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Study of Separation of Leds from Post-onsumer Lamp Modules

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Abstract: LED lamps, widely consumed and necessary for society, impact the environment and contribute to the growing generation of electronic equipment waste. When discarded, they can be considered secondary sources of critical materials, which makes it necessary to think about ways of returning them to the production chain. The removal of LEDs from the module is the most complex step of the process. This work aimed to study a separation method for LEDs, with the goal of better metal recovery. The methodology involved obtaining LED modules, removal in a heating plate at different temperatures, grinding, and chemical characterization. After the tests, different compositions of the solder were identified in the LED-Plate connections. Some modules (removed at 150°C) had led in them, while others did not (removed at 200°C). This last case meets international standards, which restrict its use.

Keywords: LED lamps; Disassembly; LED module; Critical materials; Lead soldering; Chemical characterization.

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Introduction

The global economic and technological development reached in the last few decades is related to the consumption of electrical and electronic equipment (EEE), as this type of equipment has increasingly become more necessary for modern society. In this context, reports point out that the global generation of electrical and electronic equipment waste (WEEE), in 2019, was about 53.6 MT, a number that has been rising since 2014, when the total WEEE produced in the world was 44.4 Mt. The increase, just from 2019 to 2020, was 20.7%. The per capita analysis shows that, in 2019, 7.3 kg of WEEE were produced per person, while in 2014 that number was 6.4 kg of WEEE per person (Forti *et al.*, 2020).

LED-type lamps are EEE, composed of a series of physically identical LED, mounted in series or parallel circuits, which provide a high and intense luminous flow. For them to work, they need a triggering system with a feeding source (also called a driver) (ABILUX, 2023). The function of this driver is to convert the alternating current, coming from the electrical network, into continuous current, which is necessary for the LEDs to operate.

The United Nations Institute for Training and Research (UNITAR) monitors the global data about WEEE and publishes them in a report called “The Global E-Waste Monitor”. The 2020 Global E-Waste Monitor specifies 6 different WEEE categories, with one of them being a category exclusively for lamps, including LED type ones (FORTI *et al.*, 2020). For this category, the report quantified a global generation of 0.9 Mt of lamps, including LED lamps. It is worth noting that, since 2014, there has been an increase of more than 4% in the generation of WEEE from the category of lamps and small equipment (Forti *et al.*, 2020).

The recovery of the materials from these lamps is relevant from the point of view of the environmental impacts and the recycling of materials, as they have metals that are of great economic value and/or critical, such as gold, silver, indium, and rare-earth. Apart from these, they also contain metals in higher volume that also have economic value, such as copper, iron, and aluminium; thus, they can be considered a secondary ore and, in some cases, have a higher content of precious metals than the ore of origin in nature. Apart from these materials with economic value, the WEEE can also contain substances that are harmful to human health and nature, such as lead, cadmium, and arsenic (Pradiian, 2013; Nicolai, 2016; Pourhossein; Mousavi, 2018; Santos, 2021).

In order for the EEE reverse logistics process to occur in its complete form, that is, for each different material to return back to the parties interested in reusing them, it is essential for the disassembly step to be performed adequately, separating the different parts and identifying correctly the materials that make up each of them (Silveira; Santos; Moraes, 2019).

The disassembly process of LED lamps presents a series of difficulties, as they are a complex and heterogeneous waste, especially when it comes to design variations between different brands, models, and the assembly method of the LEDs, in which the LED chips are encapsulated by other materials, being named a LED component (Pourhossein; Mousavi, 2018; Bossche *et al.*, 2019; Santos *et al.*, 2019; Santos *et al.*, 2020; ABILUX, 2023).

When used in lamps, in general, the LED components are assembled in an aluminium plate, and this set (LED+Plate) is named LED module. Apart from this module, a layer of copper is applied to conduct electricity, as well as an isolating organic film (ABILUX, 2023; Illès; Kèkesi, 2023).

