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Öğrenci Bitirme Tasarım Projesi – 2021 BAHAR – CEVHER-2
The Characterization and Mechanical Separation of Metals from Printed Circuit Boards in Printers

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**Bitirme Tasarım Projesi Danışmanı Öğretim Üyesi*

ÖZET

Dünya nüfusunun artması ve teknolojinin gelişmesi elektrikli ve elektronik cihazlara olan talebi artırmaktadır.

Araştırmalara göre dünya genelinde yıllık tüketilen e-atık miktarının 2021 yılında 57,4 milyon tona ulaşacağı tahmin edilmektedir. Elektronik atıklar içerdikleri civa ve kadmiyum gibi toksik bileşenler nedeniyle çevreye ve canlılara ciddi zararlar vermektedir. Zararlı bileşenlerin yanı sıra altın, gümüş ve bakır gibi değerli metaller de içerirler. Günümüzde hemen hemen her türlü elektronik ekipmanda bulunan baskılı devre kartları, elektronik atıkların önemli bir bölümünü oluşturmaktadır. Baskı devre kartları çok sayıda metal içermeleri nedeniyle son yıllarda ikincil bir malzeme kaynağı olarak ön plana çıkmıştır. Bu çalışmada yazıcılardan bulunan baskı devre kartlarının karakterizasyonu incelenmiştir. Birçok farklı türdeki yazıcılardan toplanan baskı devre kartlarına boyut küçültme işlemleri uygulanarak elde edilen ürün eleklerle farklı boyut gruplarına sınıflandırılmıştır. Bu boyut gruplarındaki malzemelere görüntü analizi uygulanarak tanelerin fazları belirlenmiştir. Sonuçlar yorumlanarak belirtilmiştir.

ABSTRACT

The increase in the world population and the development in technology has increased the demand for electrical and electronic devices. It is estimated that the amount of e-waste consumed worldwide annually will reach 57.4 million tons by the year 2021. E-wastes cause serious damage to the environment and livings due to their toxic components such as mercury and cadmium. In addition to them, they contain precious metals such as gold, silver, and copper.

Nowadays, printed circuit boards (PCBs) are found in almost all types of electronic equipment, and they constitute an important part of e- waste. PCBs in printers (PPBCs) have been evaluated as a secondary material source due to their high metal contents. In scope of this thesis, the characterization study of the printed circuit boards in printers (PPCB) is investigated. Size reduction processes have been applied to printed circuit boards collected from many different types of printers. The products obtained after size reduction processes were screened with various sieves and divided into different size groups. The fractions were subjected to image analysis for identification of the phases. These results and comparements are interpreted and stated.

PRINTED CIRCUIT BOARDS (PCBs)

Printed circuit board (PCB), providing the electrical interconnections between components, is the platform upon which microelectronic components such as semiconductor chips and capacitors are mounted. PCBs consist of electrical components and connectors to route electrical signals and power within and between devices connected by conductive circuits, generally copper. Printed circuit boards (PCBs), which are found in all forms of electronics, are of great significance since they are secondary raw materials that rich in copper and precious metals such as gold, silver, and palladium. The precious metal content of PCBs is 10 times higher than a typical rich ore (Burat & Özer, 2017). A single cell phone, for example, can contain large levels of gold (24 mg), silver (250 mg), and palladium (9 mg) (Oguchi et al., 2011). PCBs are made up of a wide range of materials, and populated PCBs are said to contain the majority of the elements in the periodic table. Typically PCBs contain 40% of metals, 30% of organics and 30% ceramics. PCBs contain a great amount of elements in metal forms. According to Figure 2.4, it can be understood that PCBs contain variety of elements (Rajarao et al., 2014).

