Comparison of the Recyclability of Flame-Retarded Plastics

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Mechanical recycling of plastics from waste from electrical and electronical equipment (WEEE) is increasingly expected by regulators and demanded by origina equipment manufacturers (OEMs); however, mechanical recycling is generally recognized to be the most economically costly and technically challenging method of recovering WEEE plastics. With 12% of WEEE plastics requiring the use of flame-retardants in order to ensure appropriate levels of consumer fire safety, there is a distinct need for data from comparative tests on recyclability of various flame-retarded plastics. Ten commercially available flame-retarded plastic grades commonly used in electronic equipment (eight "halogen-free" grades and two grades containing brominated flame-retardants (BFRs)) were subjected to two different recycling scenarios. A standard recycling scenario was carried out by repeatedly extruding the materials and an accelerated hydrolysis scenario was carried out to study the influence of humidity from air during use on the process. Both, virgin and recycled materials were tested for a potential formation of polybrominated dibenzodioxins/furans (PBDD/Fs), their mechanical properties were assessed and the fire safety rating was determined. Results indicate that none of the tested materials showed a potential to form the PBDD/Fs regulated by the German Chemicals Banning Ordinance. The halogen-free plastic grades showed a significant deterioration of mechanical properties after recycling, whereas those plastics containing BFRs were able to pass all test criteria, thus maintaining their original properties. With respect to the fire safety rating, none of the eight tested halogen-free plastic grades could maintain their fire safety rating after five recycling loops, whereas both BFR plastics continued to achieve their fire safety ratings. Therefore the tested BFR containing plastic materials showed superior recycling properties compared to the tested halogen-free plastic grades with respect to all investigated parameters.

1. Introduction

1.1. Need for Flame Retarded Plastics. Acrylonitrile Butadiene Styrene (ABS) is a plastic material commonly used for producing housings of IT equipment, such as video display units, laser printers, or copy machines. The inherent flammability of plastic materials constitutes a fire hazard to users and in many cases it is necessary to improve their resistance to ignition in order to comply with fire safety regulations or even to surpass them in the event they are inadequate. This is usually achieved by adding suitable flame-retardants to the plastic matrix.

The most suitable flame retardants for ABS-plastic are Tetrabromobisphenol A (TBBPA) and brominated epoxy oligomers (BEO) (*1*). In the past years new ABS applications have been developed that are based on "halogen-free" flame-retardants. These applications use a blend of ABS or High Impact Polystyrene (HIPS) with Polycarbonate (PC), called PC/ABS plastic or PC/HIPS plastic, together with halogen-free flame-retardants based on organophosphorus compounds.

In view of the growing interest in the sustainable use of resources, recyclability is becoming a more and more important criterion for consumer products. Upcoming regulations, such as the draft EU directive on waste from electrical and electronical equipment (WEEE) are setting high recycling targets for E&E waste plastics, including mechanical recycling, which is the process of collection, dismantling, sorting, grinding, granulating and extrusion or injection to make new plastic parts. The WEEE Directive (*2*) will also set targets for other modes of recycling such as energy and feedstock recovery.

In this paper we compare 8 different PC/ABS and PC/HIPS plastic grades, flame retarded with halogen-free flame retardants, and two ABS plastic grades containing brominated flame-retardants with respect to their compatibility for mechanical recycling.

1.2. Compatibility of Flame-Retarded Plastics with Mechanical Recycling. To be suitable for mechanical recycling, the plastic material has to fulfill a wide range of requirements. During the primary use (its service life) of the plastic product, the material is being exposed, among others factors, to humidity from air and to light. When the plastic material is being mechanically recycled, the material will be exposed to temperatures up to 250 °C during the processing steps, such as extrusion or injection molding. After having been exposed to all these factors, the recycled product must have properties comparable to the "virgin" material to meet the specifications required by the application. It should retain its various physical properties, still have the same color, the same fire safety rating, and should not contain toxic byproducts, such as Dioxins/Furans, above the limits set by some legislations, such as the German Chemical Banning Ordinance.

2. Materials and Methods

2.1. Tested Materials. Eight different PC/ABS and PC/HIPS plastic materials, flame-retarded with a nonhalogenated phosphate ester flame retardant and two ABS plastic materials flame-retarded with brominated flame retardants have been tested. All tested materials were commercially available, and were purchased from the Japanese plastic market. These samples represent common plastic grades used in applications for business machine enclosures. For confidentiality reasons, the different plastic grades have been assigned sample codes and the manufacturers are not disclosed. The tested materials are described in Table 1.

2.2. Recycling Experiments. The testing materials were subjected to two separate recycling scenarios: a thermal stability scenario was carried out simulating the influence of thermal stress on the plastic material properties, and a

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