When disassembling a LED lamp, aiming to separate the components and recycle the materials, the step of removing the LED is considered the most difficult one. Some studies used a utility knife as the removal tool of the LED, thus, acting with shear forces (Santos *et al.*, 2019; Cenci, 2020; Oliveira, 2022). However, this procedure does not seem to be very adequate, as, apart from having a significant loss of material, as many LEDs break or do not come off whole, this process can cause accidents to those that are executing it (Santos *et al.*, 2019). Another negative point is that the time necessary for this step using a utility knife is too long, which means an acceptable productivity is unfeasible if this process was employed in Screening Units (SU) (Santos, 2021; Santos *et al.*, 2022).

For desoldering in motherboards, printed circuit boards (PCB), and cellphone boards, the heat gun has been used. In this method, the desoldering is performed one by one, with the help of a metal spatula. In this case, the heat gun is angled at 45º, focusing heat directly over the soldering points until they fuse, and the connectors are freed (Nicolai, 2016). As it is a method that removes the material one by one, it is also slow. Maarefvand, Sheibani, and Rashchi (2019) opted for separating chips from LEDs through incineration, in order to remove flammable and low melting point polymers. In the incineration process, the polymers were melted, evaporated, or made easier to remove from the chip holders. Finally, the remaining material was removed with acetone and the chip was detached from the LEDs.

Even with the difficulties, the removal step of the LEDs is very important for a more efficient recovery of the critical metals contained in them. This results in a higher concentration of these materials in the final sample to be processed, while, by applying recovery techniques in every LED module, some metals in lower concentrations may be diluted even more (Santos *et al.*, 2019; Santos, 2021).

Furthermore, an efficient removal of the LEDs one by one may make reusing these components feasible (Wehbie; Semetey, 2022).

According to Santos (2021) and Santos *et al.* (2022), as there is no consolidated technology for recycling LEDs, they may end up entering the recycling cycle of aluminium, together with its "base" plate, being lost as a contaminant in the slag when the aluminium is melted.

The LED components are fixed to the base plates through soldering, generally by the addition of a tin alloy, whose composition may significantly vary (Martins; Tanabe; Bertuol; 2020; Wehbie; Semetey, 2022; Illès; Kèkesi, 2023). According to Wehbie and Semetey (2022), tin-lead solders (SnPb) are widely used in electronic applications due to their low melting point, low cost, and other soldering properties. However, these alloys have gradually been replaced, especially in the European Union and the United States, through regulations such as Directive 2011/65/EU, named "Restriction of the use of certain hazardous substances (RoHS)". Since 2006, this directive restricts the use of some hazardous substances, such as lead, in electronic products (European Union, 2011; Cheng; Huang; Pecht, 2017; Wehbie; Semetey, 2022; Illès; Kèkesi, 2023).

Thus, the tin-silver-copper alloy (SnAgCu) has been the main solder user to replace solders with lead, in general in the proportion 96.5Sn3.0Ag0.5Cu (Cheng; Huang; Pecht, 2017; Illès; Kèkesi, 2023). However, with the use of 3.0% mass of Ag, other cheaper materials have been sought after to replace it, especially in less complex applications, with short service life and low cost (Cheng; Huang; Pecht, 2017). Another material that has been used to replace lead is bismuth (Bi), which has a low melting point (Wehbie; Semetey, 2022). The composition of the material used in the solder directly affects the melting point of this solder. Thus, in case there is the intention to remove the LEDs from their baseplate using heating, instead of removal by shearing, as indicated previously in the text, the composition of the solder's material will impact the process directly.

The context shows the importance of the removal step of the LEDs from their modules for the later step of separating the metals. However, it is important to highlight that the choice and definition of the method that is used should take into consideration other factors, apart from agility and efficiency: the safety of the people involved so that there are no accidents; the minimization of environmental impacts, such as atmospheric emissions and energy consumption are also essential parameters in this choice.

