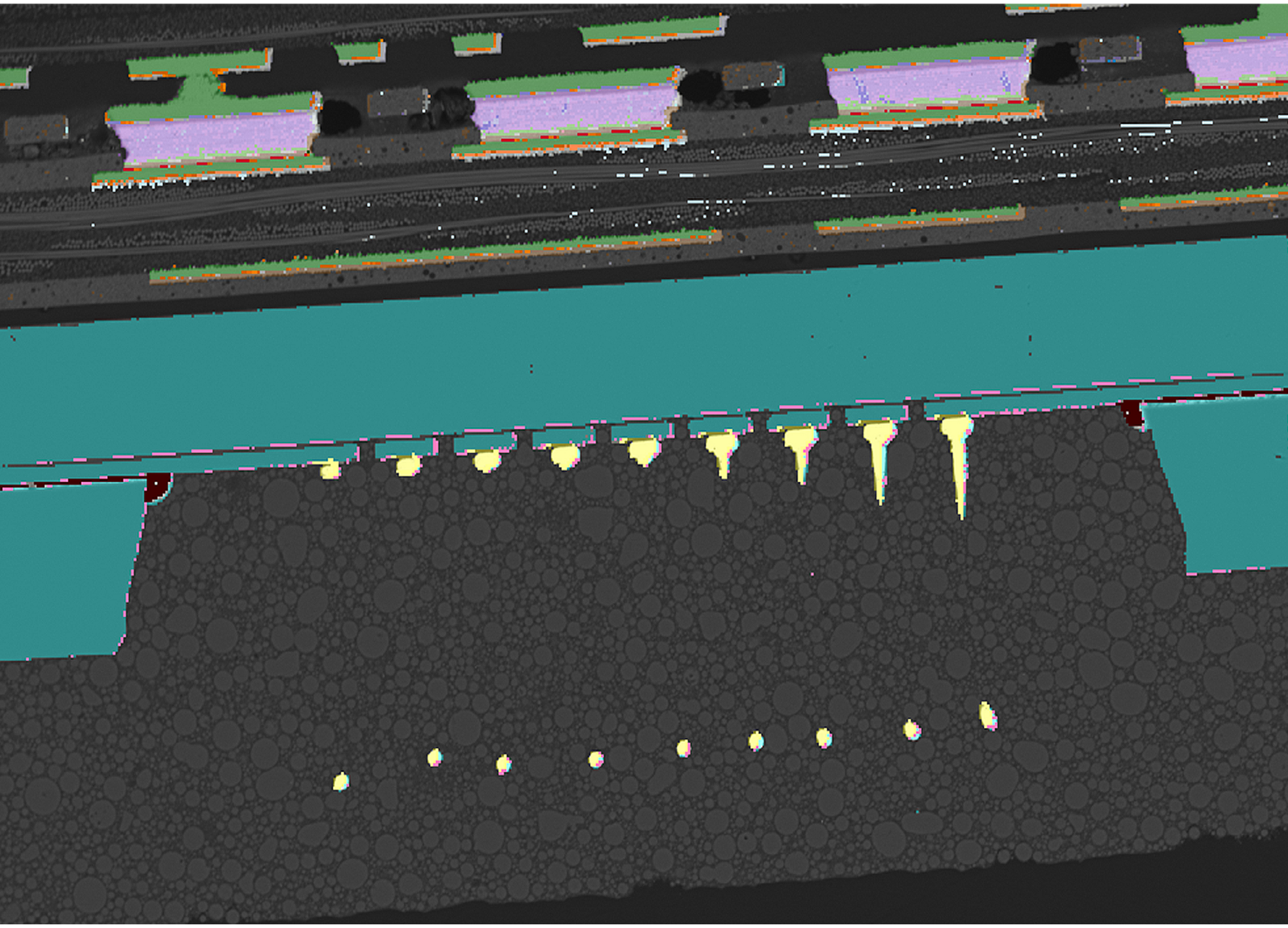
White Paper



e-waste Characterization

for Metal Recycling with ZEISS Mineralogic

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By the end of 2018 more than 50 million tonnes of electronic waste or WEEE (Waste Electronics and Electronic Equipment) will be produced with an estimated value of 50 billion euro of metals contained inside (Balde et al., 2017). These startling figures therefore outline a substantial opportunity and resource for the sustainable extraction of precious metals (and possibly critical metals) from WEEE recycling.

