Electronics Recycling

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Introduction

Almost 100 billion pounds of plastics are produced in the U.S. each year, and these include such common materials as polyethylene, polypropylene, polystyrene and PVC; these are routinely turned into fibers, films, tubing, containers, and molded articles. From the viewpoint of both energy and resource conservation and environmental protection, it is desirable to recycle and reuse as much of the plastic as possible. Indeed, there have been large programs directed at recycling nylon carpet fibers, polyethylene milk jugs and PET beverage bottles. However, these efforts are hampered by the low resale value and poor quality of the recycled materials, especially in an environment where high-quality virgin polymers are freely available at lower cost. It is, therefore, logical to blend recovered plastics with virgin plastics, but it should be noted that for a material to be termed “green” it must have a reasonably high recycle content. Additionally, any material must satisfy all performance requirements for the intended application.

In this research, we have focused on recycling plastics used in electronic applications such as computer and printer housings. There are two reasons for this choice: (i) Computers are discarded after only three or four years of use, and a large amount of plastic is likely to end-up in landfills; this material may have to be treated as hazardous waste due to contamination with mercury and lead that are found in computers and computer monitors. (ii) The plastics used in electronic applications are polymers such as acrylonitrile-butadiene-styrene (ABS), polycarbonate (PC) and their blends, and these are relatively expensive polymers. Attempting to recover and reuse ABS and PC is economically less challenging than recycling polyethylene and polypropylene. A total of about 150 million pounds of such plastic goes into electronic applications each year.

Objective

The key challenge in recycling polymers used in computers is that a given computer housing contains more than one kind of plastic. Also, different computer makers do not use the same polymer for the same application; the choice typically depends on the price and performance behavior of an available polymer. The result is that a facility built to recycle electronic polymers has to deal with mixed polymer waste. Unfortunately, mixed plastics have unacceptably poor mechanical, flow and thermal properties. As a consequence, recovered (but mixed) material cannot be reused to make new computer housings. Mixed waste must be separated by chemical type before any recycling is attempted, and a relevant question is the purity level that must be achieved in such a separation process. Furthermore, the separated material has to be standardized. This is because polymers are large molecules, and there is typically a distribution in sizes in any given sample. Unless this size distribution can be kept the same, flow properties vary from batch to batch. The initial objectives of our work have, therefore, been to determine the necessary purity level of separated polymers and to come up with a strategy for standardizing the size distribution in the recovered material.

Approach

The general approach to the recycling of mixed plastics is to grind the plastic parts into small chunks, remove labels and non-plastic parts, and then to use wet processing to separate the different plastics by chemical type to different purity levels. Each of the different plastics is then melted in an extruder where it is mixed with various additives and converted into little pellets that can be processed back into moldings. The effect of purity level and the subsequent compounding operation can be assessed by measuring the mechanical, thermal and flow properties of the compounded and pelletized polymer.

Project Description

A variety of techniques, such as float-sink tanks and hydrocyclones, can be used to separate mixed plastics based on differences in density. For plastics with overlapping density, other methods, such as froth flotation, can be employed. These techniques were utilized by our previous project partners, MBA Polymers of Richmond, CA, to give us ABS and PC samples, each at three different purity levels ranging from 88% to more than 99% purity. The mechanical, thermal and flow properties of the as-received materials were measured, and these polymers were also blended with different amounts of virgin polymers of the same chemical type. The blending was done in a twin-screw extruder, and the blended and pelletized samples were also subjected to the same battery of tests. The virgin ABS and virgin PC were general-purpose polymers made by the GE Plastics Company.

In order to determine the influence of the chemical nature of the impurities, representative polymers that were likely to be found mixed with the recovered ABS were compounded with virgin ABS at the 1% impurity level; the impurities were identified to be of two different kinds: (i) thermodynamically miscible with ABS and (ii) thermodynamically immiscible with ABS. Also, the impurities could have a processing temperature that was similar to the processing temperature for ABS or dissimilar to the processing temperature for ABS. These ABS blends, containing different impurities, were characterized for their mechanical properties.

Results

At high purities, melt viscosity measurements were found to be insensitive to the purity level of the recovered polymers. In other words, material purity affected only mechanical properties, and this influence could be quite large even when the purity level was close to 99%. Furthermore, the properties that were sensitive to the purity level were primarily the impact strength (in a large strain rate experiment) and the yield strength and elongation-to-break (or ductility) in a (small strain rate) tensile test [1]. It was also found that the most damaging impurities were those that were neither miscible with the polymer of interest nor were processable with it at the same processing temperature. As opposed to this, an impurity that was miscible with the recovered plastics and which softened in the same temperature range had little effect on the mechanical properties.

Concerning the batch-to-batch variation of flow properties of the highly pure polymers obtained at the end of the separation process, it was found that this variation could be large, and it was essentially related to variations in the molecular weight and molecular weight distribution of the recovered polymers [2,3]. This variation could be masked by blending the separated plastics with virgin polymers, but no more than 15% of the recycled material could be tolerated in the blend before differences in viscosity became evident.

Application

Our research shows that in order to recycle polymers from electronic applications back into the same application, it is necessary to separate mixed plastics by chemical type. Furthermore, this separation has to be carried out a purity level of at least 99% if the separated polymer contains plastics that are incompatible with it. Even so, it is difficult to reuse this material as-is due to batch-to-batch variations in viscosity. This variation in flow properties can be eliminated by blending separated polymers with virgin polymers of the same chemical type, but the blend is limited to containing no more than about 15% recovered material. Such blend a can be reused in the original application, and this would constitute primary recycling.

Future Activities

In order to increase the recycled content of the blended polymers beyond 15%, an advanced strategy is being attempted. This involves blending the recovered and separated polymers with two virgin polymers, each having a different molecular weight distribution. This should allow for the development of a “green” product having a recycled content of at least 50%. An on-line viscometer is being purchased for this purpose so that the truth of the hypothesis can be demonstrated.

References

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