THERMALLY CONDUCTIVE RESIN ARTICLE FOR FOOD CONTACT AND FOOD PROCESSING AND METHOD FOR MANUFACTURING SAME

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ABSTRACT
A method of making a net-shape molded article for use with food processing and food contact is disclosed. The article is made from a molten resin including a polypropylene base matrix loaded with a thermally conductive filler such that the molten resin has a thermal conductivity between about 1.0 W/mK and about 20 W/mK when fully set. The molten resin is formed into an article, such as a food tray, using injection molding techniques. Preferably, the thermally conductive material includes hexagonal boron nitride and natural graphite.
THERMALLY CONDUCTIVE RESIN ARTICLE FOR FOOD CONTACT AND FOOD PROCESSING AND METHOD FOR MANUFACTURING SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims priority to earlier filed U.S. Provisional Patent Application No. 60/725,211, filed Oct. 11, 2005, the contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention is related generally to thermally conductive resins and in particular to a thermally conductive resin for use in contact with food and food processing.

[0004] 2. Background of the Related Art

[0005] In the food packaging, preparation and processing industries it is desirable to prepare or process certain food products by applying heat to the food product or by chilling or freezing the food product. For instance, to freeze dry foods the frozen water contained within the food product must be sublimed in order to preserve the food product. This process necessarily involves applying heat to the food product while it is in a partial vacuum. To mold other food products, such as chocolate, ice cream, candies and even ice cubes, the food product, while in a liquid or semi-liquid state, is poured into a mold and chilled or frozen until it condenses into a solid.

[0006] During these chilling or heating processes, whatever container the food product is being held within is also necessarily heated or chilled. If the container has a low thermal conductivity it resists the change in temperature and thereby requires more energy and time to prepare the food product. Therefore, it would be advantageous to have a container made of a material that has a high thermal conductivity in order to reduce the time and energy consumption of the chilling or heating processes being applied to certain food products.

[0007] Because of safety concerns and regulatory restrictions regarding food products, it is also desirable that thermally conductive materials that are used in close proximity or contact with food products are safe and suitable for such use. Thermally conductive materials that might be candidates for use in food processing applications, such as aluminum, aluminum oxide, aluminum nitride, beryllium oxide and copper, suffer from the disadvantage of being unsuitable for food processing applications because of their chemical composition, ability to transfer contaminants, or the product form. Therefore, there is a need for a thermally conductive material that is suitable for use in close proximity or contact with food products.

SUMMARY OF THE INVENTION

[0008] The present invention solves the problems of the prior art by providing a thermally conductive resin that is safe to use with food processing applications. The thermally conductive resin of the present invention is composed of polypropylene with a thermoplastic additive that includes natural graphite and hexagonal boron nitride. The thermal conductivity of the resin is between about 1.0 W/mK and 20 W/mK when fully set, and more preferably between about 2.0 W/mK and 10 W/mK to have improved mechanical properties. Also, a method of making a net-shape molded article for use with food processing and food contact is disclosed.

[0009] Accordingly, among the objects of the present invention is the provision for a thermally conductive resin that can be used in food processing and food contact.

[0010] Another object of the present invention is the provision for a thermally conductive resin that exhibits sufficient mechanical strength.

[0011] Another object of the present invention is the provision for a thermally conductive resin that can be formed into an article for use as a food mold that has good mold-release characteristics.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] These and other features, aspects, and advantages of the present invention will become better understood with reference to the following description, appended claims, and accompanying drawings where:

[0013] FIG. 1 is a perspective view of an exemplary food tray that can be constructed using the resin of the present invention;

[0014] FIG. 2 is a side view of the food tray shown in FIG. 1; and

[0015] FIG. 3 is a bottom view of the food tray shown in FIG. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0016] Thermally conductive molding compounds based on polypropylene with specific constituents impart thermally conductivity have been found to be sufficiently thermally conductive and have the appropriate food contact requirements that allow them to be broadly used in the food processing industries as food molds, trays and other components that come in direct contact with foods and consumable water or water products.

