

## On the Occasion of the IPA's 25th Anniversary We Present: 25 Prominent and Promising Applications Using Platinum Group Metals

The International Platinum Group Metals Association (IPA) was founded in 1987 and has since then dedicated its work to promoting the use and knowledge of Platinum Group Metals (PGMs). PGMs play a vital role at the heart of everyday living. One in four goods manufactured today either contains PGMs or has PGMs play a key role in their manufacture. These noble metals will also be central to our future choices in the fields of power generation, transportation, healthcare and a host of other areas.

PGMs are uniquely durable and can be used extremely efficiently meaning that a very little goes a very long way. Their recyclability means that they have a very long lifecycle, allowing them to contribute significantly to the protection of the environment by reducing any negative impact which is normally associated with metal waste disposal. Over 96 per cent of PGMs collected for recycling are successfully recovered through highly-efficient processing techniques.

### 1. Aircraft Turbines

Civilian air fleets are primarily propelled by turbofan jet engines. Air is forced into the combustion chamber by a series of fans and compressors, then mixed with fuel and ignited. The gas temperature augments as the gas is compressed throughout the engine, and the efficiency of the engine rises dependent on this gas temperature. Advances in technology have led to an increase in the operating temperature, meaning that the materials used have to withstand higher and higher temperatures (1500°C or more). In order to protect the blades from these extreme temperatures, internal air cooling and coatings are used. Also, the blades must be protected against corrosion. Platinum-aluminide coatings are a well-established technology to provide protection against corrosion and their surface allows a further thermal barrier layer to be applied that protects the blade from high temperatures. ■

### 2. Autocatalysts

By far the largest use of PGMs today is for automobile catalytic converters, a pollution control device fitted to cars, trucks, motorcycles, and non-road engines. Platinum, palladium and rhodium are coated onto a substrate housed in the exhaust system and act as catalysts to reduce levels of carbon monoxide, hydro-

carbons and oxides of nitrogen to legislated levels. Autocatalysts convert over 90 per cent of hydrocarbons, carbon monoxide and oxides of nitrogen from gasoline engines into less harmful carbon dioxide, nitrogen and water vapour. Autocatalysts also reduce the pollutants in diesel exhaust by converting over 90 per cent of hydrocarbons, carbon monoxide and particulate matter into carbon dioxide and water vapour. Diesel engines operate at lower temperatures than gasoline engines and run with a leaner gas stream containing lots of oxygen. Under these conditions platinum is a more active catalyst for the conversion of CO and hydrocarbons to harmless emissions. However, the addition of some palladium to the platinum catalyst can improve its thermal stability. This is an advantage when reducing diesel particulate matter (PM) from the exhaust. This process involves trapping the PM, or soot, in a filter and then raising the temperature of the system to oxidise the soot to carbon dioxide. At these higher temperatures palladium improves the thermal durability of the catalyst, helping it perform optimally for the lifetime of the vehicle.

As the number of cars on the road increases, further cuts in pollution per vehicle are needed to keep improving air quality. Many governments, including those of the fast growing emerging markets of Brazil, Russia, India, and China – the BRIC countries –, are putting legislation in place to catch up with the standards already implemented in the US, Europe and Japan. Catalysts are now also required on construction and agricultural equipment in many markets. ■

### 3. Cancer Drugs & Treatment

PGMs' role in the fight against cancer is twofold: as the active ingredient in chemotherapy drugs and in radio-active implants for radiation therapy (brachytherapy).

In the first of these, platinum compounds cisplatin, carboplatin and oxaliplatin have the unique quality of inhibiting the splitting and growth of cancerous cells. These compounds have been particularly successful in the treatment of testicular and ovarian cancers. More recently, palladium compounds have also been successfully tested.

In brachytherapy, implants are made of platinum with the active ingredient of iridium isotopes. These are placed directly into tumours, giving a high radiation dose to the tumour while reducing the effect on surrounding healthy tissue.

CarboPalladium-103, a radioactive isotope of palladium, is seeing promising applications in the treatment of prostate cancer. A newly emerging added area of research is potential use in the treatment of breast cancer. Here, still using the principles of brachytherapy, small seeds of Palladium-103, which releases very low doses of radiation over the course of two-months, are permanently implanted directly into the centre of the tumour. The procedure is done in an outpatient setting under local anaesthesia and the patient can go home after a few hours.

Rhodium foil has found its way into mammography x-ray machines. ■

### 4. Ceramic Capacitors

Multi-layer ceramic capacitors (MLCC) store energy in electronic devices in the form of an electrostatic field.

