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(72) Inventor: NONNEMACHER, Gail, S.; 197 Highmeadow Drive, Gahanna, OH 43230 (US).


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(54) Title: THIN POLYSTYRENE FILMS CONTAINING POST-CONSUMER RECYCLED POLYSTYRENE

(57) Abstract

Thin, substantially clear, oriented polystyrene films containing post-consumer recycled polystyrene and possessing physical properties substantially similar to that of polystyrene films not containing post-consumer recycled polystyrene. Films of the present invention may comprise up to 100 percent post-consumer recycled polystyrene and are useful as window envelope films.
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THIN POLYSTYRENE FILMS
CONTAINING POST-CONSUMER RECYCLED POLYSTYRENE

This invention relates to thin, substantially clear, oriented polystyrene films containing post-consumer recycled polystyrene. More specifically, this invention relates to such films that can be useful as window envelope films.

A window envelope is an envelope with one or more openings of any shape, usually rectangular, which allows examination of any information, typically a name and an address, printed on a limited area of matter within the envelope. The opening or openings in the envelope are sealed or closed by a window patch composed of a substantially clear film, typically polystyrene. Patching is the process in which window envelope film is cut into patches of a desired length and width, and applied to the window envelope.

Window envelope films are typically composed primarily of extruded polystyrene and, optionally, contain a small proportion of a rubber-modified polymer, such as high-impact polystyrene ("HIPS"), to add a cosmetically desirable haze or measure of translucency to the film. Window envelope film may be manufactured in biaxial or uniaxial orientations. Biaxial orientation is generally preferred because of the superior cutability of the film in the transverse or cross machine direction.

For environmental reasons, it has become increasingly important to reduce the volume of plastics which are landfilled. To reduce this volume of landfilled plastics, many efforts have been made to utilize post-consumer recycled plastic in various products. However, efforts to utilize post-consumer recycled polystyrene in thin, substantially clear, oriented polystyrene films has proven difficult. Accordingly, there still exists a need in industry to utilize post-consumer recycled polystyrene in thin, substantially clear, oriented polystyrene films, including window envelope films.
The present invention provides thin, substantially clear, oriented polystyrene films containing post-consumer recycled polystyrene and possessing physical properties substantially similar to that of polystyrene films not containing post-consumer recycled polystyrene. Films of the present invention may comprise up to 100 percent post-consumer recycled polystyrene.

Films of the present invention are generally at least about 0.25 mils (6.35 microns), and preferably at least about 0.75 mils (19.05 microns) thick. Films of the present invention are generally not more than about 7 mils (177.8 microns), preferably not more than about 4 mils (101.6 microns), and more preferably not more than about 2.5 mils (63.5 microns) thick.

Films of the present invention are either uniaxially or biaxially oriented. Preferably, films of the present invention are biaxially oriented.

Films of the present invention generally are composed primarily of extruded polystyrene. The films may contain small amounts of an antiflecking agent and an acid scavenger such as taught in U.S. Patent Nos. 5,009,953 and 5,190,814. The films may also contain a small proportion of a hazing agent, such as high-impact polystyrene ("HIPS") for example, to add a cosmetically desirable haze or measure of translucency to the film. A preferred HIPS useful as a hazing agent is STYRON 404 (available from The Dow Chemical Company).

The extruded polystyrene useful in making films of the present invention may contain up to 100 percent by weight of post-consumer recycled polystyrene. The post-consumer recycled polystyrene meets the definition of post-consumer materials given in ASTM D5033-90. The extruded polystyrene useful in the present invention may also contain general purpose polystyrene. The particular general purpose polystyrene is not especially critical. However, one preferred general purpose polystyrene is STYRON 665 (available from The Dow Chemical Company). The extruded polystyrene useful in the present invention may also contain in-plant scrap from films of the present invention.
Typically, the extruded polystyrene is a blend of general purpose polystyrene, scrap from films of the present invention, and post-consumer recycled polystyrene.

The post-consumer recycled polystyrene useful in the present invention must be substantially free of particulates such as paper fibers, rubber bands, and crosslinked gels in order to prevent agglomerates or holes in the film upon orientation. A Soxhlet extraction technique was used to test the amounts of particulates in various samples of post-consumer recycled polystyrene. This Soxhlet extraction technique used a 10 micron filtration process with toluene as the solvent. Using the Soxhlet extraction, each sample of post-consumer recycled polystyrene was weighed and then dissolved in toluene. The dissolved sample was filtered using the 10 micron filtration process and any nonsoluble solid particulates recovered by the filtration process was weighed. The weight of the filtered particulates was divided by the weight of the original sample to determine the weight percent of particulates in the original sample. Generally, post-consumer recycled polystyrene useful in the present invention should have less than about 0.1 percent by weight particulates as measured by this Soxhlet extraction technique. Preferably, the post-consumer recycled polystyrene will contain no detectable amount of particulates as measured via this Soxhlet extraction technique.