[0017] For example, FIG. 1 shows perspective view of a food tray that can be constructed using the resin of the present invention generally at 10. The food tray 10 has a tray body with a food holding portion formed by a bottom wall 12 and bounded by sidewalls 14. Optional handles 16, 18 can be formed to ease handling of the tray 10. The tray 10 shown is by example only and one skilled in the art would appreciate the fact that other trays having multiple wells and other food handling implements could be formed using the resin of the present invention.

[0018] Referring now to FIGS. 2 and 3, the food tray 10 has an underside 20 with a number of surface area enhancements 22 to improve the thermal conductivity of the food tray 10. Although the surface area enhancements 22 shown are a number of space-apart parallel grooves, one skilled in the art could appreciate that other configurations are possible.
Polypropylene has been found to be the most suitable thermoplastic base resin in these uses because it provides:

- a composition that can be food approved;
- a tensile and flex modulus that is appropriate so that in combination with thermally conductive additives provides a final part that has sufficient mechanical properties including impact strength; and
- forms a resin rich layer at the molded surface that contributes to good release and other properties.

Although polypropylene is preferred, other polymers may be used such as polyethylene, polyethylene terephthalate, and liquid crystal polymers to name a few. Polypropylene is more advantageous, however, because it retains flexibility where other polymers are too rigid. For example, fins could be used as well. To maximize the thermal conductivity of the food tray, it is desirable that the surface area enhancements are pronounced to maximize the surface area of the underside of the food tray.

Additives that have been found to be suitable for providing the thermal conductivity enhancement to the thermoplastic composition of the invention include: 1) natural graphite and 2) hexagonal boron nitride. These materials add suitable thermal conductivity enhancement and are capable of passing food contact regulations when compounded with specific polypropylene materials. Natural graphite is preferred to synthetic graphites since synthetic graphites start as lower molecular weight organics that may include restricted compounds that form during their high temperature processing (e.g., PNA). Natural graphites do not contain these compounds. Hexagonal boron nitride is a synthetic material but the boron nitride itself and impurities resulting from the synthetic process do not contain regulated ingredients. The majority of materials that might be considered for enhancing the thermal conductivity of a resin to the level required for suitable heat transfer in food applications are not suitable for food contact due to their chemical composition, contaminants, or product form (e.g., aluminum, aluminum oxide, beryllium oxide, aluminum nitride, and copper).

The suitable conductivity range of the invention for the intended use is approximately 1.0 W/mK to 20 W/mK, and most optimally in the range of approximately 2.0 W/mK to 10 W/mK. The suitable level of additive in the polypropylene compositions is 10-70 weight % and more preferably 20-50 weight %. Loading as low as between 5 and 10 weight % of the additive can be used if conductivity of 1.0 W/mK threshold is desired.

Low loading levels may be desirable where self-heating properties induced by microwave ovens is desired. In this case, graphite is preferably used as the thermally conductive additive.

The compositions and preferred compositions have also been discovered to have other properties required in food processing including but not limited to: 1) release characteristics; 2) sufficient mechanical properties throughout a temperature range from -40° C. to near 100° C.; 3) resistance to detergents and other cleaning agents; 4) resistance to cooling/heating fluids.

Therefore, it can be seen that the present invention provides a unique solution to the problem of providing a thermally conductive molding compound that can be used safely in the food preparation industries.

It would be appreciated by those skilled in the art that various changes and modifications can be made to the illustrated embodiments without departing from the spirit of the present invention. All such modifications and changes are intended to be within the scope of the present invention except insofar as limited by the appended claims.

