

International Solvent Extraction Conference – ISEC 2011

Refining and processing of platinum group metals at the 19th ISEC

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The 19th International Solvent Extraction Conference (ISEC 2011), with the theme of building bridges between industry and academia (1, 2), was held in Santiago, Chile, between 3rd and 7th October 2011. It was the first time this conference had been held in South America and it was located there to recognise the large amount of solvent extraction research being carried out to support the continent's mining industry, especially copper mining. The conference was attended by over 350 delegates from around the world and over 200 papers were presented.

Presentations were given in three parallel sessions covering a range of eight different topics. The session topics were:

- Industrial practices and new projects;
- Hydrometallurgy and metals extractions;
- Nuclear fuel reprocessing;
- Process chemistry and engineering;
- Analytical and preparative applications;
- Biotechnology, pharmaceuticals, life science products and organic products;
- Fundamentals;
- Novel reagents, materials and techniques.

There were also eight excellent plenary lectures over the course of the conference with poster sessions interspersed between the oral presentations. Although the focus of the metal refining in South America is on Cu there were still a number of papers and posters presented on developments in platinum group metal (pgm) refining and processing. This review only covers the papers and posters which involved the pgms. Comments on the papers are split into the different session topics under which they were presented and their ISEC paper numbers (as found on the CD of papers accompanying the proceedings (1)) are given in brackets.

Hydrometallurgy and Metal Extractions

Sarah Belair (Johnson Matthey Technology Centre (JMTC), UK) and coworkers from Anglo Research, South Africa, (ISEC Paper No. 54) presented an interesting paper on a new solvent extraction system

that could be used to separate ruthenium, iridium and rhodium. The process involved nitrosylating the Ru to produce extractable Ru nitrosyl species. These species, along with some Cu can then be separated from the non-extractable Ir(III) and Rh(III) species using a 0.5 M amide solution in TMCH. The raffinate could then be oxidised to produce a solution containing Ir(IV) and Rh(III) from which the Ir(IV) could be extracted using the same solvent system. Due to the success of this process a degradation study was carried out which simulated the industrial process and the results were presented in a separate paper (ISCE Paper No. 178) in the Fundamentals section.

Fundamentals

Following on from Sarah Belair's paper (ISCE Paper No. 54) on the separation of Ru, Ir and Rh, Barbara Breeze and coworkers (JMTC, UK) (ISCE Paper No. 178) presented a poster detailing the degradation study carried out on the proposed solvent system (Figure 1). The stability of the organic phase (0.5 M amide in TMCH) in both acidic non-oxidising conditions and acidic oxidising conditions was determined. In the case where no oxidant was added the performance of the organic phase remained constant over the course of the trial. However in the case where oxidant was added there was a noticeable decrease in extraction

performance when using the aged organic phase. Gas chromatography-mass spectrometry (GC-MS) data revealed that the organic phase had degraded forming mostly chlorinated derivatives of TMCH. This showed that the oxidising conditions present in the Ir extraction caused the TMCH to degrade casting doubt on the suitability of this process (Figure 2).

Another solvent extraction system was investigated by Basudev Swain (Indiana University Southeast, USA) and coworkers from the Korea Institute of Geoscience and Mineral Resources, Korea, (ISEC Paper No. 182) in which they used Alamine 300 (tri-*n*-octylamine) to separate platinum and palladium from a chloride medium. Two methods of separation were investigated: the selective extraction of Pt leaving Pd in the raffinate; and the co-extraction of Pt and Pd, followed by selective stripping of Pt first and then Pd. A very high separation factor between Pt and Pd was achieved when the organic phase (0.005 M Alamine 300 and 5% TBP in kerosene) was contacted with a solution of Pt and Pd in a saturated aqueous sodium chloride solution. The separation factor dropped by a factor of almost 20 when 0.5 M hydrochloric acid was used instead of saturated NaCl. The selective stripping of Pt could be achieved by using 0.05 M sodium thiocyanate followed by the selective stripping of Pd using 0.1 M thiourea in 0.5 M HCl.

