Light at the End of the Tunnel

Recycling of Plastic-Metal Composite Materials from Headlights

Rarely does a single material meet all automotive engineering requirements. Yet hybrid materials cannot be disassembled manually with reasonable effort, so that production waste is only being used thermally to date. Sensor-assisted plastic sorting however promises good yields and has economic potential.

Hardly any product has undergone such an unparalleled transformation and technical progress in the last few decades as the automobile headlight. While the first headlights produced in 1908 consisted of no more than 30 components, today's models encompass 300 to 500 components – with a rising trend. This growing complexity of the components has two causes in particular: The continuous development and integration of new lighting technologies, and the use of headlights as a design element that, as an identifying feature, gives the car its "face" [1]. Improving technical polymers with various temperature and performance profiles is necessary due to the complexity of lighting and projection modules. High-performance plastics meet high functional and aesthetic standards, and can be individually adapted to the single components [2]. Although current headlight production figures are not known, they can be estimated based on correlated data such as the number of new vehicle registrations.

All process steps in production are monitored through regular quality controls and defective products are separated out directly since headlights are highly relevant for safety. In the production plants of two selected European headlight manufacturers, this results in 1100 t of mixed waste per year consisting of complex headlight modules and individual plastic components (**Fig. 1**). Recycling plastic from headlights is not realizable with adequate purity using state-of-the-art technology. They contain largely black plastic materials that cannot be separated using conventional spectroscopic sorting. Metalized reflectors and decorative trim as well as the diffusion disks with special hardening and UV coatings also constitute major challenges for monofraction sorting and realizing the existing material potential. Since suitable recycling methods are lacking, mixed production waste is currently being used thermally with costs.

Processing and Sorting

In the ForCycle project group subsidized by the Bavarian State Ministry of the Environment and Consumer Protection, the Fraunhofer Institute for Process Engineering and Packaging IVV, Freising, Germany, demonstrated that material recycling of this waste stream is possible using suitable process chains. **Figure 2** shows the process concept for the sample waste from production scrap that was studied.

An initial market analysis led to cooperation with Automotive Lighting GmbH, Reutlingen, and ZKW Lichtsysteme »

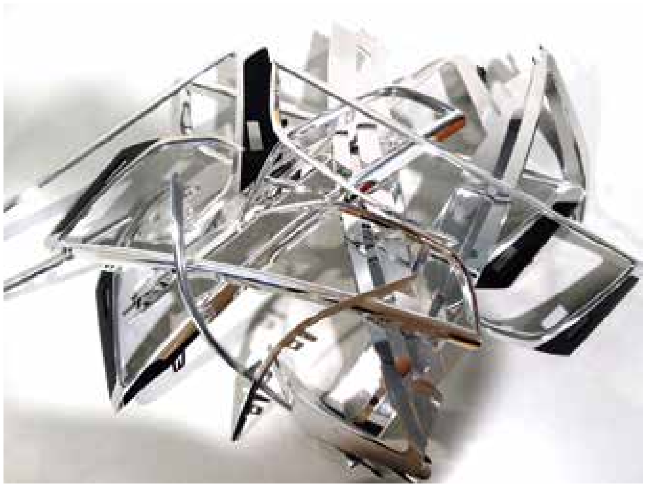

Fig. 1. Mixed waste from headlight production: fully assembled headlights (left), and aluminum-coated plastics (right) (© Fraunhofer IVV)

GmbH, Wieselburg, who have been producing headlights for decades as automobile industry suppliers. Mechanical processing of the production waste (shredding, metal extraction, screening) required for laboratory and small-scale technical testing was realized in cooperation with Erlos GmbH, Zwickau, and Bameta GmbH, Buchloe. After material disintegration, the studies focused on two project objectives: Separating the metal-plastic composites through specific analyses by Fraunhofer IVV, and the mono-fraction sorting of the remaining mixed plastic fraction using the systems of Unisensor Sensorsysteme GmbH, Karlsruhe, and RTT Steinert GmbH, Zittau. All of these companies are from Germany.

