Versatile chemical extraction processes for valuable metals in WEEE

Within the project RECYVAL-NANO, one of the main tasks was related with the development of chemical solvent extraction processes for the recovery of valuable metals. For this reason, Chalmers University of Technology was working with different routes for the recovery of indium and yttrium present in the waste streams coming from Flat Panel Displays (FPD) wastes.

As a result of mechanical recycling work and chemical analyses, it was concluded that there are several materials of interest for the FPD recycling, resulting from different mechanical treatments of the FPDs. In particular, two fractions were of interest, one of simple composition (few metal components) and one of more complex composition (many different elements).

- This simpler material was crushed glass coming from the disassembled FPD panels (CG) which contains mainly indium.
- The second material was a mixed powder (MP) resulting from a crushing process from a mixture of parts of FPD waste. This powder contains many metals, among them yttrium.

Based on these material fractions, different processes were proposed for the recovery of indium and yttrium. Here, the main process routes are explained, including the results obtained for these processes.

SOLVENT EXTRACTION ROUTES

Two solvent extraction routes were developed, one for the CG simpler material and focused on the recovery of indium and one for the more complex material, MP for the recovery of yttrium and also indium.

The process focused on the recycling of indium from CG used 1 M H2SO4 as leaching acid and DEHPA as extractant. An indium purity >90% was achieved by two counter-current extraction and stripping stages using 0.2 M DEHPA diluted in kerosene and an addition of 15%vol TBP.

In the other process where yttrium but also indium was recovered from MP, the process was using 1 M HCl as leaching acid and Cyanex 923 and DEHPA as extractants. This process was so much more complicated than the one starting from CG due to the complexity of metals present and also the low concentration of these.

SELECTIVE LEACHING/PRECIPITATION ROUTES

The relatively low concentration of valuable metals obtained in solutions after leaching either glass (CG) or mixed waste (MP) from FPDs means large treatment facilities. The reason for this is the relatively high L/S values required to extract the entire metal content. Considering the valuable metals it would be more effective to pre-treat the leach solution and precipitate the bulk metals (in this case Al and Fe). Thus, an alternative route based on selective precipitation steps was proposed.

In order to reduce the volume size the metals are immediately precipitated after dissolution with hot 1.0 M hydrochloric acid (lower concentrations can also be used). The majority of metals are leached by the hydrochloric acid excluding some metals, for example gold. Hydrochloric acid was used since it gave the best dissolution of indium, but sulfuric acid is a possible alternative to the hydrochloric acid. The precipitation can be done in multiple ways, here sodium hydroxide was used.

The precipitate was then be re-dissolved in order to increase concentration since this way excludes the matrix of the material (glass, plastics, etc.) that was in the original sample. The re-dissolution was done in selective leaching steps to investigate if the precipitate shows equal ability to utilize selective dissolution as the original material.

An ammoniacal selective leaching step was tested in order to selevtively leach zinc simultaneously with aluminium and soldium hydroxide, however has been abandoned due to very low yeald of zinc extracted. This does, however, neglect the possibility of leaching other metals such as nickel during the ammonium-based leaching step and the ammoniacal leaching can be added if deemed appropriate depending on the composition of the waste.

Depending on the residue composition certain metals can be selectively leached from the residue using concentrated sodium hydroxide (5-10 M) or sodium hydroxide at high pressure and temperature (high pressure was not investigated but remains a possibility).

After the sodium hydroxide treatment any silver and mercury can be recovered using a thiosulfate leach solution. The original material can also be treated with a thiosulfate solution in order to recover gold. This was demonstrated to yield all the gold for the shredded glass fraction.

After the selective dissolution steps the residue can be fully re-dissolved using hydrochloric acid or sulfuric acid and a number of choices are available to recover the indium and rare earths. Sulfuric acid dissolves the indium and it prevents the re-dissolution of some metals, especially lead and strontium, which is good since they can contaminate the rare earths otherwise. Hydrochloric acid can be useful as well since a chloride based separation can be used on the solution of re-dissolved material.

The optimal choice can differ between the glass fraction (CG) and the mixed FPD fraction (MP), since the glass contains very low amounts of rare earths an acidic extractant base extraction system can be used, such as Cyanex 272 in kerosene. For the mixed FPD fraction a dual mechanism extraction system based on Cyanex 923 and Cyanex 272 was used. This allows all the indium and rare earth metals to be extracted from either a sulfuric or hydrochloric based system given a sufficiently high pH at the end of leaching. A separation can then be achieved using hydrochloric acid strip since the rare earths easily strip in such conditions leaving indium extracted. The rare earths can be recovered by selectively precipitating them with oxalic acid after strip. The indium can also be selectively extracted from the rare earths given an acidic chloride aqueous phase of sufficient chloride concentration.