Examples using natural graphite additive and a polypropylene base:

<table>
<thead>
<tr>
<th>% nat. graphite/remainder polypropylene</th>
<th>W/mK</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>18</td>
</tr>
<tr>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>30</td>
<td>3</td>
</tr>
<tr>
<td>25</td>
<td>5</td>
</tr>
<tr>
<td>15</td>
<td>2</td>
</tr>
</tbody>
</table>

Note: depending on the type of natural graphite, different thermal conductivities may be obtained.

Examples using Boron Nitride as an additive and polypropylene as a base:

<table>
<thead>
<tr>
<th>% BN/remainder polypropylene</th>
<th>W/mK</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>5.8</td>
</tr>
<tr>
<td>60</td>
<td>4.5</td>
</tr>
<tr>
<td>25</td>
<td>1.3</td>
</tr>
<tr>
<td>15</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Comparative examples using Alumina as an additive and polypropylene as a base:

<table>
<thead>
<tr>
<th>% Alumina (Al2O3)/remainder polypropylene</th>
<th>W/mK</th>
</tr>
</thead>
<tbody>
<tr>
<td>65</td>
<td>1.2</td>
</tr>
<tr>
<td>65</td>
<td>1.2</td>
</tr>
<tr>
<td>60</td>
<td>NA</td>
</tr>
<tr>
<td>25</td>
<td>NA</td>
</tr>
</tbody>
</table>

What is claimed is:

1. A thermally conductive resin for use with food processing and food contact, consisting essentially of:
   - a polypropylene base matrix;
   - a thermally conductive filler loaded into the polypropylene base matrix;
   - said resin having a thermal conductivity between about 1.0 W/mK and about 20 W/mK.
2. The resin of claim 1, wherein said thermally conductive filler comprises a mixture of hBN and natural graphite.

3. The resin of claim 1, wherein said resin had a thermal conductivity between about 2.0 W/mK and about 10 W/mK.

4. The resin of claim 1, wherein said thermally conductive filler comprises about 5 to about 70 weight percent of said resin.

5. The resin of claim 1, wherein said thermally conductive filler comprises about 20 to about 50 weight percent of said resin.

6. A thermally conductive food tray, comprising:
   a tray body having a bottom wall bounded by at least one side wall defining a food containing portion therein;
   said tray body, net-shape molded from a resin, consisting essentially of:
   a polypropylene base matrix;
   a thermally conductive filler loaded into the polypropylene base matrix;
   said resin having a thermal conductivity between about 1.0 W/mK and about 20 W/mK.

7. The tray of claim 6, wherein said thermally conductive filler comprises a mixture of hBN and natural graphite.

8. The tray of claim 6, wherein said resin had a thermal conductivity between about 2.0 W/mK and about 10 W/mK.

9. The tray of claim 6, wherein said thermally conductive filler comprises about 5 to about 70 weight percent of said resin.

10. The tray of claim 6, wherein said thermally conductive filler comprises about 20 to about 50 weight percent of said resin.

11. The tray of claim 6, further comprising a plurality of surface area enhancements.

12. The tray of claim 11, where said plurality of surface area enhancements are a number of spaced-apart parallel grooves.

13. A method of making a net-shape molded article for use with food processing and food contact, comprising the steps of:
   providing a mold press having a mold cavity;
   providing a molten resin consisting essentially of
   a polypropylene base matrix; and
   a thermally conductive filler loaded into the polypropylene base matrix;
   said molten resin having a thermal conductivity between about 1.0 W/mK and about 20 W/mK when fully set;
   and
   injecting said molten resin into the mold cavity of the mold press to form said net-shape molded article.

14. The method of claim 13, wherein said thermally conductive filler comprises a mixture of hBN and natural graphite.

15. The method of claim 13, wherein said resin had a thermal conductivity between about 2.0 W/mK and about 10 W/mK.

16. The method of claim 13, wherein said thermally conductive filler comprises about 5 to about 70 weight percent of said resin.

17. The method of claim 13, wherein said thermally conductive filler comprises about 20 to about 50 weight percent of said resin.

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