Thus, the main objective of this work was to study a feasible method to separate LEDs from their module, under the perspective of optimizing the process, as well as worker safety, aiming for better recovery of the metals and a chemical characterization of the LEDs obtained in this process.

Methodology

All the following methodology steps described were carried out in the Laboratory of Characterization and Recovery of Materials at the university.

Training and Materials Preparation

The university's research group carried out a training session for some workers from a Screening Unit (SU) in the city of Porto Alegre, in the south of Brazil. Topics such as electronic equipment types, examples of equipment or parts that cannot be disassembled/processed in the waste picker cooperatives (which will be called 'cooperatives' in this paper), types of necessary basic tools for waste disassembly, use of individual protection equipment for the safety of those involved with the disassembly activity and handling of the waste, main materials that can be recovered, as well as proper storage of this waste were addressed. This training's main aim was to disassemble LED lamps to recycle their components, considering the importance of recycling cooperatives for the circular economy of this waste (Santos *et al.*, 2022). In order to do that, the training session presented different types of LED lamps, the difference between them and fluorescent lamps — to avoid the possible breaking of fluorescent lamps and the consequent mercury contamination of the workers —, and, finally, a step-by-step explanation of the disassembly of LED lamps, followed by a practical test disassembly of these lamps. The step-by-step and methodology of this training were better described in previous works, such as Santos *et al.* (2022) and Santos, Barrozo, and Moraes (2021).

As the LEDs do not yet have a consolidated recycling and metal recovery technology, nor a market for commercialization (Santos, 2021), the SU started receiving and separating the LED boards for the research group. Thus, only LED boards, from mostly bulb-type lamps and other diverse lamps, that came from the SU were used to carry out this work. The research group then removed the LEDs from the boards and, later, returned the clean boards to the SU, so they could sell the material. In total, 239 LED boards were disassembled for this study.

Removal of the LEDs

Based on the literature studied in works that applied different methodologies to remove LEDs, the temperatures employed varied from 138 °C to 260 °C (Cheng; Huang; Pecht, 2017; Martins; Tanabe; Bertuol, 2020; Cheng; Wehbie; Semetey 2022; Illés; Kékesi, 2023). Thus, preliminary experiments were carried out, testing the temperatures on the heating plate (going from 130 °C to 200 °C), verifying if the LEDs were releasing or not, with the help of tweezers. Finding that the 150 °C and 200 °C temperatures released most of the LEDs, without immediate release in the intermediate temperatures, it was determined that these would be the temperatures employed in this work.

The LEDs were removed on a heating plate, from Warmnest, model DB-IVA, installed inside an exhaustion hood, in which the plates were heated up to two different temperature stages: 150 °C and 200 °C.

Figure 1 shows how the removal of the LEDs was carried out by using the heating plate.

Figure 1 - Removal of the LEDs using the heating plate

Source: the authors, 2024.

First, the heating plate was programmed at 150 °C and, as soon as it hit the programmed temperature, a removal test of the LEDs was done to verify if they were released, with the help of tweezers; if the result was positive, the released LEDs were removed, also with the tweezers.

After removing the LEDs that were released at 150 °C, the temperature of the heating plate was adjusted to 200 °C, waiting until the temperature was reached. After this new temperature stage stabilized, a new round of LEDs removal from the motherboards was carried out. Finally, only a small fraction of the LEDs did not release at the 200 °C temperature and needed to be removed at an even higher temperature, as will be shown in the results.

Grinding

The LEDs removed from the motherboards were ground in an analytical cutting mill, from Janke & Kunkel, for about 5 minutes. This step aimed to generate samples with smaller and more homogeneous particle size, which was necessary for chemical characterization, as it is known that X-Ray Fluorescence analysis, which was used, is a superficial technique, limited to the more external layers of the samples, as the penetration level of the X-rays in the material is low, in the microns range (Paula; Fernandes, 2015; Nascimento-Dias; Oliveira; Anjos, 2017). Thus, by grinding the LEDs, important materials that are encapsulated in their interior (Santos *et al.*, 2020) can also be identified. Apart from that, according to the literature, a comminution process can provide separation of the materials in WEEE, including LEDs (Cenci *et al.*, 2021; Silveira *et al.*, 2024).

