	0.0	Time (hrs)	31.0	Time (hrs)	99.5
	Temp.	27°C	Temp.	27°C	Temp.	27°C
Sample #	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %
14	1.9300	0.00%	1.9282	-0.09%	1.9255	-0.23%
31	1.9303	0.00%	1.9282	-0.11%	1.9247	-0.29%
8	1.9305	0.00%	1.9285	-0.10%	1.9265	-0.21%
2	1.9357	0.00%	1.9340	-0.09%	1.9312	-0.23%
15	1.9328	0.00%	1.9342	-0.07%	1.9321	-0.04%
20	1.9312	0.00%	1.9288	-0.12%	1.9259	-0.27%
13	1.9323	0.00%	1.9302	-0.11%	1.9276	-0.24%
11	1.9374	0.00%	1.9353	-0.11%	1.9321	-0.27%
23	1.9332	0.00%	1.9311	-0.11%	1.9283	-0.25%
Average		0.00%		-0.09%		-0.23%
Std. Dev.		0.0000		0.0006		0.0007

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TABLE 15B

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Jar #2	Time (hrs)	147.8	Time (hrs)	622.0
	Temp.	27°C	Temp.	27°C
Sample #	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %
14	1.9229	-0.37%	1.9209	-0.47%

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31	1.9222	-0.42%	1.9178	-0.65%
8	1.9239	-0.34%	1.9223	-0.42%
2	1.9289	-0.35%	1.9265	-0.48%
15	1.9298	-0.16%	1.9278	-0.26%
20	1.9238	-0.38%	1.9219	-0.48%
13	1.9252	-0.37%	1.9232	-0.47%
11	1.9302	-0.37%	1.9285	-0.46%
23	1.9263	-0.36%	1.9245	-0.45%
Average		-0.35%		-0.46%
Std. Dev.		0.0007		0.0009

TABLE 16A

Jar #3	Time (hrs)	0.0	Time (hrs)	31.0	Time (hrs)	99.5
	Temp.	27°C	Temp.	27°C	Temp.	27°C
Sample #	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %
12	1.9224	0.00%	1.9216	-0.04%	1.9199	-0.13%
18	1.9229	0.00%	1.9215	-0.07%	1.9164	-0.34%
15	1.9251	0.00%	1.9243	-0.04%	1.9227	-0.12%
28	1.9221	0.00%	1.9206	-0.08%	1.9191	-0.16%
19	1.9170	0.00%	1.9163	-0.04%	1.9152	-0.09%
30	1.9199	0.00%	1.9186	-0.07%	1.9175	-0.13%
21	1.9301	0.00%	1.9292	-0.05%	1.9284	-0.09%
8	1.9197	0.00%	1.9193	-0.02%	1.9179	-0.09%
31	1.9173	0.00%	1.9160	-0.07%	1.9147	-0.14%
Average		0.00%		-0.05%		-0.14%
Std. Dev.		0.0000		0.0002		0.0007

TABLE 16B

Jar #3	Time (hrs)	147.8	Time (hrs)	622.0
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	Temp.	27°C	Temp.	27°C
Sample #	Weight (gm)	Iodine wt. %	Weight (gm)	Iodine wt. %
12	1.9180	-0.22%	1.9187	-0.19%
18	1.9179	-0.26%	1.9183	-0.24%
15	1.9209	-0.22%	1.9214	-0.19%
28	1.9173	-0.25%	1.9157	-0.33%
19	1.9135	-0.18%	1.9140	-0.16%
30	1.9156	-0.22%	1.9160	-0.20%
21	1.9265	-0.19%	1.9267	-0.18%
8	1.9157	-0.21%	1.9167	-0.16%
31	1.9132	-0.21%	1.9136	-0.19%
Average		-0.22%		-0.20%
Std. Dev.		0.0002		0.0005

15 Mechanical Testing Study:

20 This study measured the tensile properties of the samples prepared in the previous absorption study. The same control group utilized in the absorption study was also used as a control in this study. Each of the samples were evaluated based on a pull test on an Instron tensile tester.

25 Tables 17 - 20 detail the results of this study. Table 17 shows testing results on the control group, dry unimpregnated Hytrel® samples. Table 18 shows testing results on Hytrel® samples impregnated with .43% dry iodine. Table 19 shows testing results on Hytrel® samples impregnated with 1.06% dry iodine. Lastly, table 20 shows testing results on Hytrel® samples impregnated with 2.29% dry iodine.