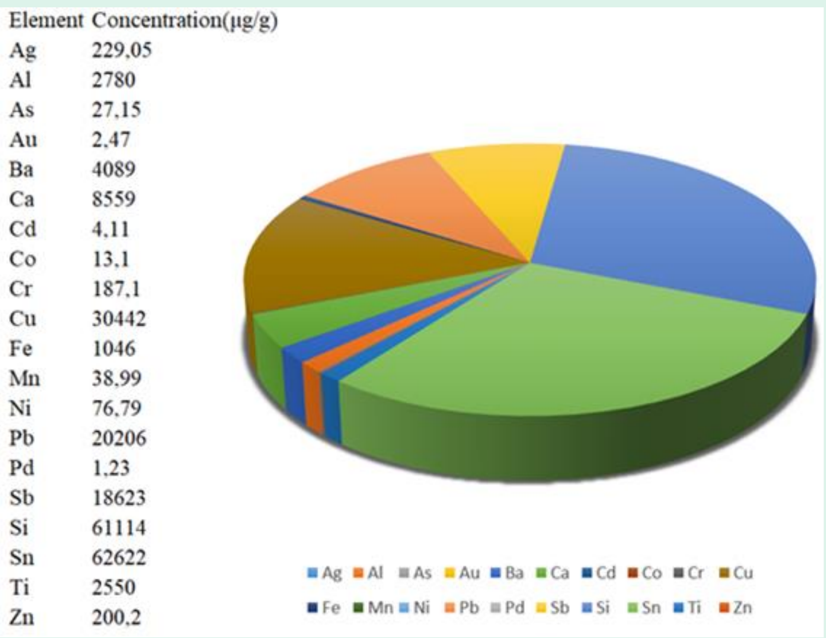

Figure 1. Elemental composition of PCB by ICP analysis.

MATERIAL

About 5 kg of waste printer mainboards were supplied from Exitcom Recycling Company. The mainboard includes PCB consisting of composite fiberglass material on its base, and many components attached to the surface such as switch, diode, buzzer, battery, diode, transistor, inductor, capacitor, integrated circuit, etc.

Figure 2. The material consisting ofprinter printed circuit boards

METHOD

Firstly, the undesirable attachments and components were manually disassembled (Fig. 3), and then comminution processes (shredding, crushing, and grinding) were successfully subjected to achieve sufficient liberation of metals from the waste matrix. Size reduction processes were applied in multiple stages. Net Plasmak brand shredder was used as a primary crusher. After the first stage of crushing process, the material was classified using a sieve with an opening of 2 mm. The material over 2 mm contains a high amount of locked particles, therefore a hammer crusher was used for further liberation of particles. Again, the over screen material (+2 mm) was introduced to the milling. Retsch RS-1 model ring mill was used. After the comminution process is completed the material was classified into various fractions and sent to image analysis.

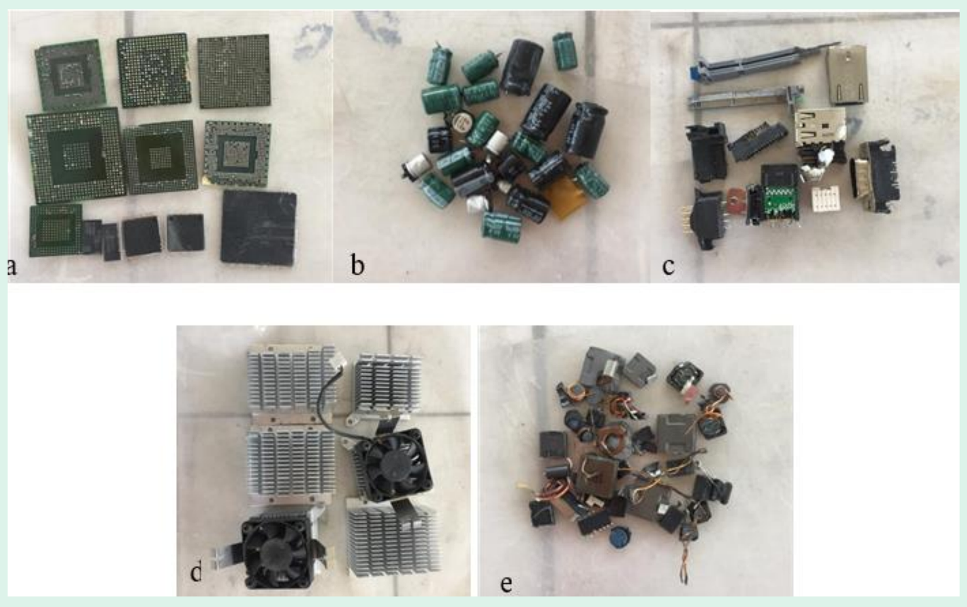

Figure 3. Components after manual disassembly:
a) chips, b) capacitors, c) integrated circuits & switches,
d) cooling fan, e) inductors.