Chemical characterization

The qualitative chemical characterization of the inorganic phase of the materials, performed in this work, was carried out by the X-Ray Fluorescence (XRF) technique, employing a model equipment EDX 720 HS, from Shimadzu. Apart from being a quick analysis, the use of this technique contributes to the objective of identifying preliminarily the materials in the LEDs, as well as verifying the difference in the composition of the plates (solders) and LEDs that were released in different temperatures.

First, the LEDs were ground, as described in the grinding item, and analyzed by XRF, once separating the LEDs released at 150 °C and 200 °C and then mixing them, that is, the two types were joined to get a homogeneous sample. Apart from that, the XRF analysis was carried out on the LED plates where the LEDs were released, that is, on the solder. XRF was also performed in a material of difficult grinding found in the comminution step.

Results

The results are presented below.

Recovery of post-consumer LED lamps in the US

After the training, the US started disassembling post-consumer LED lamps, which are discarded alongside waste sorting waste. Nowadays, the US sells practically all the materials that constitute lamps, except the LEDs, to recycling companies.

However, shortly after this study, the US started selling the LED modules, being sold together with aluminium or PCB, generally as aluminium scrap, in which the LED enters as a contaminant. Furthermore, other interested buyers in the LEDs also appeared, but without detailing their application.

Either way, this appreciation in the market is still too volatile, that is, there are periods when the cooperative can sell them and others when they cannot (this also happens with the bulb). This practice also occurred in other cooperatives that were visited and are in accordance with what was predicted by the literature (Santos 2021; Santos *et al.*, 2022). In some cooperatives, this market is absent.

Thus, the LED lamp started to be considered a recyclable material of interest to the US, a generator of work and profit, but still with irregular demand and offer. Table 1 shows how much the US may receive for selling 1 kg of each material in the lamp (Santos *et al.*, 2022). Contaminated aluminium is considered a material that has other materials mixed in, while non-contaminated alumimiun is one that does not have that mixture (Santos *et al.*, 2022).

Table 1 - Price by kg of each material

Material	Value/kg
Non-contaminated aluminium	R$ 3.50
Contaminated aluminium	R$ 3.00 – 2.80
Polymers	R$ 1.20
PCB	R$ 7.00

Source: the authors, 2024.

According to Santos *et al.* (2022), with these values, a worker in a cooperative, after disassembling 2,400 LED bulb-type lamps per month, could generate R$ 360.00/month for the cooperative.

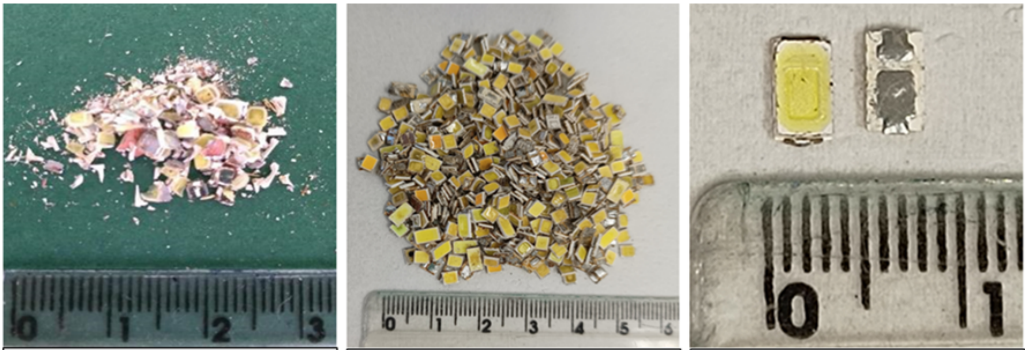
However, there is a worry regarding the destination that has been adopted for the LEDs, as, by entering the recycling cycle of aluminium, the critical and precious metals in them are diluted and lost, and as stated before, become contaminants in the fusion of aluminium. This results in the urgency to develop and apply an economical and environmentally adequate technology to recover these metals.