It could be pointed out that this material conforms to being called WEEE in a broader sense and that the new process is suitable, in whole or parts, for WEEE recycling in general, if the WEEE in question has significant amounts of Au/Ag/Ln/Y/In/Zn.

The most important next step could be an investigation into burning the initial precipitate before re-leaching in order to create iron oxides instead of hydroxides to change the leaching behavior (reducing iron leaching levels). The dual mechanism system can also be further strengthened by showing that stripping with nitric acid (suitable pH) can separate extracted indium from iron(III). This was shown in some screening experiments but not investigated in detail.

In the following Figures, it can be seen as conclusion the flow-sheet proposed for a more complex fractions like MP and for a simpler fraction like CG.

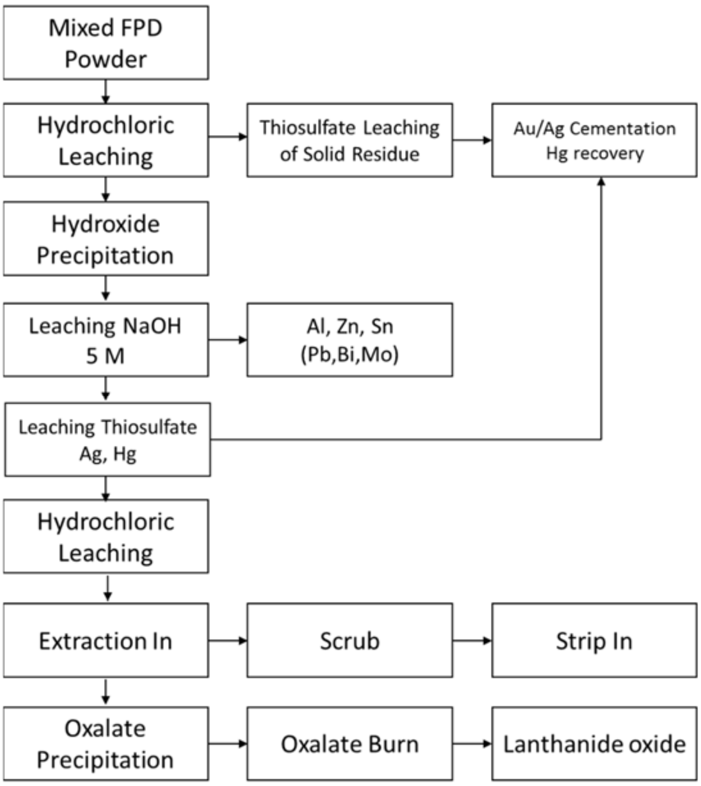

Figure 1. Treatment process flow-sheet for a fine fraction of mixed FPD powder (MP). This recovers gold, silver, rare earths and indium (simplified, there can be some purification steps excluded).

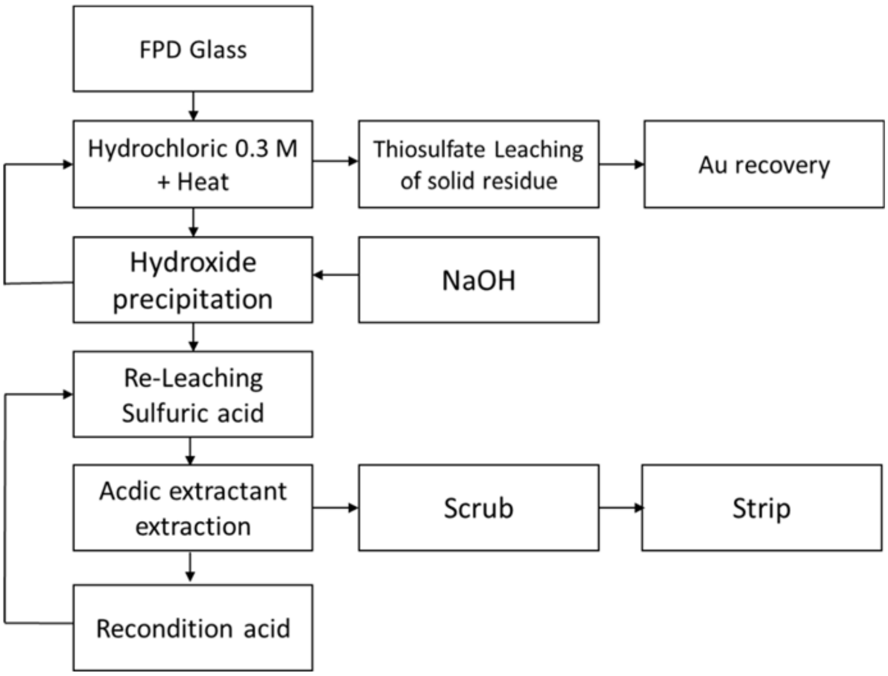

Figure 2. Treatment process flow-sheet for FPD crushed glass (CG). This recovers gold and indium.