Typically, they consist of two coated conducting plates separated by an insulating material called the dielectric. They are used in broadcasting equipment, mobile telephones, computers, electronic lighting and high voltage circuits to name but a few applications, which all have one thing in common: they require a high reliability. Hence, due to their conductivity, durability, high temperature stability and oxidation resistance, palladium, and to a less extent platinum, are the materials of choice to coat multi-layer ceramic capacitors. ■

### 5. Computer Hard Disks

Computers have impacted on nearly every aspect of our professional and personal lives in the last two decades. The performance of computer hard disks is reliant upon a complex structure of layered materials, including platinum and ruthenium. Advances in consumer electronics and the increased need for data storage have seen hard disk drives expand their number of applications outside computing, and find use in digital TV recorders and home data centres. The adoption of perpendicular magnetic recording (PMR) technology saw an increase in the ruthenium content, in order to increase the data storage capacity per unit area. This is in keeping with the predictions of Moore's Law, which portends the doubling of data storage density every 18 months. ■

### 6. Crucibles

Because of their hardness, high melting points and high temperature stability PGMs are the perfect materials for industrial crucibles where high temperatures are necessary to produce chemicals and synthetics with the utmost efficiency.

The high temperature stability, melting points and corrosion resistance of platinum, rhodium, and iridium and their alloys allow for higher temperatures to be achieved in crucibles, a key factor in any chemical process.

The “nobility” of PGMs is also crucial. High purity conditions are required for these processes and PGMs' high temperature stability means that they do not contaminate the products being fabricated.

Due to its high melting point and resistance to chemical attack, iridium is the preferred material for crucibles used in the production of high purity single crystals of various metal oxides. Crucibles normally take the form of a cylindrical tube onto which a flat base is welded.

A variety of crystals are grown by a number of different techniques. The principal method of growth involves the pulling of a single crystal from a pool of molten salts contained in the crucible. ■

### 7. Dental

Palladium, and to a much lesser extent platinum, are the principal platinum group metals used in dental restorations. The metals are usually mixed with gold or silver as well as copper and zinc in varying ratios to produce alloys suitable for dental inlays, crowns and bridges. Small amounts of ruthenium or iridium are sometimes added.

The most common application is in crowns, where the alloy forms the core onto which porcelain and other materials are bonded to build up an artificial tooth. The aim of using PGMs in dental alloys is to provide strength, stiffness and durability whilst the other alloyed metals provide malleability. ■

### 8. Electrodes & Other Electronics

Platinum, palladium, rhodium and iridium are used to coat electrodes, the tiny components in all electronic products which help establish electrical contact between non-metallic parts of a circuit and control the flow of electricity.

Smaller amounts of palladium are used in conductive tracks in hybrid integrated circuits (HIC) and for plating connectors and lead frames.

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Ethylene absorber helps to reduce spoilage of fresh fruits and vegetables;  
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Palladium is widely used in electronics applications on account of its electrical conductivity and its durability. Palladium-containing components are used in virtually every type of electronic device, from basic consumer products to complex military hardware. Although each component contains only a fraction of a gram of metal, the sheer volume of units produced results in significant consumption of palladium. ■

### 9. Ethylene Absorber

Ethylene is an odourless, colourless gas. Whilst it can be man made, it is also often produced by plants and released into the surrounding atmosphere. Most fruit and vegetables are affected by ethylene as it is a plant hormone that accelerates the ripening of fruit.

Controlling the ethylene concentration in the atmosphere in which fresh fruits and vegetables are stored can have a significant impact on the level of spoilage, quality and shelf life which in turn helps reduce wastage. A palladium based ethylene scavenger named E+™ Ethylene Remover has been developed that helps to keep fruit and vegetables in tip top condition from harvesting and right through its journey to our homes.

Key to the palladium based technology is the interaction of a specific precious metal, palladium, with a carefully selected zeolite support to remove ethylene at low and room temperature. ■

### 10. Forensic Staining

The science of forensics is most famous for its detection of fingerprints and, in more recent times, the matching of DNA samples.

Osmium tetroxide (the metal's most common form) is used as a stain for fingerprints and DNA. It is relatively inert and does not harm the samples while efficiently revealing fats by binding at double bonds of unsaturated lipids and imparting a dense brownish or black colour. ■

## 11. Fuel Cells

Fuel cells are electrochemical devices that convert the energy of a chemical reaction directly into electricity, with heat and water as by-products. The fuel and oxidant (oxygen or air) are supplied externally, enabling them to continue operating as long as they are fed. So, unlike batteries, they never “run out”. Platinum and ruthenium play a large role in the technology.

Platinum is the catalyst which converts hydrogen and oxygen to heat, water and electricity. Palladium will likely also play a role in the fuel cell, as well, but it is unknown yet how big.