Removal of the LEDs

Removing the LEDs from the aluminium baseplate is a complex task (Santos *et al.*, 2019). In previous works, this process was carried out by using a utility knife; however, apart from the risks of accidents from this procedure, there were too many losses, as the LEDs would break and/or get lost and/or detach incompletely (with important parts of the LEDs remaining on the plate). Another essential point is that this step demanded too much time, making it unfeasible for cooperatives. However, the cited works do not report the time needed for this procedure, as this was not the aim of these works.

As shown in Figure 2, removing the LEDs through the heating plate proved to be more efficient, as it removed them completely. Furthermore, Figure 2 also shows a LED removed whole. From the point of view of possibly reusing the LEDs, this process is more recommended than the mechanical one (utility knife) (Wehbie; Semetey, 2022). And, from the point of view of metal recovery, in which a comminution step will be used, the removal of the whole LED is not necessary; however, some aspects, such as losing part of the LED's materials, as well as work time and safety, should still be considered in the sense of it becoming a practice in cooperatives (Cenci, 2020; Oliveira, 2022; Santos *et al.*, 2019; Santos *et al.*, 2021; Santos *et al.*, 2022).

Figure 2 - Removal of the LEDs using a utility knife versus a heating plate, and a whole LED removed



LEDs removed using a craft knife | **LEDs removed with heating plate** | **LEDs removed whole**

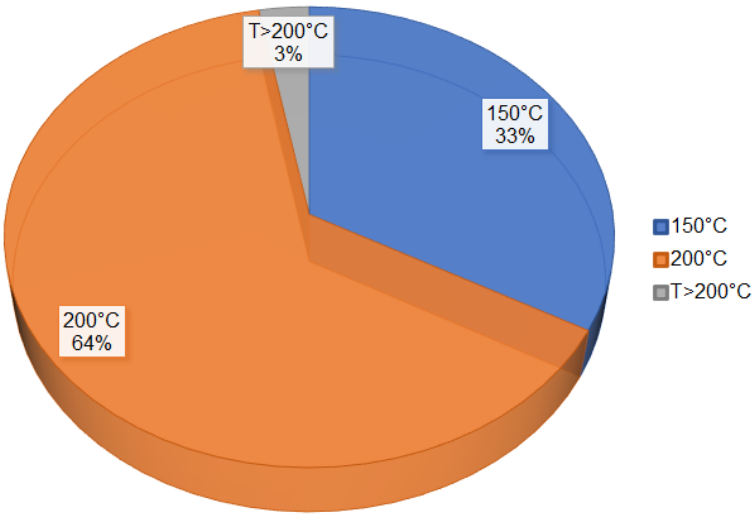
Source: the authors, 2024.

That said, the LEDs released easily from the baseplate to which they were soldered, needing only the help of fine-tipped tweezers to remove them without any difficulty. However, in the first test, there was a difference in melting temperature of the solders, in which some released when reaching a temperature of 150 °C and others at 200 °C. The time for the complete release of the LEDs was about 5 to 10 minutes for the 150 °C temperature and about 3 minutes for the 200 °C temperature.

A small portion (3%) did not release in any of the two temperatures and were named T>200°C; these did not remain in the next steps of this study at this moment, due to their small quantity.

Figure 3 shows the proportion of released LEDs at 150 °C, 200 °C, and above 200 °C.

Figure 3 - Proportion of released LEDs at 150 °C, 200 °C, or T>200 °C



Source: the authors, 2024.

As can be seen in the graph in Figure 3, from the 239 modules, 153 (64%) were released at 200 °C, 79 (33%) at 150 °C, and only 7 (3%) were not released at any of the temperatures.