The post-consumer recycled polystyrene must also be substantially free of contamination with other types of polymers such as polypropylene and polyethylene in order to avoid melt incompatibility. Melt incompatibility can result in a mottled film surface. Preferably, the post-consumer recycled polystyrene materials would indicate only one glass transition temperature at about 100°C when analyzed via digital scanning calorimetry using the method cited in ASTM D-3418.

The post-consumer recycled polystyrene should be substantially clear in order to produce good optical clarity in the resulting film. The post-consumer recycled polystyrene must be substantially free of inks, food oils, and other pigmented
contaminants. Plaques made from post-consumer recycled polystyrene pressed on a platen press at 400°F (204.4°C) to a thickness of approximately 0.10 inches (0.254 cm) should have less than 20 percent haze as measured by ASTM D-1003.

Preferably, the post-consumer recycled polystyrene useful in the present invention would be recycled from clear, injection molded or thermoformed polystyrene parts. More preferably, the recycled polystyrene materials would be sourced from compact disc jewel boxes, compact disc jewel box clear inserts, audio tape boxes, cookie trays, or berry boxes.

Calcium carbonate is an undesirable contaminant sometimes found in post-consumer recycled polystyrene. Sources of post-consumer recycled polystyrene containing less calcium carbonate are preferable for use in the present invention. Although the upper limit of calcium carbonate acceptable in post-consumer recycled polystyrene used in the present invention is not precisely known, post-consumer recycled polystyrene having amounts of calcium carbonate as high as 575 ppm have been successfully incorporated into films of the present invention. The amount of calcium carbonate acceptable may depend on the percent of post-consumer polystyrene used and the particular end-use of the film produced. This amount should be determinable without undue experimentation.

Films of the present invention can be made by any technique known in the art. More specifically, films of the present invention can be oriented by any technique known in the art. However, when processing resin containing post-consumer recycled polystyrene to manufacture films of the present invention, it may be necessary to make minor adjustments to the melt temperature in order to maintain the orientation levels one would get when similarly processing resin containing no post-consumer recycled polystyrene. These adjustments generally result in a decrease of up to about 10°C in melt temperature. The level of adjustment in melt temperature needed to maintain a given level of orientation may depend on the source and amount
of post-consumer recycled polystyrene. However, this level of adjustment can be determined without undue experimentation.

A number of post-consumer recycled polystyrene sources proved difficult or impossible to process into thin, oriented films. For example, resin from recycled foamed cups and foam sheet food-service container (SP-012 available from Dart Container Corporation) contained many large gels clearly visible to the unaided eye. During processing of SP-012 significant extruder surging was observed, apparently due to inconsistent resin pellet size.

Another source of post-consumer recycled polystyrene tested was PC-1000 (available from the National Polystyrene Recycling Company). PC-1000 is produced from food-service containers and serviceware (trays and plates). The Soxhlet extraction test showed that PC-1000 contained approximately 1.7 percent by weight of particulates.

An attempt was made to process a resin containing 65.75 percent by weight of general purpose polystyrene (STYRON-665), 25 percent by weight of PC-1000, 8 percent by weight high-impact polystyrene (STYRON 404), and 1.25 percent CN-201 (available from Polycom Huntsman) into a .2 mil (130.48 micron), biaxially oriented film. However, the film web broke about every 20 to 45 minutes, making it difficult to collect samples. CN-201 is a pre-compounded blend of 20 percent by weight polytetrafluoroethylene, 1 percent by weight calcium stearate, and 79 percent by weight STYRON 665.

The National Polystyrene Recycling Company produces another source of post-consumer recycled polystyrene: PC-1000D. PC-1000D is recycled food-service waste from the Los Angeles school system. This source of post-consumer recycled polystyrene is lower in contaminants than PC-1000 due to tighter source controls. Analyzed lots of PC-1000D showed between 0.1 percent and 1.6 percent insolubles via Soxhlet extraction.

An attempt was made to produce a biaxially oriented film from the resin above except the 25 percent by weight of PC-1000
was replaced with 25 percent by weight of PC-1000D. However, the film web broke approximately every 30 minutes. This is a clear indication that even contamination levels as low as 0.1 percent (as measured by Soxhlet extraction) present significant processing problems.

**Examples**

Five separate biaxially oriented films were produced: a control sample, two comparative samples, and two examples of the present invention. The thickness of each film was 1.2 mils (30.48 microns).

The control film contained 95 percent by weight of general purpose polystyrene (STYRON 665) and 5 percent by weight of high-impact polystyrene (STYRON 404). Each of the other four films had enough general purpose polystyrene displaced with post-consumer recycled polystyrene so that each of the other four films contained 25 percent by weight of post-consumer recycled polystyrene.