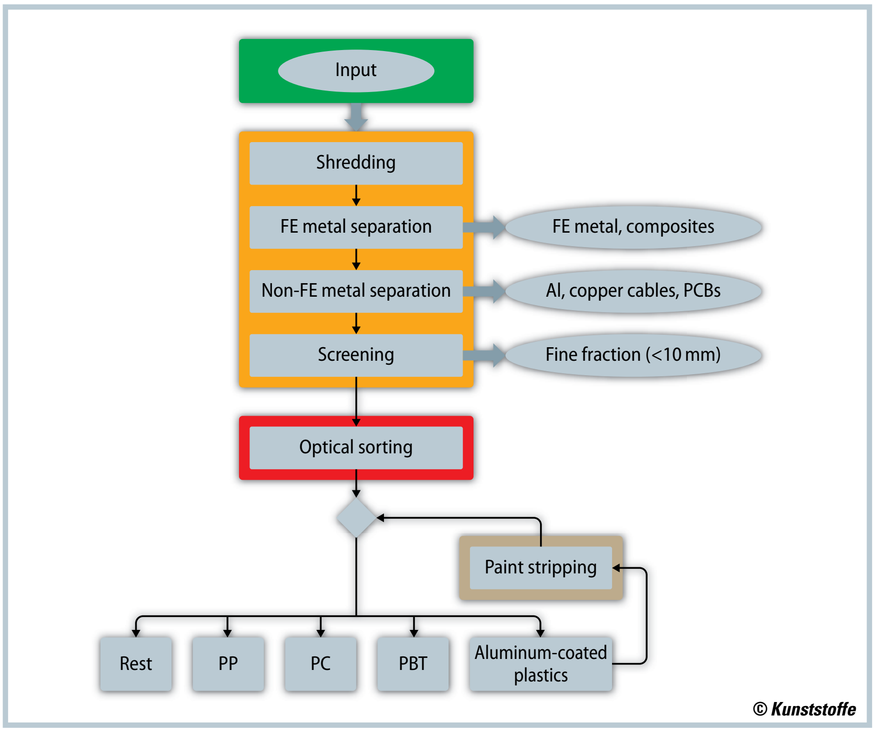

Fig. 2. Process concept in the ForCycle project group for recycling headlight production waste (source: Fraunhofer IVV)

Identifying and Separating Plastics in Headlights

Initially the main plastic materials were identified after the manual disassembly of a headlight. As shown by the mass balance in **Figure 3**, the disintegrated headlight consists of 94 % plastics, mainly polycarbonate (PC), polybutylene terephthalate (PBT), and polypropylene (PP-TV40), most of which are black in color. Aside from PC and PBT, high-temperature-resistant polycarbonate (PC-HT) and polyetherimide (PEI) were identified as aluminum-coated plastics.

Direct classification of the plastics is no longer readily possible after mechanical disintegration. However, the results of the manual analysis of several headlights show that they contain about 50 % black and 20 % metalized plastics. This coincides with the expectations of the manufacturers that use PC, PBT, and PP-TV40 as the main plastics. However, continuous changes in the mass distribution of the individual components have to be considered in a subsequent recycling process due to the variability of the headlight models and the associated different assemblies.

The aluminum coating was separated in this project by means of leaching that works faster under alkaline conditions compared to acidic solutions. The reaction of aluminum with the leachate releases the aluminum layer and exposes the plastic. **Figure 4** shows that the aluminum concentration in the plastic dropped to 5 % after one third of the total leaching time. Increasing the leachate concentration reduces the leaching time, which also depends on the chosen leaching agent, turbulence, temperature, and pressure. Qualitative analyses using Fourier Transformation Infrared Spectrometry (FTIR) and the melt flow rate (MFR) showed no influence of the leachate on the quality of the plastic. Non-destructive further processing is therefore possible.

Recycling in Small-Scale Technical Tests

To test the sortability, plastic samples from the headlight waste were systematically examined with both spectroscopic sorting methods. The aluminum coated plastics can generally be separated as a single stream by both methods. This applies correspondingly to the detection of plastics with an additional coating. Black and transparent components of the major plastic types PP, PC, and PBT can also be reliably separated into fractions with both sorting methods, but PBT detection

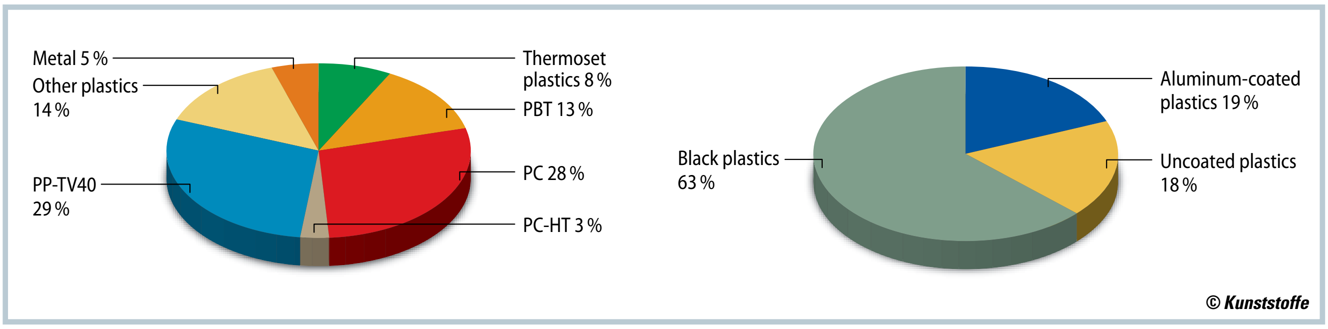

Fig. 3. Exemplary composition of a headlight in percentages by weight with differentiated examination of the combined fractions (left) and pure plastic fraction (right) (source: Fraunhofer IVV)