According to Wehbie and Semetey (2022), the use of desoldering by heat is an efficient way to separate electronic components, even though there is a risk they will be damaged, and the desoldering temperature is directly connected to the chemical composition of the solder.

Grinding

The comminution in a countertop cutting mill was efficient for the purpose it was employed for, having a less than 1% loss, apart from providing the separation of the materials. The process was relatively easy, in a short time (about 5 minutes) a smaller and more homogeneous sample was obtained. However, there was a metal hard to grind in this kind of mill, remaining whole after the process.

The process was confirmed to be efficient for the purpose of chemical characterization, as can be seen in the XRF results, which will be addressed in the next item, from a great variety of metals identified by the analysis and that could be found in the literature.

This work did not address an investigation of the obtained particle size, as that does not interfere with its objectives. However, future works plan to investigate this matter more deeply. Although particle size analysis was not performed in the samples, in other works the particle size found after grinding were between 1 and 2 mm in a pot-spray mill (Annoni *et al.*, 2020), less than 2 mm in a planetary ball mill (Vinhal *et al.*, 2022), and less than 1 mm in a cutting mill (Cenci *et al.*, 2021).

Chemical characterization

Table 2 shows the qualitative results of the XRF of the released LEDs at 150 °C and 200 °C, of them mixed, of the plates at the solder spot, and of the non-grinded material.

Table 2 – XRF of the released LEDs at differente temperatures, mixed, of the plates at the solder spot, and non-grinded material

Material	(>50%)	(5% < x < 50%)	(< 5%)
LED 150°C	-	Ti, Si, <u>Sn</u>, C*u*, Y	Ca, **Pb**, Al, Zn, Ga, **Ag**, Bi, Fe, Mg, Ni, Sr, P, Cr, Mn, Br
LED 200°C	-	Ti, Si, <u>Sn</u>, C*u*, Y, Ca	**Pb**, Al, Zn, Ga, **Ag**, Bi, Fe, Mg, Ni, Sr, P, Cr, Mn, Br, Ac, Th,
Mixed LEDs	-	Ti, Si, <u>Sn</u>, C*u*, Y	Ca, **Pb**, Al, Zn, Ga, **Ag**, Bi, Fe, Ni, Sr, P, Cr, Mn, Br, Zr, I
LED plate 200 °C	<u>Sn</u>	Si	Ca, **Ag**, Bi, C*u*, Br, Th
LED plate 150 °C	<u>Sn</u>	**Pb**	**Ag**, Ni, C*u*, Ra, Ti,
Non-ground material	C*u*	Fe, Ni	**Ag**, Cr, Mn, Y, <u>Sn</u>

Source: Authors, 2024.

As seen in Table 2, it was found in the LEDs, independent of the solder used, yttrium (Y), gallium (Ga), silver (Ag), as well as other elements that are common in its composition, already verified by the literature, such as titanium (Ti), calcium (Ca), aluminium (Al), bromine (Br), among others (Oliveira; Benvenuti; Espinosa, 2021; Rebello; Xavier, 2021; Balinski *et al.*, 2022; Illés; Kékesi, 2023). Pb appeared in every LEDs sample.

In the LED plates where the XRF analysis was performed only over the solder, Sn was found as a major element (>50%) in both samples, however, Pb was found only in the ones that released at 150 °C and as an intermediate material (5% < x < 50%). Although Ag and Cu were detected as trace elements (<5%), it can be inferred that it is a SnPb solder.

In the solders that melted at 200 °C, no Pb was detected. Adding the presence of Ag and Cu as trace elements, it can be inferred that it is a SnAgCu solder. In this sample, Bi was also detected; although it can be considered a contaminant, it has been reported in the literature as a potential additive in free Pb solders and as more economic (Cheng; Huang; Pecht, 2017; Wehbie; Semetey, 2022; Illés; Kékesi, 2023).