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TABLE 17
Unimpregnated Hytrel® -control group

Specimen Number	Peak Load (lbs)	Break Load (lbs)	Elongation at Break (in)	% Strain at Auto, Break (%)	Displacement at Thresh Yield (in)
1	126.8	126.6	5.170	1034.0	.4474
2	123.9	123.9	4.990	998.0	.4649
3	116.7	116.7	4.810	962.0	.4849
4	126.9	126.9	5.100	1020.0	.4776
5	117.8	117.6	4.770	954.0	.4515
6	123.8	123.7	4.980	996.0	.4450
7	125.4	125.3	5.070	1014.0	.4615
8	126.2	126.2	5.200	1040.0	.4615
9	122.2	122.2	4.970	994.0	.4687
Mean:	123.3	123.2	5.007	1001.0	.4625
Standard Deviation:	3.8	3.8	.147	29.5	.0134
Minimum:	116.7	116.7	4.770	954.0	.4450
Maximum:	126.9	126.9	5.200	1040.0	.4849

TABLE 18
Hytrel® Impregnated with .43% dry iodine

Specimen Number	Peak Load (lbs)	Break Load (lbs)	Elongation at Break (in)	% Strain at Auto, Break (%)	Displacement at Thresh Yield (in)
1	119.10	118.90	4.960	992.0	.4646
2	117.70	117.40	4.990	980.0	.4983
"Excluded"	60.50	59.15	2.430	486.0	.5150
4	121.70	121.70	5.070	1014.0	.4646
5	118.80	118.50	4.930	986.0	.4781
6	126.70	126.60	5.300	1060.0	.4781
7	120.70	120.70	5.060	1012.0	.4853
8	116.00	115.80	4.860	972.0	.4937

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9	117.80	117.80	4.930	986.0	.4944
Mean:	119.80	119.70	5.001	1000.0	.4821
Standard Derivation:	3.30	3.36	.141	28.2	.0131
Minimum:	116.0	115.80	4.860	972.0	.4646
Maximum:	126.70	126.60	5.300	1060.0	.4983

TABLE 19**Hytrel® Impregnated with 1.06% dry iodine**

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Specimen Number	Peak Load (lbs)	Break Load (lbs)	Elongation at Break (in)	% Strain at Auto, Break (%)	Displacement at Thresh Yield (in)
1	124.8	124.8	5.270	1054.0	.4777
2	123.2	123.0	5.220	1044.0	.4784
3	119.7	119.7	5.040	1008.0	.4683
4	111.4	111.4	4.770	954.0	.4659
5	122.8	122.5	5.110	1022.0	.4691
6	119.5	119.3	4.990	998.0	.4656
7	117.1	117.0	4.920	984.0	.4822
8	118.6	118.4	5.020	1004.0	.4786
9	118.2	118.2	4.950	990.0	.4822
Mean:	119.5	119.4	5.032	1006.0	.4742
Standard Derivation:	4.0	3.9	.153	30.7	.0069
Minimum:	111.4	111.4	4.770	954.0	.4656
Maximum:	124.8	124.8	5.270	1054.0	.4822

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TABLE 20**Hytrel® Impregnated with 2.29% dry iodine**

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Specimen Number	Peak Load (lbs)	Break Load (lbs)	Elongation at Break (in)	% Strain at Auto, Break (%)	Displacement at Thresh Yield (in)
1	110.6	110.5	5.110	1022.0	.4688
2	111.6	111.5	5.140	1028.0	.4822

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3	105.9	105.8	4.820	964.0	.4786
4	104.0	104.0	4.900	980.0	.4654
5	107.3	107.1	4.930	986.0	.4822
6	113.5	113.3	5.040	1008.0	.4825
7	103.9	103.9	4.760	952.0	.4782
8	104.5	104.5	4.870	974.0	.4822
9	113.0	113.0	5.140	1028.0	.4825
Mean:	108.3	108.2	4.968	993.6	.4781
Standard Derivation:	3.9	3.9	.144	28.8	.0065
Minimum:	103.9	103.9	4.760	952.0	.4654
Maximum:	113.5	113.3	5.140	1028.0	.4825

Based on these mechanical testing methods, iodine was found to not adversely affect the elongation at break. However, the break force decreased slightly in the 2.29% iodine caps. The inventors believe this result is possibly due to the 60° F temperature exposure during absorption.

Antibacterial Effectiveness Study:

To measure the ability of the impregnated plastic components to eliminate microorganisms, two experimental analyses were conducted. The first experiment used the impregnated caps prepared in the prior absorption study to disinfect approximately 10^5 colony forming units of *Staphylococcus aureus* bacteria.

Connecting devices were purposely contaminated with 10^5 cfu (colony forming units) of *S. aureus*. Caps impregnated with the three levels of iodine were then placed onto the connecting devices and left on for one hour. After one hour, the caps were removed and the connecting devices placed into bacteriological growth medium containing an iodine inactivating agent to halt

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any continuing bactericidal activity. The media were incubated at 35C and observed for growth of S. aureus. The results are displayed in Table 21.

Table 21

5	Test Samples	<u># samples showing total disinfection</u>
		# samples tested
	Group 1	7/7
	Group 2	7/7
	Group 3	6/7

- 10 The second experiment evaluated the antimicrobial efficacy of iodine impregnated plastic disks placed at the bottom of the caps as opposed to iodine impregnated caps. The test design was essentially the same as for impregnated caps. Test results indicated that the iodine
- 15 vapors from the disks were sufficient to disinfect the connecting devices.