To unlock this potential resource, there are challenges to overcome in the recycling process. One of the greatest challenges is therefore in the characterization of the mobile phone components and crushed material to understand the "mineralogy", texture and associations. Once an understanding of these key characteristics is gained, it is a simpler process to design and optimize a process to recover these target metals.

Whilst this type of characterization is new to the world of e-waste recycling, the framework for characterizing these components is already clear and widely practiced in mining with the application of Process Mineralogy and Geometallurgy.

In this white paper, we outline how we are using Automated Quantitative Mineralogy (AQM) – ZEISS Mineralogic Mining – to conduct a material characterization study (mineralogy, texture and association) of these components that can then be used to understand and optimize the recycling process.

Introduction

In electronic waste, the main concentration of precious metals is found within Printed Circuit Board (PCB) (Cucchiella et al., 2015; Golev et al., 2014; Hagelüken and Meskers, 2008) but, also in screens, monitors and other parts of small IT equipment (Buchert et al., 2012). In these components, Au and Ag can be found in concentrations of up to 300 g/t and 3,500 g/t respectively.

Critical metals such as Ta, In, REEs and Co are also abundantly present, often in much higher concentrations than in typical ores currently mined. These impressive grades therefore make e-waste an interesting resource for these precious and critical metals.

Despite this, challenges in the collection and processing phases add complication and typically combine to lower economic viability of these resources. Low recovery is often due to design complexity and insufficient liberation of the critical and precious metal bearing components in the devices (Reuter et al., 2013).

This study outlines to what means electron microscopy and the ZEISS Mineralogic (Automated Quantitative Mineralogy) solution can be used to characterize e-waste. In this application, the use of automated and quantitative mineralogy is much the same as with conventional applied mineralogy applications.

Methodology

Discarded smartphones were examined in two different states. First where a smartphone was sliced in parallel sections to have a throughout interior look in the phone. Second crushed mobile phone particles are set in resin and polished for ZEISS Mineralogic analysis.

A ZEISS Mineralogic analysis was carried out with a 30 keV electron beam and a 5 µm mapping-pixel resolution. ZEISS Mineralogic is unique, in that it uses fully quantitative EDS analysis and applies in-built matrix corrections and peak deconvolutions to each acquired EDS spectrum. These spectra are then quantified to provide measured chemical composition of each analysed point and thus allow phase classification based on the directly measured wt% contribution of the elements present.

This composition is then assigned a phase classification based on pre-defined rules based around the elemental composition (measured wt%), BSE value and elemental ratios and also a combination of morphology / texture and chemistry.

This quantitative approach allows more accurate measurements of the elemental content and thus produces more accurate phase classifications, assay and elemental deportment data which were required for this study to be successful.

Results

ZEISS Mineralogic analysis quantified and provided key information of the;

1) Mineralogy / Phase compositions / Chemistry – through the ability to quantify the chemistry and thus classify the phases based on their measured chemistry.
2) Assay and Distribution – Directly measured chemistry from the sample and subsequent phase classifications where used to produce elemental distribution data.
3) Phase, Textural associations and Liberation – quantitative measurements on the abundance of each phase therefore allows for data to be provided on the associations of phases with one-another.

Figure 1 shows a section of the smartphone through the PCB with the classified different metals and alloys within.

Relevant information for such samples are weight % for the different compositions in the sample, association data and in minor extent liberation data which is often more easily deduced from the association data. The Weight % data for the given slice is given in Figure 2. From these data, it can easily be deduced how a metal is deported between the different phases.