Cenci (2020) verified, in his study, through the analysis of ICP-OES, the presence of lead in bulb-type LED lamps in the LED module (0.001% concentration), while in the tubular-type they were in the LEDs (1.025% concentration), PCBs (0.233% concentration), and LED module (0.011% concentration). The presence of lead generally depends on the manufacturer and is employed as a solder (Cenci, 2020).

According to Cheng, Huang, and Pecht (2017), due to the good properties of soldering, manufacturability, reliability, and price, for over 50 years the SnPb solder has been used in the assembly of electronics. However, since 2006, due to the toxicity of Pb, it started to be eliminated from solders in consumer electronics because of the RoHS directive of the European Union and, later, also started being restricted in other products and countries.

Thus, a race started to develop and elect an alloy without Pb, with acceptable properties and cost. Thus, the SAC305 alloy (96.5% composed of Sn, 3.0% of Ag, and 0.5% of Cu) was elected the standard alloy for the electronic industry. This alloy has a 217 °C melting point (Cheng; Huang; Pecht, 2017).

In Brazil, there still is no definition of the restriction on using hazardous substances in the EEE. In 2018, a workgroup elaborated a draft of a norm based in the European Union with similar rules to restrict the use of these substances, as it is necessary to develop protection mechanisms, both for the people involved in the manufacturing and recycling as for the consumers that use these products, as well as establish national strategies for their management (Ministério do Meio Ambiente e Mudança do Clima, 2017; Ministério do Meio Ambiente, 2023).

Illés and Kékesi (2023) verified, through the analysis of EDS solder with Sn-Pb alloys between the LEDs and the base-plates, that they had a 45.14 Sn and 54.86 Pb in mass percentage proportion. To separate the LEDs from their plates, these authors used an acid bath with aqua regia, in which the tin oxide precipitated and the Pb and Ag were dissolved, being removed with the addition of NaCl and Na2SO4 salts. Although the authors had success, this process generate a liquid effluent that needs to be treated later.

Martins, Tanabe, and Bertuol (2020) separated the LEDs from their baseplate using a heating plate at 200 °C temperature for 5 minutes and a glass stick to remove the LED chips. The authors also found solders made up of Sn, Ag, and Pb, apart from Cu, by mapping via Scanning Electron Microscopy (SEM) with Energy-dispersive spectroscopy (EDS) (Martins; Tanabe; Bertuol, 2020).

Wehbie and Semetey (2022) desoldered through heating plate and oven, in which the authors used an initial temperature of 160 °C in the oven experiment for 10 minutes; from a total of 10 modules, 4 were released; later, the temperature was raised to 260 °C, using the same time, and the rest released. Then, when using the heating plate, they applied a temperature of <240 °C for 5 minutes, and all the 11 modules were desoldered.

By carrying out EDS analysis by SEM, Wehbie and Semetey (2022) verified that the LED modules that desoldered at 160 °C used BiSn solders, while the ones that released at 260 °C were only composed of Sn. According to them and to the previously mentioned literature, Bi has been applied to replace Pb and provide a solder with a lower melting point, as the $Sn_{57}Bi_{47}$ solders have an 138 °C melting point and the ones with pure Sn 231.9 °C (WEHBIE; SEMETEY, 2022).

Although the two processes, chemical and physical separation, attend the aim of separating the LEDs for later and better recovery of the metals contained in them or for reusing them, the negative environmental impacts caused during each technique must be taken into consideration. The chemical process consumes more raw material and generates acidliquid effluents, while the thermal process may generate atmospheric emissions, which makes it necessary to use PPEs and exhaustion systems. In any case, a more viable and productive process must be thought of for the cooperatives and SUs, in which the materials of the plates mean a source of income for them.

From the results discussed in this work, there is a need to deepen research on the impacts associated with the processing of the LEDs, from a balance of mass and energy, as well as in the environmental and economic evaluation involving the three processes (mechanic, chemical, and thermal), in which issues such as energy consumption, atmospheric emissions, generation of acid liquid effluents, economic and technical viability, and worker security and health must be quantified, taking into consideration the chosen work routes (that is, reuse, reparation, or recovery of the LEDs materials).

