"Precious Materials Handbook"

Edited by U. Sehrt (PR Beratung Sehrt, Germany) and M. Grehl (Umicore AG & Co KG, Germany), Umicore AG & Co KG, Hanau-Wolfgang, Germany, 2012, 576 pages, ISBN: 978-3-8343-3259-2, €89

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The "Precious Materials Handbook", edited by Ulla Sehrt and Matthias Grehl and published by Umicore, the global materials technology and recycling group, aims to give an overview of how precious and other metal-based materials and compounds contribute to crucial applications, ranging from electronics to emissions control. This it does extremely well, emphasising that metal-based materials, through their unique and fundamental properties, form an integral part of everyday life in tools, equipment and devices, and in synthesising other products *via* catalysis. The book focuses on four 'mega-trends': resource scarcity, emissions control, electrification of vehicles and renewable energy production, which emerge throughout each of the ten main chapters. Readers who are interested in platinum group metals (pgms) will find much valuable information in this book, from metallurgy and the refining of pgms, to fundamental chemistry and the use of pgms in applications such as vehicle emissions control and fuel cells. Each chapter is written by a group of internationally-recognised experts and focuses on current technology trends as well as assessing their future potential. Although containing a great deal of technical information, including a detailed appendix of phase diagrams, thermodynamic data and crystal lattice data, the book is written in an accessible way to appeal to specialists and non-specialists alike. From this large, multidisciplinary book a sample of the chapters and sections relating to pgms have been selected for this review.

Sustainability and Recycling

The first chapter, 'Availability of Metals and Materials' by Christian Hagelüken, Ralf Drieselmann and Kris Van den Broeck, focuses on sustainability. The concept of 'metal scarcity' is introduced, the difference between absolute, temporary and structural scarcity is explained, and the importance of reducing losses in the production, manufacturing, use and recycling of metals is emphasised. The pgms, which offer many

unique properties making them suitable for various applications, have the potential to contribute to human wellbeing over the long term making it essential to understand supplies of the material as well as the uses, markets and market drivers (**Figure 1**). The chapter also contains an overview of metal trading, pricing and management which is essential reading for anyone wishing to understand the complex dynamics of metal markets.

Building on the theme of sustainability, the next chapter, 'Recycling and Loop Concept for a Sustainable Usage' by Christian Hagelüken and Matthias Grehl, focuses on the recycling of metals, including the opportunities and challenges of recovering metals from the 'mine above ground' – for example pgms in spent automotive catalysts. The reader is introduced to the concept of the life cycle of pgms, building on the work of Christian Hagelüken of Umicore, one of the chapter's co-authors. Two distinctly different life cycle structures are identified – the first being 'closed loop' cycles such as those for recycling pgm-containing oil refining catalysts where the metal is part of an industrial product owned by and located at an industrial facility. Typically the metal has a high concentration and economic value and this facilitates recovery. By contrast, 'open loop' recycling systems are generally confined to consumer products such as autocatalysts and mobile phones where the product frequently changes ownership. The metal content per unit is low but the huge product volumes in use represent a significant and valuable resource. For more about this, see (1).

Also in this chapter, recycling techniques are introduced, with details given of Umicore's Integrated Smelter-Refinery Process which is capable of recovering precious and base metals from complex feed materials. The often complementary processes of pyrometallurgy and hydrometallurgy are discussed, and the reader is given an overview of commercial precious metal refining.

