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D 2.8 Life-Cycle-Analysis and considerations about recyclability

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Abstract

This deliverable D2.8 contains the life-cycle analysis of the Enhanced Piezoelectric Sensor (EPS) and an evaluation of its recyclability.

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1. Considerations regarding recycling, end-of-life analysis

The Enhanced Piezoelectric Sensor (EPS) consists of inorganic particles embedded in a PVDF matrix sandwiched between two conductive PEDOT/PSS layers. PET is used as the flexible substrate. In Figure 1 a schematic representation of this layout incorporating $BiTiO_3$ particles is given:

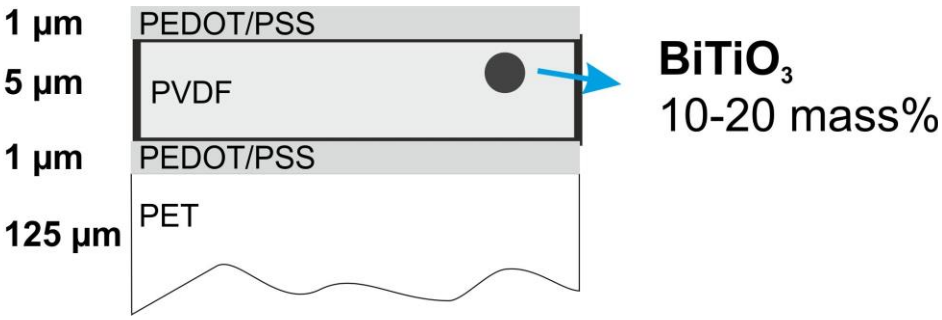

Figure 1 Schematic layout of the EPS.

This base structure may be the substrate for subsequent flexible electrophoretic display assemblies. Possible applications are medium- to large area panels or small-sized smart cards down to the standard area of 85*55 mm².

1.1 Toxicity

As a result of this project lead-containing piezoelectric powders such as $PbTiO_3$ were replaced by the non-toxic $BiTiO_3$ compositions. Therefore in the worst-case scenario of incineration at the end of life cycle environmental hazards may only originate from the thermal decomposition of fluorinated hydrocarbons. In [Hubert et al. 2009] these aspects are reviewed, which are non-specific to the EPS components

1.2 Material flow and recycling

The life cycle of EPS devices is schematically displayed in Figure 2 The use as, for instance, smart cards by many individual end users is highly dissipative. At the end of life of these devices they are most likely to be disposed with the normal household waste. Only a small fraction of these cards is expected to end up in general electronic waste management systems. As the metallic contents of the cards ($BiTiO_3$) are nontoxic, standard disposal is not critical. Hazards originating from waste incineration of the fluorinated functional polymers are moderate due to the small film thicknesses in comparison to the substrate material.

In contrast to that inoperative interactive stationary or mobile panels will be considered as electronic waste. In the early stages of commercialization no separation from other electronic dump material will take place due to the minor market penetration. The EPS materials, however, will not negatively interfere with standard procedures such as de-soldering, chemical stripping or open burning for the removal of noble metals. The adverse effects of the fluorinated polymers are low as already stated for the waste incineration of smart cards.

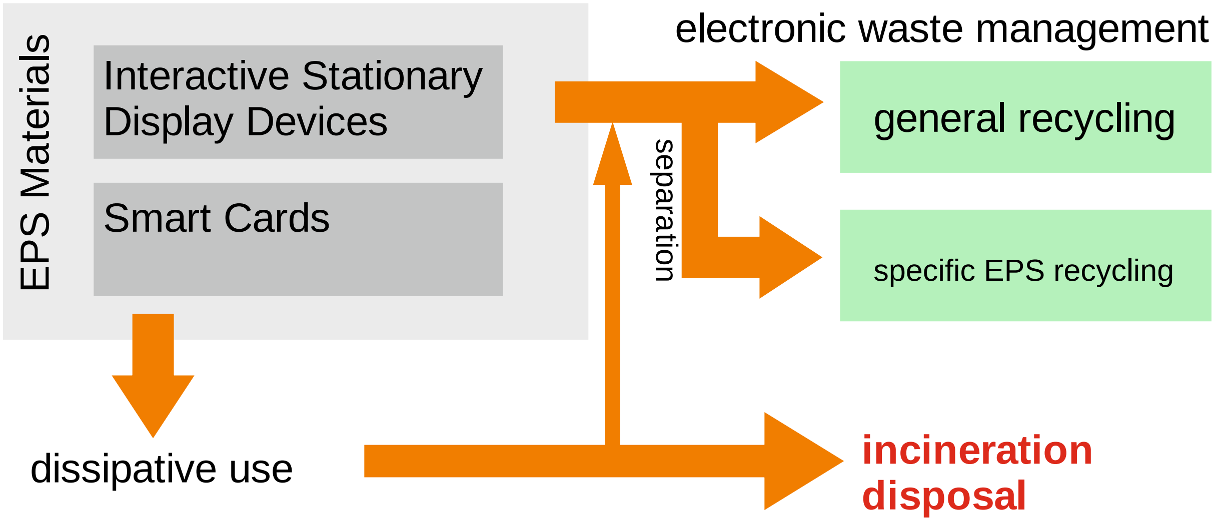

Figure 2 Material flow during the life cycle of EPS.

In the case of further spread of the devices under investigation the separation of EPS materials from standard electronic waste may become economically advantageous. Based on the layout shown in Figure 1 the cost of the polymer materials involved were calculated per square meter of device, the results are summarized in Table 1. It is obvious that the recovery of the conductive polymer PEDOT/PSS has priority from the economic point of view.

Material	price [€/g]	price [€/m²]
PEDOT/PSS	56-170	132 - 400
PVDF	1,11	5,55
PVDF-TrFE	5,00-8,00	27,8-44,4
PET foil		< 0,5

Table 1 Estimated material costs for EPS

The PEDOT/PSS component can be delaminated from the PET substrate by ethanol and separated from the insoluble PVDF by filtration. Laboratory experiments show that the performance of the PEDOT/PSS recovered is comparable to its initial properties. Therefore PEDOT/PSS applications with similar specifications can be envisioned for recycled materials, “downcycling” is not necessarily required.
PVDF and the Copolymer PVDF-TrFE are less expensive than PEDOT/PSS, therefore its recovery is economically unviable. This is especially true if only downcycling of the material is possible.
Since the PVDF is soluble in acetone, the $BiTiO_3$ particles generally could be separated by ultrafiltration. As the surface of sol-gel derived materials is reactive for condensation reactions, irreversible aggregation of the $BiTiO_3$ particles is inevitable. The cost of ceramic BiTiO3 (~45$/kg) and the related BST are low, therefore recycling of the inorganic precipitate does not make sense from the economic point of view.

Due to the easy polymer material separation by solubility activities regarding design for recycling are not required.

2. Conclusions

Specific recycling pathways for EPS components are possible, but they will only make sense after their widespread application is realized. For the time being the materials under investigation will have no adverse effects on standard recycling processes for electronic waste materials. Even incineration or disposal of EPS materials is not hazardous from the environmental point of view.

References

Sandra Huber, Morten K. Moe, Norbert Schmidbauer, Georg H. Hansen and Dorte Herzke „Emissions from incineration of fluoropolymer materials“ Norwegian Institute for Ais Research (2009).