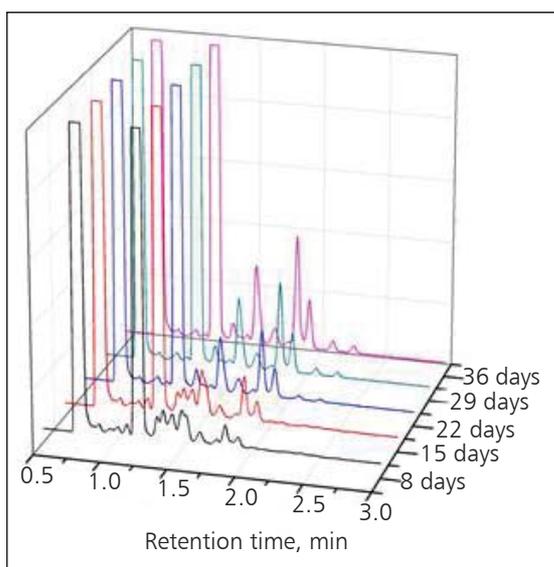


Fig. 1. The gas chromatography-flame ionisation detector (GC-FID) trace of the impurity region of the organic phase during the extraction degradation study of ruthenium

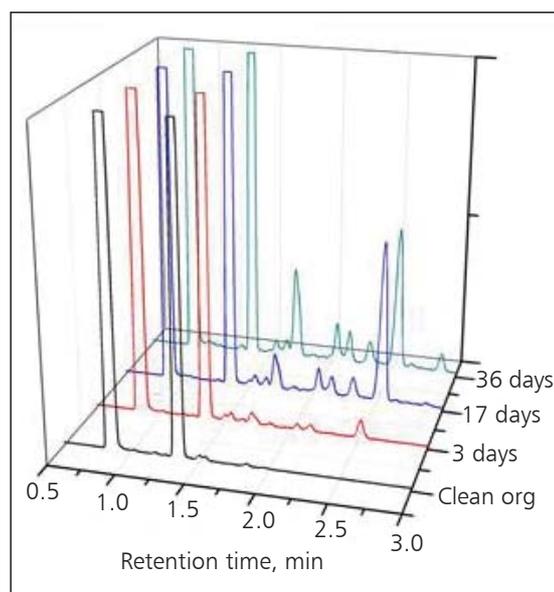


Fig. 2. The GC-FID trace of the impurity region of the organic phase during the extraction degradation study of iridium

Matthew Wilson (The University of Edinburgh, UK) and coworkers from JMTC, UK, (ISEC Paper No. 188) presented a paper evaluating the performance of a simple aldoxime (4-tert-butylbenzaldehyde oxime) and ketoxime (4-tert-butylacetophenone oxime) as extractants for Pd(II) from acidic chloride solutions. The aldoxime showed faster extraction kinetics and reached a higher level of extraction than the ketoxime but this could have been because the ketoxime is more susceptible to hydrolysis and not because the aldoxime is intrinsically a better extractant.

The idea of moving away from the traditional organic-aqueous solvent extraction systems seems to be a growing area of interest with the possibility of replacing the organic phase with an aqueous polymer phase. Kun Huang and coworkers (Institute of Process Engineering, Chinese Academy of Sciences, Beijing, China) (ISEC Paper No. 190) demonstrated the possibility of using aqueous two-phase extraction to extract Pt, Pd and Rh. This technique avoids the use of an organic solvent which has been proposed to be advantageous for safety and environmental reasons. EO-PO in sodium sulfate solution was used as the second aqueous phase and it was found that the extraction occurred by ion exchange at the interfaces of the micellar microphases produced during mixing. By changing the concentration of Na₂SO₄ it was possible to control the mass transfer of the different metal ions into the micelles.

Novel Reagents, Materials and Techniques

John Ralston (Ian Wark Research Institute, University of South Australia, Australia) and coworkers from The University of Tokyo, Japan, (ISEC Paper No. 214) presented a paper on process intensification of solvent extraction systems using microfluidics. Microfluidics involves using small chips to contact two phases under laminar flow conditions resulting in a very high surface area to volume ratio as shown in Figure 3 (3). He showed that these chips could cope with fine silica particles in the feed without forming crud. Although the examples presented involved Cu extraction this technology has the potential to increase the efficiency, yield and containment of a solvent extraction process and so is of great interest to pgm refining.