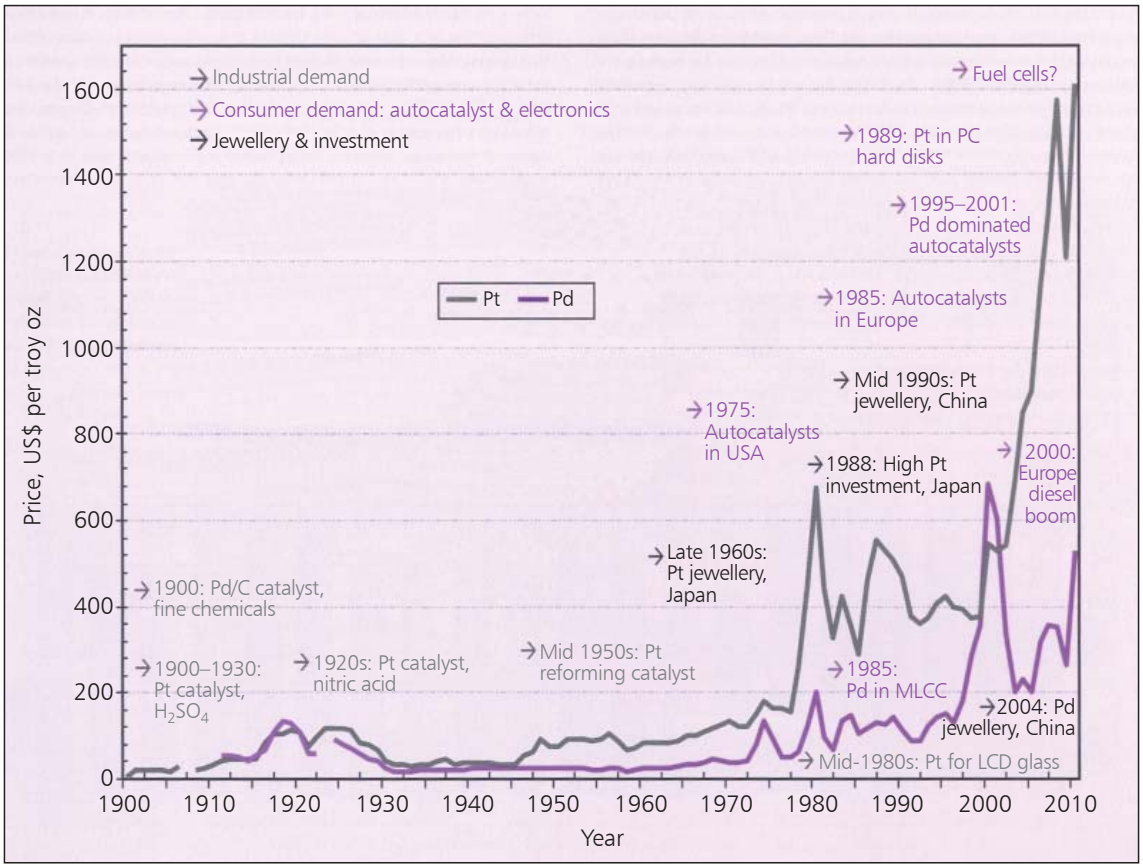

Fig. 1. Long-term development of prices for platinum and palladium and application milestones

Properties and Applications of Precious Metals

The largest chapter, simply titled 'Precious Metals', is written by Matthias Grehl, Bernd Kempf, Ingo Kleinwächter, Francis Van den Broeck, Andreas Brumby, Sven Jantzen, Uwe Manz and Peter Braumann and comprises around a third of the book. It is devoted to the properties and industrial applications of precious metals (gold, silver and the pgms). There is a very brief introduction to pgm supplies and mining followed by a more substantial section on the primary winning and refining of pgms. Properties of precious metals and their alloys are then covered in a section that gives a wealth of technical information in the form of data tables on electrical resistivity, thermal expansion coefficients and corrosion stability. The next section outlines the basic principles of precious metal compound synthesis, with a focus on the industrial applications of both organometallic and inorganic pgm compounds. The importance of platinum compounds is further illustrated with a brief section on how platinum anticancer drugs work (2). Selected applications of precious metals are covered in the final section of this chapter, including platinum's unique properties of mechanical strength and corrosion resistance which make it suitable for high purity glass production (**Figure 2**).

The coverage of precursors and preparation of heterogeneous catalysts in the above chapter, 'Precious Metals', covers the fundamentals of this significant area of application for the pgms. Vehicle emissions control, arguably the most important application of heterogeneous catalysis from an economic and technical point of view, is the main subject of the following chapter, 'Materials for Heterogeneous Catalysis' by Jürgen Gieshoff and Barry W. L. Southward. As is remarked on in the preface to the chapter, the development of high performance emissions control catalysts capable of removing multiple pollutants simultaneously while interacting automatically with engine control systems is one of the most impressive achievements in heterogeneous catalysis, all the more so when it is considered that this is done profitably on a large scale within the short timeframes of the automotive industry. The subject of exhaust gas catalysis is given a comprehensive treatment, covering the reactions, materials used and characterisation of emissions control catalysts (**Figure 3**). Three-way catalysts, diesel oxidation catalysts, diesel particulate filters and solutions for NOx control are then looked at in turn with the catalytic processes, system layout and outlook for the future discussed in each case.

In the chapter on 'Homogeneous and Industrial Catalysis' by Ralf Karch, Steven P. Nolan (EaStCHEM

