Innovations in Recycled Expanded Polystyrene Foam for Use in Electronic Protective Packaging

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Abstract

This report presents a non-proprietary overview of the principals and processes in which expanded polystyrene (EPS) can be reprocessed into a raw pentane impregnated resin; suitable for reintroduction into a finished product in heavy electronic packaging.

The information in this report reflects my research during an engineering internship with a major electronics manufacturer and one of their key suppliers where data was compiled on the processes and related manufacturing variables over the past few years. In light of this, references that could reveal proprietary or intellectual property have been omitted to protect these companies.

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Introduction

In recent times, cities across the world have begun banning packaging materials from being used and brought into city limits. This strong push for environmental protection has been demanded with little regard to the performance of the alternative packaging methods that are considered environmental friendly. Currently no “green” alternative packaging methods have proven adequate for packaging large and heavy electronics that require the utmost protection. In response to these pressures and a heightened environmental consciousness, some key large electronics companies have made significant inroads to develop these alternative materials and the processes associated with them.

Expanded Polystyrene (EPS) is one of the most common forms of packaging and cushioning material used today. According to the U.S. Post-Consumer & Post Commercial EPS Recycling Collection Data, in 2006 166 million pounds of EPS was sold domestically; of this only 32 million pounds (19.3%) was recycled (3). In its solid form polystyrene is one of the densest plastics (~1050kg/m^3), but when expanded in foam form, EPS is approximately 96% air. These lightweight, but large volumes of materials fill our landfills and do not degrade. Though EPS does not leech or pose toxic dangers like many other materials, the volume used in land fills by EPS are a reason for receiving a bad name as a large scale polluter in our environment. This bad reputation brought political turmoil in the early 1990's causing many regions in the world to place a ban on this material while industry was pushed into alternative materials or processes for packaging.

Modern EPS Recycling Practices

The current state of EPS recycling is limited to large uncontaminated blocks of foam (1)(5)(6). This foam is ground, re-heated or degraded using a de-polymerizing agent. There are very few post consumer recycling programs for EPS, but post industry recycling is very common.

Re-Grinding

The most common recycling method is to re-grind EPS. This re-grind is then reintroduced into the machine hopper during molding production. The re-grind acts as dead filler in molds with the setback that it weakens the cushion. In thinner cushioned packaging, or packaging for heavier products requiring structural strength, only 5-10% of the volume can be added because it weakens the structure of the cushion. Re-ground EPS is also used as an aggregate in insulation and moderate strength lightweight concretes. This "Group 1" classification of concrete is made for use as fill in thermal and sound insulating floors, walls, and roofs.(8)

Re-Melting

Expanded Polystyrene that has been re-melted or de-polymerized traditionally is used in consumer products in solid form as it is difficult to re-introduce pentane to the polymer. In the re-melt process EPS is ground, melted and sent through a contamination filter where it then has the ability to be mixed with additives, colorants and virgin material for use in solid products.

De-Polymerization

The use of de-polymerization is also on the cutting edge. By using ionic liquids or a terpene hydrocarbon such as d-limonene, an orange byproduct, EPS can be degraded. The resulting polystyrene gel can then be separated from the solvent and be mixed with other additives and materials. This has a large advantage over re-melting as its process produces 30% less CO_2 emissions and consumes 20% less energy while achieving the same goal. (2)(4)(7)

Recycled EPS Resin Manufacturing Process

Material Preparation:

The process of returning scrap EPS into a pentane re-impregnated resin, begins at its recovery. Only EPS that is clean of dust, debris, tape, labels, corrugate, etc., is able to be processed. The international manufacturing facilities, where most commercial scrap is produced, assigns a worker to the re-collection stage of the processing. Before placing material into a compactor workers take each piece and carefully inspect and remove the mentioned contaminates. After the EPS is compacted, for shipping cost purposes, it is transported to the resin supplier.

Extrusion:

After arriving at the supplier the bead is melted down and passed through a contamination filter to remove any foreign particulate. It is then further compacted and heated before being rapidly face cut underwater exiting the extruder.