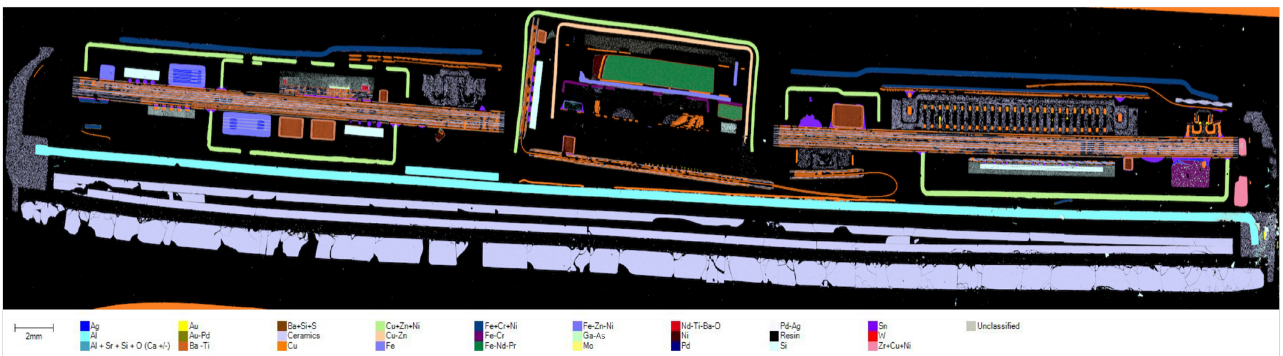

Figure 1 *Fully classified image of a section through the PCB and main camera of the phone*

Au is the most valuable metal contained in this sample and mainly occurs in its native state. It is also found as an Au-Pd alloy coating on Cu and Ni sheets. Some textural associations of Au show that it is locked in SiO2 wires or in close association with Ga-As components.

Figure 3 is a detailed section through a part of the PCB. In this example, Au forms a bridge between Ta, W and Mo. This example clearly displays the design complexity and the scale of these e-waste components.

A shredded smartphone was also studied to provide quantitative and statistically valid data on how the mobile phone components behaved during this process. The most important aspects of this data are the focus on the textural associations and liberation of the most value phases.

Figure 4 shows the ZEISS Mineralogic map and can be used to visualise the phases distribution and textures.

Figure 5, shows the typical associations of native gold which is mostly split between Ceramics-Silica (40.4%), referring to the wires and Au-Pd, referring to coating on Cu and Ni sheets (35.8%).

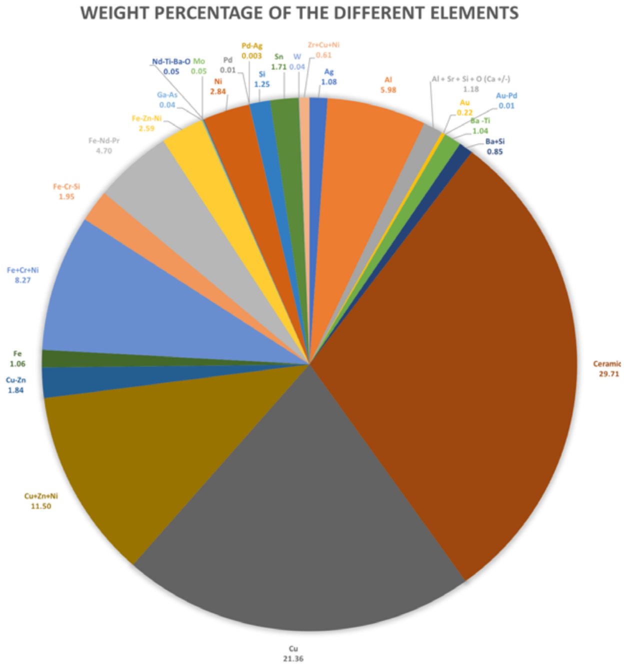

Figure 2 Weight percentage of all components of the slice shown in Figure 1.

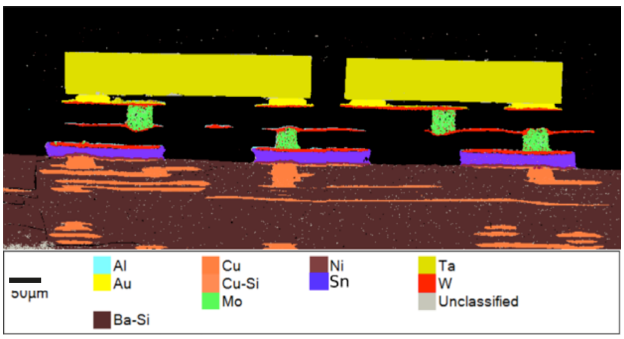

Figure 3 Detailed section of the PCB. Result of analysis at a resolution of 2 µm.