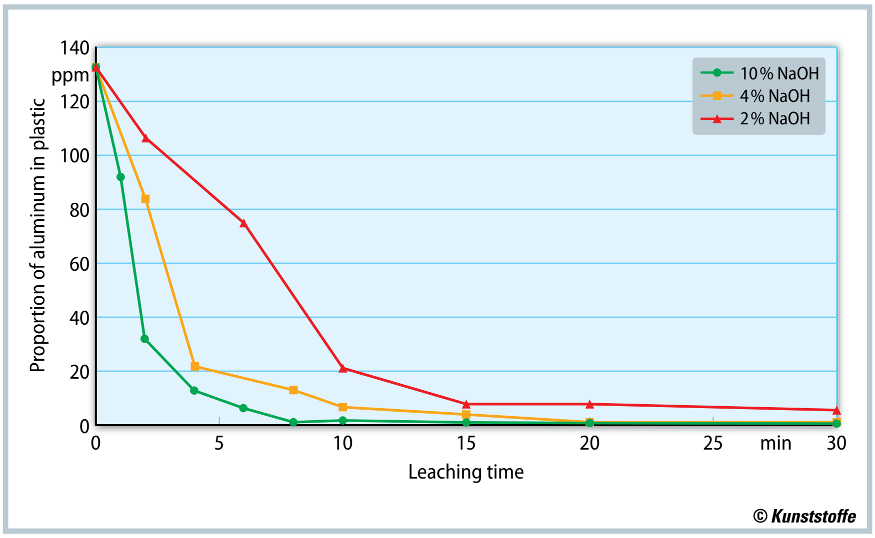

Fig. 4. Separation of metal-plastic composites by leaching: Dependency of the leaching time on the concentration of caustic soda (source: Fraunhofer IVV)

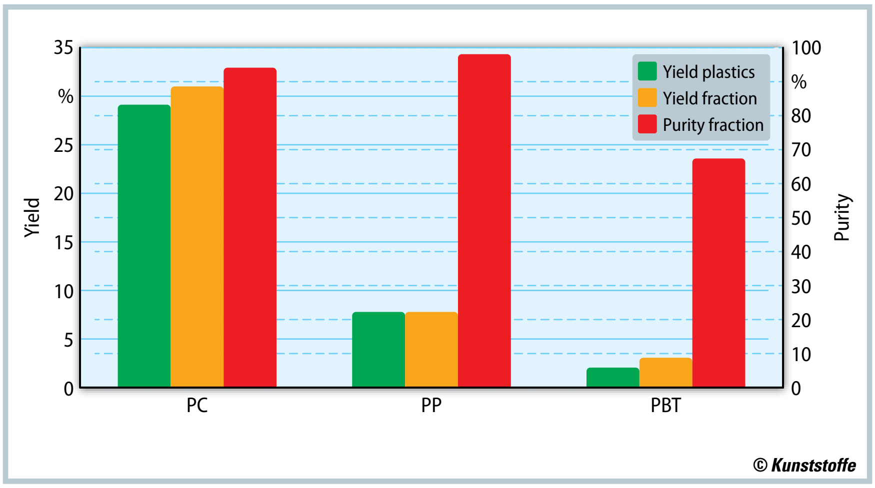

Fig. 5. Yields and purities of the fractions after automatic sorting by RTT Steinert: The specified percentage proportions respectively refer to the original input quantity after the separation of fines (source: Fraunhofer IVV)

still requires development. The method by RTT Steinert exhibits high accuracy for PE-PP separation in particular. Polyoxymethylene (POM) and PEI can be identified and sorted with the Unisensor process. The quality of both techniques is not influenced by the prior leaching of the plastics.

Based on the results of disintegration and composite separation as well as the spectroscopic studies, the process concept for the recycling of production waste shown in **Figure 2** was derived and forms the basis for the small-scale technical tests. The production waste of the two participating headlight producers was studied separately during the entire project phase. No significant differences between the products of the two OEMs can be detected after mechanical disintegration. The shredder fractions contain an average of 76.5% plastics, thereof 22.5% fines, as well as 7% each of copper and nonferrous metals and 9.5% iron. Plastics with a grain size of 8–30 mm were taken from the plastic fraction for the subsequent step of spectroscopic sorting. The mechanical recycling process can be adapted to this target grain size for larger waste volumes, so that nearly the entire plastic fraction can be passed to the next process step without losses. Sorting was aimed at the main plastic materials PP, PC, and PBT as well as aluminum-coated plastics. A purity analysis was performed by selectively dissolving the target plastics using specific solvent formulations. »

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A sorting test at RTT Steinert showed that more than 40 % of the plastic fraction can be sorted into target plastics using state-of-the-art technology, with PP and PC accounting for the largest proportion (**Fig. 5**). Unisensor obtained a somewhat higher yield but the purities of the fractions are correspondingly lower. The two methods are closely matched when the pure plastic yield is considered. Accordingly, PP and PC can be sorted with adequate purity (**Fig. 6**).