Pentane Impregnation:

Due to the proprietary nature of this new process and given the scope of the project, research to determine the method for impregnating the beads with pentane was not feasible. One method being pursued for enhancing the addition of pentane to the bead would be to subject the pelletized extrude to high pressures of pentane gas in a chamber until it is absorbed into the bead.

Process and Material Constraints

The process of recycling EPS back into pentane impregnated beads has been available for 5 years for use in specialty products such as bike helmets and car bumpers, but its application in heavy protective packaging has been scarce due to material availability and physical performance limitations .

Bead Shape:

The first limitation of this material is bead shape. Because the bead is pelletized by face cut extrusion, the beads are not spherical. When expanded there is void space between the fused beads, weakening the part's structure. This void can not be seen by the naked eye, but if one were to break a fused part you would notice the cell skin structure is not always fused to the nearest bead, regardless of steam time, steam pressure and machine cooling cycle. This is a direct result of bead shape.

Bead Size:

Bead size is also an issue when used in many production machines I experienced while working. The large scale production machines used for testing this material were designed for a B/C bead dimensions. The fill guns leading to the mold cavity were not large enough to support full bead flow for proper fill and fusion. To compensate for this improper flow the crack fill gap was increased. This allowed the machine to inject more beads into the part resulting in a proper fill upon full closure, while still molding within density specifications (20g/L ± 10%, 24 g/L ± 10%).

Pentane Content:

Pentane content impregnated into the beads was the largest issue in the testing trials with the recycled EPS bead. The first molding trials performed were done with a bead containing iso-pentane. Compared to n-pentane, the gas used in our virgin production run material, iso-pentane off gasses much slower when at room temperature. This increases its shelf life and stability to be stored in hotter and more humid climates without pentane loss. This constraint is unnecessary for a Fortune 500 Electronics Company that does not require material to sit for more than a week because of production demand. This pentane, though having its benefits, molds very differently requiring long cycle cooling times to prevent post expansion as excess gas is released. During testing cycle time nearly doubled. This increase was mostly due to the fact that the cooling cycle had to be extended to allow the steam to escape. The iso-pentane once molded, continued releasing gas causing post expanded parts which were unacceptable under quality standards. A move to n-pentane was made, with only minor cycle time improvements. This countermeasure is still in testing stages as this report is being written, and finalized data on its success is unavailable.

Contamination:

Like any recycled content, material color is not maintained once it is processed. The supplier producing the material usually colors their bead for specialty applications where most of their sales occur. Rarely is an uncolored bead used. When compared to virgin materials the color difference is noticeable and causes contamination issues for production molders who often pre-expand for multiple machines producing different products with the same system and lines.

Process Benefits

As in any new product development process, many issues arise before the benefits can be fully realized. Though research and development for use in electronics packaging is still in process, this resin has many improvements ranging from fiscal to environmental.

Environmentally Friendly:

As our use of EPS continues to increase and our fossil fuels decrease, a level of sustainability must be reached. For companies with large commercial intake of EPS and a need for virgin resin increases, this process can greatly reduce unneeded consumption of the virgin material. Producers of this material are capable of upwards of 80% yield during full-scale production, all of which can be turned back into product by the material donor company.

Cost Effective:

To produce this material, an influx of discarded EPS must be present to sustain production and in a relationship where the manufacturing company can supply discarded EPS, a large decrease in material costs appears. Companies supplying material realize lower material and labor costs thus greatly reducing their resin material costs and ultimately making their product more cost effective.

Material Properties:

Though this material is still being adapted for short cycle time large production runs, it has been very successful in long cycle time applications where the pentane release rate is not an issue. This product's shelf life also makes it a great candidate for overseas shipping as well as small production runs where the resin consumption is much slower and the EPS is required to maintain pentane levels over a longer period of time.

Conclusion

Over the past six years the process of recycling EPS has significantly grown for less critical applications; yet its use for heavy electronics packaging where material properties and high production rates are critical is still being evaluated. Bead size, gas content and other material properties are still being optimized for this application. As these trials continue, the use of recycled content in large-scale industrial settings becomes more feasible. The benefits of using this material will not only fiscally satisfy companies but improve their image as environmentally conscious consumers and producers. Environmental protection is among our top concerns as a civilization and by progressing this process in the manufacturing setting, consumption and waste will be reduced; one more step in a positive direction.

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