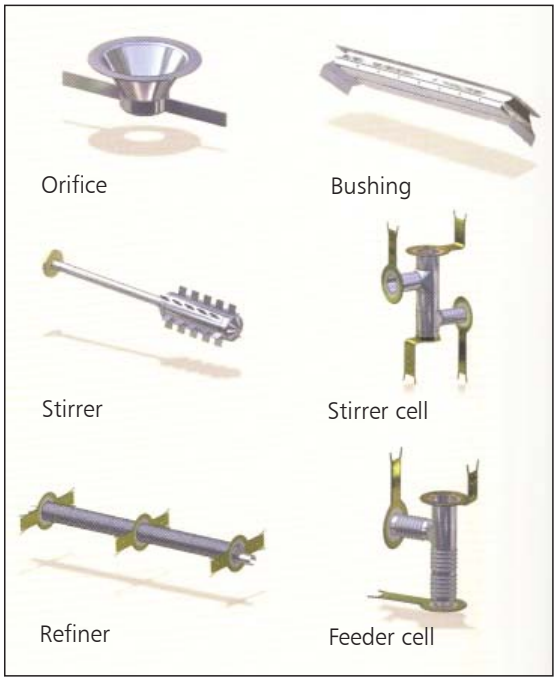

Fig. 2. Examples of platinum group metal components dedicated to the glass industry

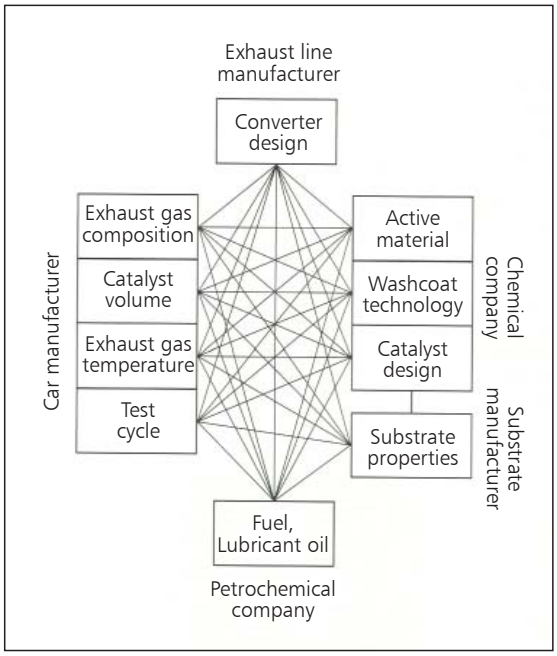

Fig. 3. Parameters that have a major influence on the function and performance of a pgm-catalysed automotive exhaust gas aftertreatment system

School of Chemistry, University of St Andrews, UK) and Sven Jantzen, the theme of sustainability emerges strongly once again. The chapter focuses on various pgm-catalysed reactions that require less energy and generate less waste than alternative stoichiometric routes as a result of being atom-efficient. One example given is the development of the Monsanto acetic acid process, a "textbook example of the beauty, simplicity and power of homogeneous catalysis", using a rhodium catalyst (**Figure 4**) (3). Other sections in this chapter focus on the economic and environmental benefits of pgm catalysis, including the hydrogenation of alkenes, an atom-economic process without any side products or waste reagents performed mostly by ruthenium, rhodium or iridium complexes. The importance of palladium-catalysed cross-coupling reactions is covered with a look at the reactions of Heck, Negishi and Suzuki (subject of the recent Nobel Prize in Chemistry 2010 (4)) and other cross-coupling reactions as well as their use in commercial scale synthetic, pharmaceutial, agrochemical and electronic applications. This chapter ends with a whistle-stop tour of other catalysts used in the chemical industry, for instance platinum-based gauzes for the catalytic oxidation of ammonia to generate nitric acid.

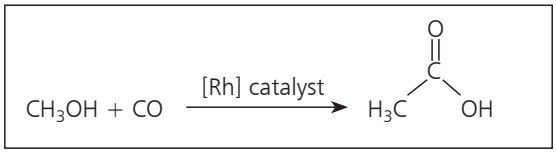

Fig. 4. The rhodium-catalysed Monstanto process for the production of acetic acid

Summary

Overall, the "Precious Materials Handbook" contains a wealth of information on the essential role that pgms and other precious metals play in the modern world, the roles they may play in future to address environmental problems, and the importance of efficient use of materials, as well as recycling, in ensuring sustainability for the future. The book champions the acceleration of research and development of new materials. It is amply supported by many references, is well laid out and impressively illustrated, with colour coded chapters and many useful diagrams and tables. The only major criticism of the Handbook is its lack of an index, making it difficult to navigate between the many detailed chapters. However there is an online, searchable preview (5) which may make up for this lack and can be accessed *via* the publishers' website. This book should find its way onto the shelves of many a practicing chemist as well as anyone with more than a passing interest in how precious materials contribute to the world we live in.

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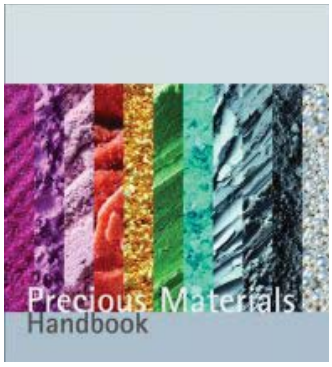

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The Reviewer

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