Comparative Samples #1 and #2 respectively contained 25 percent by weight of PC-1000 and PC-1000D. Example #1 contained 25 percent by weight of PC-4000 (available from the National Polystyrene Recycling Company). Example #2 contained 25 percent by weight of PCR-100 (available from Plastic Recycling, Inc.).

The source of the post-consumer recycled polystyrene in PC-1000 and PC-1000D has already been discussed. The source of post-consumer recycled polystyrene in PC-4000 is recycled compact disc jewel boxes and thermoformed polystyrene cookie trays. The source of post-consumer recycled polystyrene in PCR-100 is recycled compact disc jewel boxes. For both PC-4000 and PCR-100 the amount of particulates present as measured by the Soxhlet extraction test was too small to be detectable.
Each of the five films were tested for haze via ASTM D-1003; 60 degree Gloss, Outside, machine direction; via ASTM D-2457; ultimate tensile, machine direction, via ASTM D-882; and ultimate elongation, machine direction, via ASTM D-882. The results of these tests are shown in Table I.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>25 percent PC-1000</th>
<th>25 percent PC-1000</th>
<th>25 percent PC-4000</th>
<th>25 percent PCR-100</th>
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</thead>
<tbody>
<tr>
<td>Haze (percent)</td>
<td>4.56</td>
<td>24.3</td>
<td>9.22</td>
<td>4.41</td>
<td>3.30</td>
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<td>60 degree Gloss, (percent)</td>
<td>127</td>
<td>84</td>
<td>129</td>
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<tr>
<td>Ultimate Tensile, (psi)</td>
<td>13082</td>
<td>9146</td>
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<td>12894</td>
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<tr>
<td>Ultimate Elongation, (percent)</td>
<td>45</td>
<td>6.2</td>
<td>4.4</td>
<td>46</td>
<td>51</td>
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</table>

Films of the present invention have been successfully used as window envelope films. One such window envelope film contained 49 percent by weight of STYRON 665, 35 percent by weight PCR-100, 5 percent by weight STYRON 404, and 1% by weight CN-201. The film had a thickness of 1.2 mils (30.48 microns). This film was successfully tested on an F.L. Smithe High Speed Patcher at 800 patches per minute and 7 inches (17.78 cm) Hg vacuum for 4000 feet.

Another window envelope film successfully tested contained 35 percent by weight PCR-100, 34 percent by weight STYRON 665, 15 percent by weight in-plant recycled film, 15 percent STYRON 404, 0.8 percent calcium stearate, and 0.2 percent polytetrafluoroethylene (MP1100 available from DuPont). This film had a thickness of 1.2 mils (30.48 microns).
WHAT IS CLAIMED IS:

1. A film, consisting essentially of polystyrene, wherein the thickness of the film is less than about 7 mils (177.8 microns), wherein the film is either uniaxially or biaxially oriented, and wherein said polystyrene comprises post-consumer recycled polystyrene as defined by ASTM 5033-90.

2. A film according to Claim 1, wherein the post-consumer recycled polystyrene comprises recycled compact disc jewel boxes or recycled polystyrene cookie trays.

3. A film according to Claim 1, wherein the thickness of the film is less than about 4 mils (101.6 microns).

4. A film according to Claim 1, wherein the thickness of the film is less than about 2.5 mils (63.5 microns).

5. A film according to Claim 1, wherein the thickness of the film is about 1.2 mils (30.48 microns).
# INTERNATIONAL SEARCH REPORT

**INTERNATIONAL APPLICATION NO.**
PCT/US 96/13848

## A. CLASSIFICATION OF SUBJECT MATTER

**IPC6:** C08J 5/18, C08L 25/06
According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

**IPC6:** C08J, C08L, B65D

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

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

**WPI, EPDOC**

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tr>
<td>A</td>
<td>Research Disclosure, Volume 431, June 1993, Harvey C. Tung et al, &quot;Film For Producing Recyclable Polystyrene-based Trash Bags&quot;</td>
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<td>P, A</td>
<td>EP, A1, 711797 (BASF AKTIENGESELLSCHAFT), 15 May 1996 (15.05.96)</td>
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<td>A</td>
<td>EP, A1, 353513 (THE DOW CHEMICAL COMPANY), 7 February 1990 (07.02.90)</td>
<td>1-5</td>
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Further documents are listed in the continuation of Box C. **X** See patent family annex.

- **A** document defining the general state of the art which is not considered to be of particular relevance
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**Name and mailing address of the ISA/Authorized officer**

European Patent Office, P.B. 5818 Patentiaan 2  
N1-2280 HV Rijswijk  
Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+ 31-70) 340-3016  

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