SIZE REDUCTION PROCESS

After size reduction process has been completed, the representative PPCB samples were obtained through quartering of the comminuted products and particle size analysis was conducted using an electric shaker with standard sieves. The d80 value of the shredded material is determined as 8 mm and the d50 value as 5 mm. As a result of the sieve analysis of shredded material, it was seen that the liberation of metal from waste matrix was not sufficient. Therefore, the shredded material was fed to the hammer crusher for the secondary crushing. The d80 value of the material after hammer crushing was determined as 3.3 mm and d50 value as 1.8 mm. Metal and nonmetal particles are almost dissociated from each other and soft metals take the form of plates due to the impact effect of the hammer crusher. The waste matrix and metals were substantially separated from the slot, however, there were still some unallocated baseplates. Finally, the material over 2 mm was fed to tertiary comminution process. As a result of the grinding with disc mill, small metal particles with rounded corners and spherical shapes were generated. The d80 was determined as 0.5 mm and d50 value as 0.16 mm.

IMAGE ANALYSIS

To provide morphological identification of crushed PPCB particles the samples were magnified and identified using two-dimensional photographs. The samples were carefully picked from the fractions and then classified after size reduction. The photographs of the material were taken with a Leica brand image analysis device. According to the results obtained from the image analysis, the grains in the size groups were categorized as free metal, free plastic, free ceramic, free board piece, locked board piece, and locked plastics (Fig. 4). The images of various fractions after.

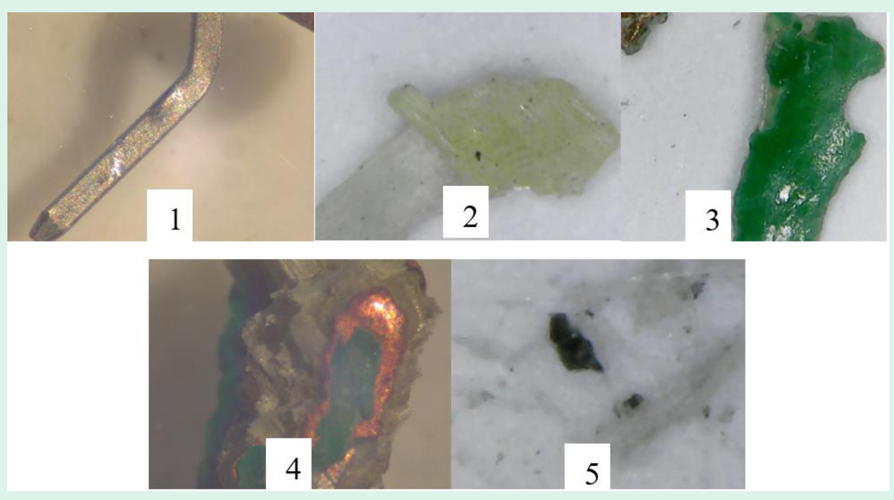

Figure 4: The particles of communited PCB: 1) free metal, 2) free plastic, 3) free board pieces, 4) locked board pieces, 5) free ceramics.

According to observations made on the images of comminuted materials, the following items were reported. In the +4.76 and -4.76+2 mm fractions, selected representative sample show that material contains copper as metal and interlocked with board particle. In the -2+1 mm fraction, locked boards, some free metals, and free plastics were observed. In the -1+0.5 mm fraction, the number of liberated particles increased. However, a large amount of locked board pieces was also observed. In the -0.5+0.212 mm and -0.212 +0.106 mm fractions, the amount of free plastics, free metals, and free boards dramatically increased. At the finest size fraction, -0.106 mm, the number of free plastic, free ceramic, and free board pieces were more than free metals.