Fig. 6. Exemplary plastic fractions with purities > 90 % after automatic sorting: PC fraction (left), PP fraction (right). For optimum comparability, the material was shredded after fractioning (© Fraunhofer IVV)

Potential Analysis and Economic Efficiency

All of the material samples (totaling almost 500 kg) from both headlight producers and both sorting methods were considered for an overall balance of the small-scale technical tests. An analysis of the economic potential on this basis showed that yields of 17 % plastic and 23 % metal can be obtained to date, so that economic efficiency is not yet realizable. The low yields in the field test are far removed from the potential of the single headlight study with > 90-95 % plastic components. Therefore, the economic efficiency analysis was based on higher yields that, from today's perspective, can be obtained by optimizing shredder disintegration (lower proportion of plastic in the metal fraction and reduction of fines) (**Fig. 7**).

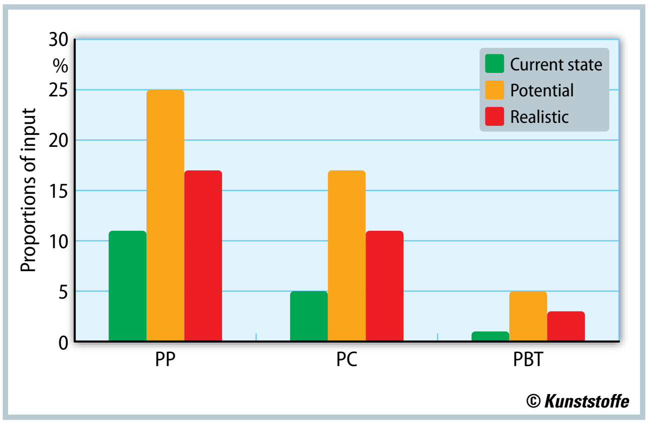

Fig. 7. Potential analysis of the pure plastic fractions (the 16.5 % proportion of metal is not considered here). Increasing the effectiveness to 80 % by optimizing material disintegration is also shown as a realistic scenario (source: Fraunhofer IVV)

Under the assumption that the plastics recovered from production waste can be used in place of new goods at the waste source, 75 % of the new goods price was assumed for the proceeds from the recycled materials. Furthermore, the conversion costs and depreciation for sorting technology were calculated for 1000, 2000 and 3000 t/a and led to positive proceeds in all cases. The economic balance for 2000 t/a is shown in **Figure 8** as an example.

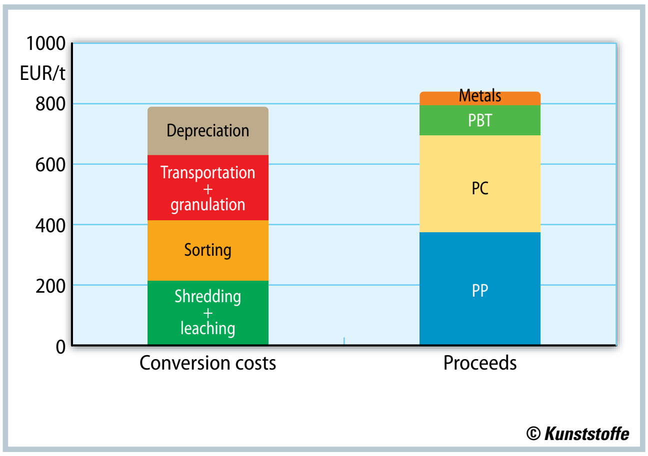

Fig. 8. Economic efficiency calculation for the developed automobile headlight recycling process with an annual waste volume of 2000 t/a (source: Fraunhofer IVV)

Conclusion

Automobile headlights are highly complex assembled products that can be recycled with good yields with the methods used in the project for material disintegration, ferrous/nonferrous separation (FE/NF), and subsequent automated sensor-assisted plastic sorting. In particular, the PP and PC purities that were obtained are highly promising. Optimization potential in the processing chain is seen mainly at the level of disintegration in the shredder and in the identification of special plastics (such as PBT and PEI). This improves the yields and purities of the polymer and metal fractions, and the economic efficiency overall. Further research and development is necessary for the required work and hardware changes in preparation for implementation. Large volumes of comparable waste streams are expected in the course of commercial waste collection and sorting in the wake of the pending Commercial Waste Ordinance, leading to great potential for the developed process chain. ■