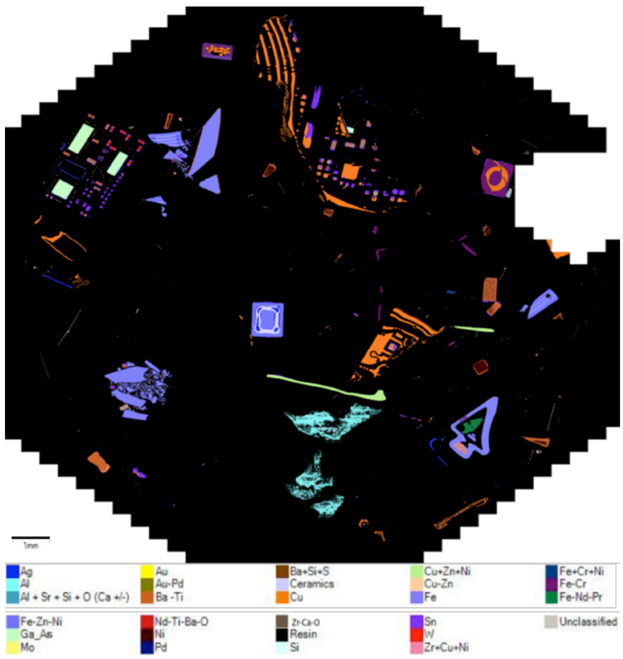

Figure 4 Fully classified image of shredded phone particles.

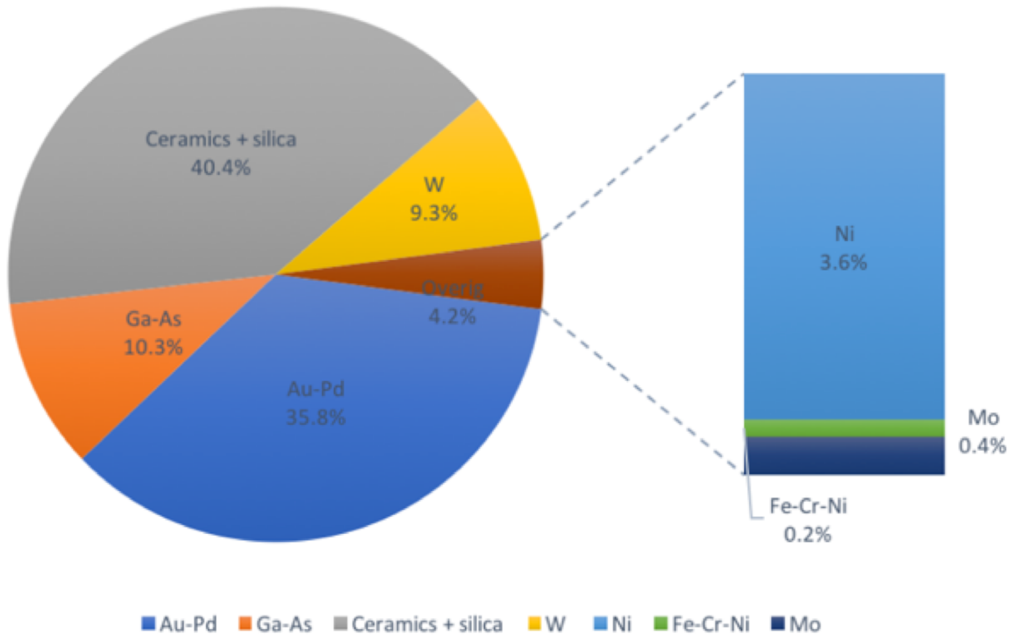

Figure 5 *Associated elements of Au based on Figure 4.*

Discussion

ZEISS Mineralogic by ZEISS provides a reliable and flexible solution to the quantification of e-waste components and their textures and associations. This data is key in understanding;

1) The abundance and chemical composition of the target phases (i.e. Au).
2) The textural association of the target phases with other components in the mobile phone (i.e. Au-Pd dominantly found as plating Cu and Ni components).
3) The liberation of the target to understand the response of these components during shredding and to understand the required processing next steps and recovery potential.

This study illustrates the added value ZEISS Mineralogic can provide in understanding complex phases, association and textural relationships. Following the blueprint designed for the application of AQM in Process Mineralogy and Geometallurgy, it highlights the power of this technique at material characterization tool for e-waste recycling.

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