Since most fuel cells are hydrogen based and often require ultra pure hydrogen to operate effectively, palladium will be important to this technology, too. Palladium can be used to generate, purify, store and detect hydrogen, thus performing many important functions in a hydrogen economy. ■

## 12. Glass

Platinum and rhodium are used in the fabrication of vessels that hold, channel and form the high-quality molten glass that is used, for example, for LCD and plasma screens. With their unique properties, they are able to withstand the harsh conditions under which the raw materials for the glass are melted, including the heat of usually 1650° C.

Unlike base metal alloys, platinum and platinum alloys do not react to glass, nor do they oxidize or scale at high temperatures, thereby maintaining the purity of the glass. Rhodium is alloyed with platinum in various proportions from 5 per cent rhodium up to 30 per cent rhodium. The addition of rhodium increases the strength of platinum alloy equipment and extends its life. ■



Row of plasma screens; © Pavel Losevsky - Fotolia.com

## 13. Hydrogen Purification

The discovery of palladium's remarkable ability to absorb hydrogen has since led to uses which take advantage of this affinity. As a thin membrane, palladium will allow hydrogen to permeate through the membrane, but block all other gases. The further discovery of the stability of palladiumsilver alloys and the ability to manufacture membranes of these alloys made hydrogen purification using palladiumsilver membranes possible. ■

## 14. Implants

Platinum and iridium are used in aural implants that electrically stimulate the auditory nerve to replace damaged or malfunctioning cochleas in those suffering from deafness. The electrical conductivity, durability, biological compatibility and oxidation resistance of these PGMs make them perfect for the electrodes in the implants. Likewise, platinum and iridium can be found in retinal implants to improve damaged or deteriorating eyesight. ■

### 15. Jewellery

Due to its rarity and purity, and its natural white colour, associated with its enduring quality and resistance to tarnishing, platinum has been used for decoration since the 7th century BC. Today, platinum is a very popular metal for bridal jewellery in many countries and as fashion jewellery in Asia in particular. With the rise of consumer wealth, China has become the largest market accounting for 50 per cent of the world's platinum jewellery off take.

Palladium, iridium and ruthenium are used in jewellery as an alloy with platinum to optimize platinum's working characteristics and wear properties. Palladium is also used as an alloying element in white gold.

As jewellery metal on its own palladium has become attractive as a wedding band for men because it is strong, durable and its low density allows bigger and bolder jewellery designs to be created and worn with ease.

In recent years, palladium has attracted a growing number of fashion-forward jewellery designers. ■

### 16. Military

Electronic equipment used by the military has platinum wiring and coating on the circuits which are crucial for functionality. Fuel cells with platinum catalysts are widely used in the military for soldier portable power, submarines, warships, and unmanned aerial and ground vehicles. ■

### 17. Neuromodulation

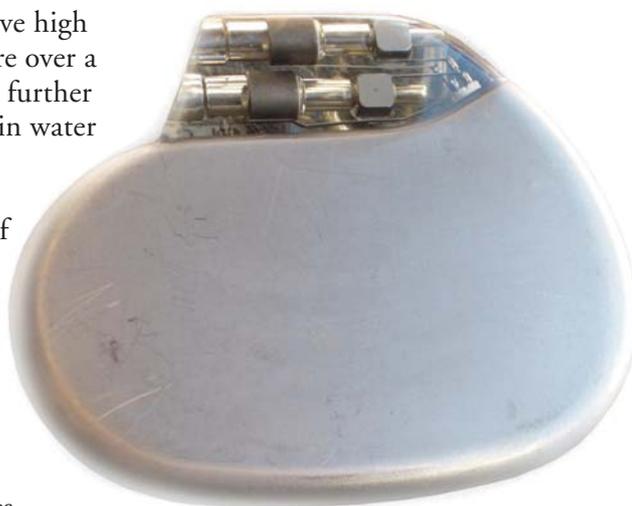
A neuromodulation device delivers electrical impulses to nerves (usually in the spinal column) or directly to the brain. Such devices are used to treat chronic pain and diseases such as Parkinson's. Similar to pacemakers, this involves an implanted pulse generator to which leads with platinum-iridium electrodes are attached. ■

### 18. Nitric Acid & Other Chemical Catalysts

Nitric acid is made in three stages. The first step is the oxidation of ammonia gas with air to form nitric oxide. In order to achieve high conversion efficiency, this is normally carried out at pressure over a platinum-rhodium catalyst. The nitric oxide is cooled and further oxidised to form nitrogen dioxide, which is then absorbed in water to nitric acid.