Conclusions

After the training carried out in a SU and the removal tests of the LEDs using a heating plate, grinding of the LEDS, and chemical characterization, the following considerations should be made:

- LED lamps are a waste of economic interest for cooperatives and SUs, as they represent a new material that could be beneficial and sold by them. After this training, the SU already started separating the materials of the lamps and selling the parts;
- The sale of LED modules directly to the buyers of other materials, without previous separation of the LEDs, becomes a negative action because important materials with added value are lost;
- Grinding the LEDs in a countertop cutting mill is possible, and showed little loss of material (1%), although part of the metallic material has not been ground, as for some recovery techniques this comminution could already be applied. However, in some specific cases, and for analyses in which the particle is determinant, a new method will be necessary.
- Removing the LEDs in heating plate proved better than the use of a utility knife, both from the point of view of optimization as of safety;
- The difference in temperature in the release of the LEDs demonstrates the application of different solders in the LEDs, in which many still use Pb (33%), although in small quantities it must be avoided, due to its known negative impact on the environment and human health;

- It is urgent to define a normative, similar to RoHS, in Brazil, as it could promote the decrease and elimination of the use of Pb;
- Having a removal step of the LEDs, during the disassembly and recovery of post-consumer lamps, inside the SUs the impacts caused by each technique, the economic and technical feasibility, as well as an optimization of the process must be taken into account;
- This work will have, as a continuity, the economic, environmental, and technical evaluation, with the intention of deciding regarding the separation process of these LEDs, contemplating all the possible different routes.

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AMBIENTE & SOCIEDADE 25 anos años years

Estudo da Separação de Leds dos Módulos de Lâmpadas Pós-consumo

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São Paulo. Vol. 27, 2024

Artigo Original

Resumo: As lâmpadas LED, muito consumidas e necessárias à sociedade, trazem impactos ao meio ambiente e na crescente geração de resíduos de equipamentos eletroeletrônicos. No descarte, podem ser consideradas fontes secundárias de materiais críticos, em que é necessário pensar formas de retorno à cadeia produtiva. A retirada dos LEDs do módulo é a etapa mais complexa do processo. O objetivo do trabalho foi estudar um método de separação de LEDs, visando a melhor recuperação de metais. A metodologia envolveu a obtenção dos módulos de LED, retirada em chapa aquecedora em diferentes temperaturas, moagem e caracterização química. Após os testes, identificou-se diferentes composições da solda nas conexões LED-Placa, em que alguns módulos (retirados a 150°C) têm a presença de chumbo, e em outros não (retirados a 200°C), este último caso atende normas internacionais que restringem seu uso.

Palavras-chave: Lâmpadas LED; Desmontagem; Módulo de LED; Materiais críticos; Solda de chumbo; Caracterização química.

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SciELO

Estudio de Separación de Leds de Módulos de Lámparas Posconsumo

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Artículo Original

Resumen: Las lámparas LED, muy consumidas y necesarias para la sociedad, impactan en el medio ambiente y en la creciente generación de residuos procedentes de equipos electrónicos. Al desechar se pueden considerar fuentes secundarias de materiales críticos, donde es necesario pensar en formas de devolverlos a la cadena de producción. Quitar los LED del módulo es el paso más complejo del proceso. El objetivo del trabajo fue estudiar un método para separar LED, con el objetivo de una mejor recuperación del metal. La metodología consistió en la obtención de módulos LED, su extracción de una placa calefactora a diferentes temperaturas, su rectificado y caracterización química. Luego de las pruebas se identificaron diferentes composiciones de la soldadura en las conexiones LED-Board, en las cuales algunos módulos (retirados a 150°C) tienen presencia de plomo, y otros no (retirados a 200°C), este último caso Cumple con estándares internacionales que restringen su uso.

Palabras-clave: Lámparas LED; Desmontaje; Módulo LED; Materiales críticos; Soldadura de plomo.