The extraction of metals from spent nuclear fuel has the additional problem of ionising radiation and so organic degradation can be a large problem. Yuji Sasaki (Japan Atomic Energy Agency, Japan) and coworkers from Ibaraki University and the Tokyo Institute of Technology, Japan, (ISEC Paper No. 219) presented a paper detailing a novel complexing agent for Pd(II), technetium(VII) and rhenium(VII) for the recovery of these metals from radioactive waste. Several IDAAs were synthesised and showed promising extraction properties from a nitric acid medium. Little degradation was observed when the extractant was exposed to gamma radiation and acid suggesting that with further development these could be promising extractants.

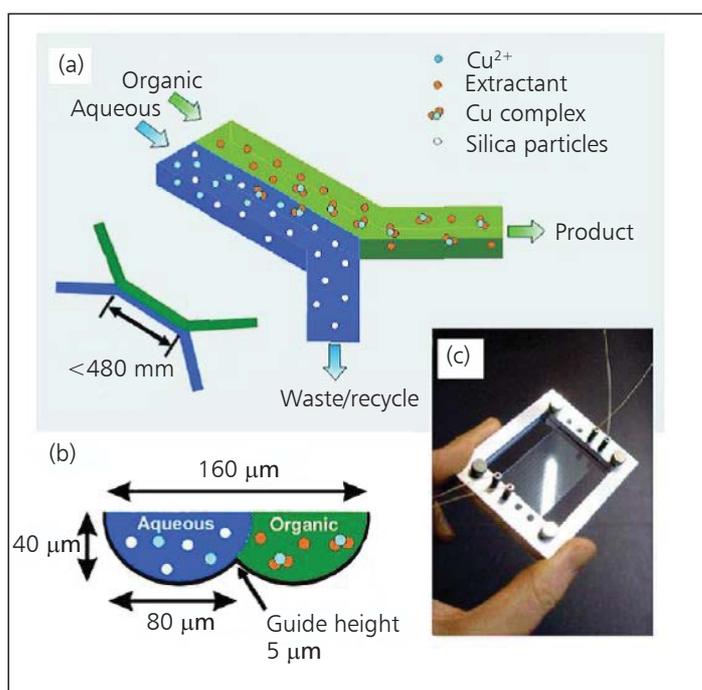


Fig. 3. Schematic of a solvent extraction microchip: (a) two liquids meet, flow in parallel through the extraction channel, and separate at a Y-junction; (b) cross-section of the extraction channel, showing the channel dimensions and the liquid-liquid interface. Flow is partly stabilised by a guide structure; (c) image of microchip mounted in an aluminium chip holder with fluid connections (Reprinted from (3) with permission from Elsevier)

Glossary

TMCH:	3,3,5-trimethylcyclohexanone
EO-PO:	polyethylene oxide-polypropylene oxide random block copolymer
IDAA:	2,2'-(imino)bis(<i>N,N</i> -dialkylacetamide)
TBP:	tributyl phosphate

Conclusions

Once again the ISEC was a highlight on the calendar for anyone working in the field of solvent extraction. The conference, with its very well attended short course on the solvent extraction of base metals and its technical tour of some of Chile's Cu mines and plant (**Figure 4**), was a great success. Solvent extraction remains one of the most attractive options for pgm separation and thus this is the best forum to share ideas. The organisers succeeded in bringing engineers, researchers, academics and consultants together to discuss the latest issues, best practices and new technologies in the field of solvent extraction and they are to be congratulated on a very well-run conference. The next ISEC conference, ISEC 2014, will be held in Würzburg, Germany, between 8th and 12th September 2014 (4).



Fig. 4. Copper cathodes in copper electrowinning plant in Chile (Image copyright Emma Schofield, Johnson Matthey Technology Centre, UK)

References

- 1 ISEC 2011: <http://www.isec2011.com/> (Accessed on 2nd May 2012)
- 2 ISEC 2011 Programme: http://www.isec2011.com/evento2011/images/stories/programa/11_isec/index.html (Accessed on 2nd May 2012)
- 3 C. Priest, J. Zhou, R. Sedev, J. Ralston, A. Aota, K. Mawatari and T. Kitamori, *Int. J. Miner. Process.*, 2011, **98**, (3–4), 168
- 4 ISEC 2014: <http://events.dechema.de/events/en/isec2014.html> (Accessed on 2nd May 2012)

The Reviewer



Neil Davidson has been involved in research into a variety of metal separation techniques while working for Johnson Matthey in the Refining Research group since 2008. The focus of the work has been on pgm and gold separation with the long term goal of improving the pgm refineries of Johnson Matthey in the UK and Anglo American Platinum in South Africa.