- 20 It should be understood that various changes and modifications to the presently preferred embodiments described herein will be apparent to those skilled in the art. Such changes and modifications can be made without departing from the spirit and scope of the present invention and without diminishing its attendant advantages. It is therefore intended that such changes and modifications be covered by the appended claims.

**WE CLAIM:**

1. An antimicrobial material comprising:
a plastic material; and
a molecular halogen entrapped within the plastic
5 material, the molecular halogen not being complexed with
the plastic material.
2. The antimicrobial material of Claim 1
wherein the plastic material is chosen from the group
consisting of: polyethylene; polypropylene; polystyrene;
10 copolyester; polycarbonate/polyester blend and styrene-
ethylene-butylene-styrene copolymers.
3. The antimicrobial material of Claim 1
wherein approximately 0 to 40% of the molecular halogen
is entrapped in the plastic material.
- 15 4. The antimicrobial material of Claim 1
wherein the molecular halogen is iodine.
5. The antimicrobial material of Claim 1
wherein the plastic material is shaped into a medical
apparatus.
- 20 6. The antimicrobial material of Claim 1
wherein the molecular halogen is partially complexed with
the plastic material.
7. A dialysis connector cap for use in
dialysis comprising:
25 a plastic material; and
a molecular halogen entrapped within the plastic
material.
8. The connector cap of Claim 7 wherein the
plastic material is chosen from the group consisting of:
30 polyethylene; polyurethane; polypropylene; polystyrene;
copolyester; polycarbonate/polyester blend and styrene-
ethylene-butylene-styrene copolymers.

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9. The connector cap of Claim 7 wherein approximately 0 to 40% of the molecular halogen is entrapped in the plastic material.

5 10. The connector cap of Claim 7 wherein the molecular halogen is iodine.

11. The connector cap of Claim 7 wherein the connector is used in dialysis.

12. A directional release material comprising:

10 a first plastic material having impregnated therein a halogen, the first plastic material and the halogen defining an outer surface having a first release rate for the halogen;

15 a second plastic material having impregnated therein the halogen, the second plastic material and the halogen defining an inner surface having a second release rate for the halogen, the second release rate being faster than the first release rate to achieve directional release of the halogen.

20 13. The directional release material of Claim 12 wherein the first and the second plastic material are each chosen from the group consisting of: polyethylene; polyurethane; polypropylene; polystyrene; copolyester; polycarbonate/polyester blend and styrene-ethylene-butylene-styrene copolymers.

25 14. The directional release material of Claim 12 wherein approximately 0 to 40% of the halogen is impregnated in each of the first and the second plastic material.

30 15. The directional release material of Claim 12 wherein the halogen is iodine.

16. A method for making a disinfectant material comprising the step of contacting a plastic material with



a halogen gas, the halogen gas absorbing in the plastic material.

17. The method of Claim 16 further defined by contacting the plastic material with an elemental halogen, the elemental halogen subliming into a halogen gas that absorbs in the plastic material.

18. The method of Claim 16 wherein the plastic material is chosen from the group consisting of: polyethylene; polyurethane; polypropylene; polystyrene; copolyester; polycarbonate/polyester blend and styrene-ethylene-butylene-styrene copolymers.

19. The method of Claim 16 wherein approximately 0 to 40% of the halogen gas is absorbed in the plastic material.

20. The method of Claim 16 wherein the halogen gas is iodine.

21. The method of Claim 16 further comprising the step of controlling a rate at which the halogen gas diffuses from the plastic material.

22. The method of Claim 16 further comprising the step of forming the plastic material into a medical apparatus.

23. A method for impregnating a plastic material comprising the steps of:

delivering iodine crystals in an enclosed vessel; and

placing the plastic material in the enclosed vessel for a time sufficient to allow iodine to absorb into the plastic material.

24. The method of Claim 23 further comprising the step of delivering dry iodine crystals in the enclosed vessel.

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25. The method of Claim 23 further comprising the steps of:

delivering a solution of elemental iodine in the enclosed vessel; and

5 allowing solution to evaporate to form iodine crystals.

26. The method of Claim 23 wherein the enclosed vessel is a dialysis connector and cap.

27. The method of Claim 23 wherein the plastic
10 material is a plastic disk.

28. A method of impregnating a plastic disk for use in a peritoneal dialysis connector comprising the steps of:

delivering iodine crystals in a cap for the
15 peritoneal dialysis connector;

placing the plastic disk over the iodine crystals in the cap; and

securing the cap on the peritoneal dialysis connector.

20 29. The method of Claim 28 further comprising the step of delivering dry iodine crystals in the cap.

30. The method of Claim 28 further comprising the steps of:

delivering a solution of elemental iodine in the
25 cap; and

allowing solution to evaporate to form iodine crystals.