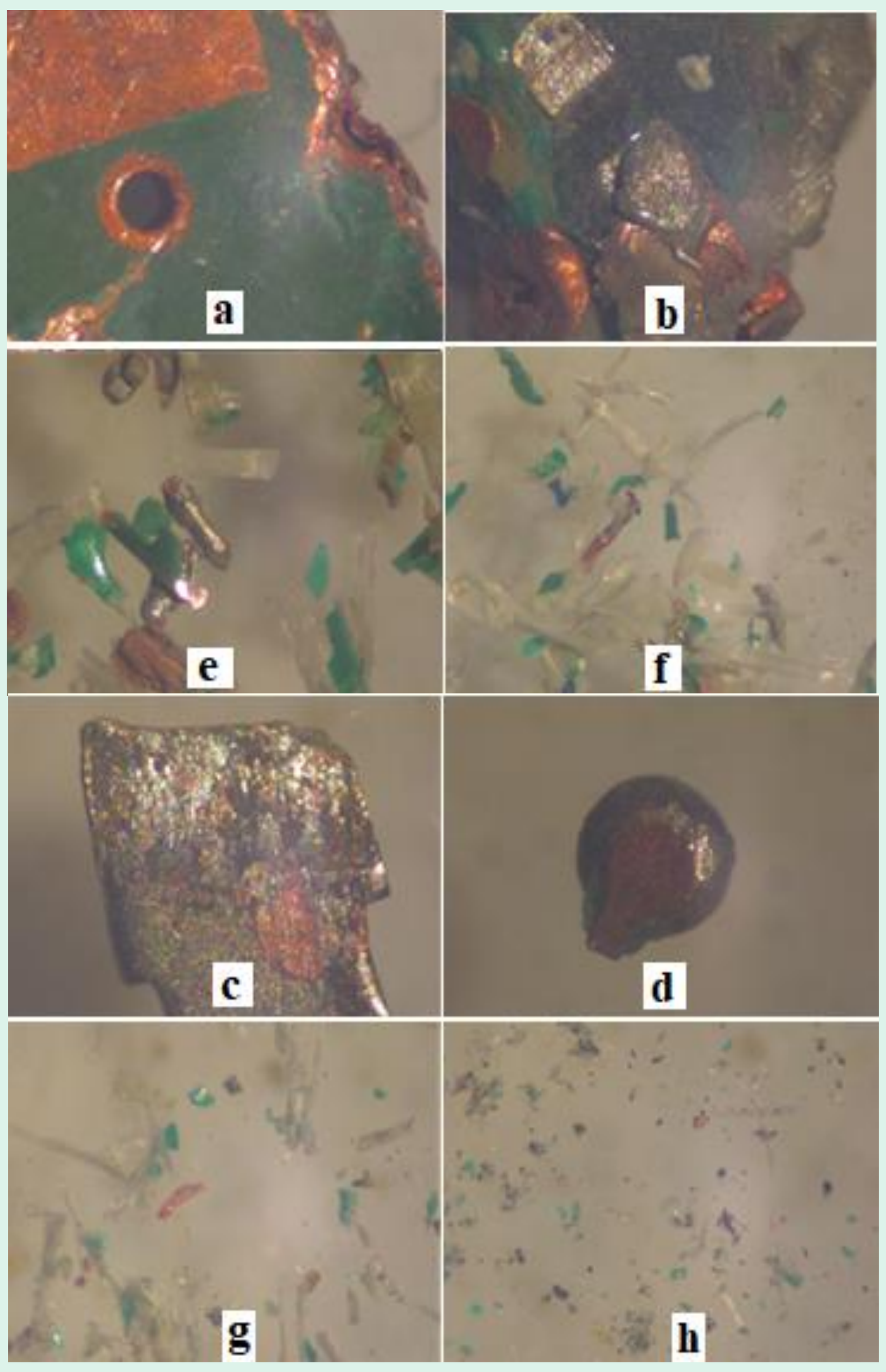

Figure 5. The images of various fractions after comminution process:
a) +4.76 mm, b) -4.76+2 mm, c) -2+1 mm, d) -1+0.5 mm, e) -0.5+0.212 mm, f) -0.212+0.106 mm, g) -0.106+0.053 mm, h) -0.053 mm

CONCLUSIONS

- In the coarse size fractions (+2 mm), the particles are mostly composed of locked particles.
- The number of liberated particles reaches a sufficient level at -1 mm and gravity-based beneficiation methods could be applied for efficient metal and non-metal separation.
- The numbers of liberated waste matrix particles are much more than free metal particles in the fine fractions. It means that liberated metal particles remain in the larger fractions since they gain plate shape and needle-like ceramic and fibers passed in small size fractions according to their shape factor.
- One stage size reduction process was not enough to achieve sufficient liberation of particles. At least, two-stage crushing is needed for physical beneficiation. To increase recovery, a third step size reduction operation could be required, however, metals should be controlled due to factors related to the shape of the misplaced material.

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