The principal end-use of nitric acid is in the production of nitrogen fertilizers, an important source of plant nutrients. Non-fertilizer uses include the production of: explosive-grade ammonium nitrate; adipic acid, for making nylon, and toluene diisocyanate, for manufacturing polyurethane.

Platinum is also used in the production of paraxylene (PX), and a palladium catalyst is used in the production of purified terephthalic acid (PTA). PX and PTA are intermediates in the production of polyethylene terephthalate (PET) used for plastics and polyester textiles. ■



Pacemakers contain platinum-rhodium electrodes;  
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### 19. Pacemakers & Defibrillators

Platinum can be fabricated into very tiny, complex components. As it is inert, platinum does not corrode inside the body, while allergic reactions to platinum are extremely rare. As a result, platinum has been used increasingly as a biomaterial. The noble metal also has good electrical conductivity, which makes it an ideal electrode material.

Pacemakers, used to treat heart disorders which result in slow or irregular heartbeat, usually contain at least two platinum-iridium electrodes, through which pulses of electricity are transmitted to stabilise the heartbeat. Platinum electrodes are also found in pacemaker-like devices which are used to help people at risk of fatal disturbances in the heart's rhythm. This risk can be minimised by implanting a device known as an Internal Cardioverter Defibrillator (ICD) which sends a massive electric charge to the heart as soon as it detects a problem.

Catheters, flexible tubes which can be introduced into the arteries, are widely used in modern, minimally-invasive treatments for heart disease. Many catheters contain platinum marker bands and guide wires, which are used to help the surgeon guide the device to the treatment site. The radio-opacity of platinum, which makes it visible in x-ray images, enables doctors to monitor the position of the catheter during treatment.

Coronary stents are another device which is manufactured using platinum alloys (together with chromium). ■

### 20. Petroleum Refining

Since the 1950s, platinum catalysts have been used in petroleum refineries to reform naphtha into high octane blending components for gasoline (i.e., reformates). This process is called catalytic reforming. Manufacturers of petroleum catalysts coat substrates (e.g., alumina) with platinum solutions. Palladium is used by some refiners for upgrading certain refinery feeds in a process known as hydrocracking. Iridium can also be used in conjunction with platinum in a few niche reforming applications. ■

### 21. Photography

Platinum and palladium processes for producing photographic prints have been known since the mid 1800s and the early days of photography. As a process descended from the Cyanotype, it was known as Platinotype. Both metals are still used as an alternative process today in producing archival and museum suitable prints. In this form, palladium and platinum are very nearly interchangeable. ■

### 22. Sensors

Platinum is used for a variety of sensor applications, including oxygen sensors in car exhaust systems. Oxygen sensors are used to help run a gasoline engine more efficiently. The oxygen content is related to the amount of unburned fuel remaining in the engine. The sensor is made of a porous platinum coating on both the inside and the outside of the zirconia tube. The outside is exposed to the exhaust, whereas the inside remains exposed to normal air. The zirconia tube is heated by the exhaust and becomes an ionic conductor.

As the oxygen content in the atmosphere at each platinum sensor is different, there will be a potential difference between them. This difference is monitored, and changes are used to control the fuel flow through the engine to ensure that the gas/fuel mixture allows for complete combustion of the fuel. ■

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### 23. Thermocouples

A thermocouple consists of two wires of different metals joined together at one end to enable the temperature of the joint between the two metals to be calculated. Platinum and platinum-rhodium alloys are used for three high temperature standard grades of thermocouples. ■

### 24. Silicones

Silicones are very durable materials with high resistance to chemical corrosion, fire and extreme temperatures. They are also pliable, waterproof and electrically insulating. Platinum is used in the manufacture of speciality silicones: adding a platinum compound to the silicone mixture catalyses the cross-linking process which results in the formation of a silicone product with the desired properties.

Platinum catalysts are also used in the production of silicone adhesive that - in the shape of pressure sensitive adhesive – makes notes stick to a surface, a common everyday product that almost everybody uses. ■

### 25. Water Treatment

Palladium is a very promising catalyst for a process of purifying groundwater contaminated by certain toxic substances that have previously been difficult to remove. The contaminants in question are termed halogenated volatile organic compounds (VOCs). VOCs are some of the most pervasive groundwater pollutants in the United States. These tend to be hydrocarbons that are used as solvents, degreasers, and used in the production of paints and adhesives.

The United States Geological Survey indicated that in a 2002 study of 1500 drinking water wells, 44 per cent contained at least one VOC. Numerous studies are now underway to pioneer techniques to use palladium as a catalyst to promote the chemical conversion of the contaminants into benign end products in the presence of added hydrogen gas. The reaction essentially replaces the chlorine atoms in the contaminant with hydrogen. ■

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*More about the various uses of PGMs can be found here:*

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