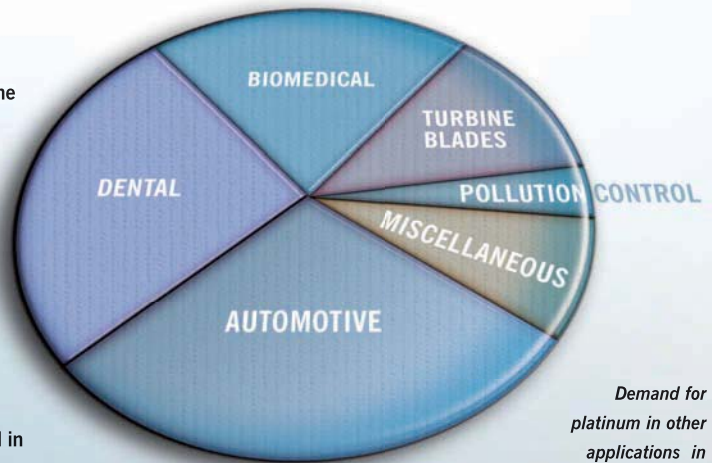


## Other Applications for Platinum

In addition to its well known applications in the autocatalyst, jewellery, chemical, electrical and glass sectors, platinum has a wide variety of other uses. These vary from automotive and medical applications for platinum consuming over 100,000 oz of metal annually, to many small end uses such as stationary source pollution control, catalytic heaters, gas safety sensors and cathodic protection which individually require just a few thousand ounces. The largest sectors of the market (tabulated below) are discussed in more detail in the following sections.



*Demand for platinum in other applications in 2005 amounted to 470,000 oz*

Main sectors of demand for other applications for platinum in 2005	
non-catalytic automotive	> 130,000 oz
dental alloys	> 120,000 oz
biomedical	> 100,000 oz
turbine blades	> 50,000 oz
<i>Combined demand for these four sectors in 2005 amounted to almost 90 per cent of the total demand of 470,000 oz</i>	

palladium and base metals.

The use of platinum in high gold alloys is principally to improve the strength and stiffness of the alloy, enabling the crown or bridge to withstand the forces generated during biting and chewing. Its high melting point is advantageous as this helps to minimise the risk of deformation when firing porcelain bonded crowns, while its resistance to corrosion and tarnishing are also beneficial.

The low gold category encompasses a much wider range of alloy types. These generally contain gold, palladium and silver in varying quantities, but do not incorporate platinum. Palladium is usually a significant component, accounting for up to 80 per cent of the alloy by weight.

The choice of alloy is partly based on its technical characteristics such as melting point, strength and ductility, ability to retain fine details when cast, bonding performance with porcelain, and resistance to corrosion and tarnishing. However, the preferences of dentists and their patients also play an important role, resulting in great variations between patterns of alloy consumption in different parts of the world.

Finally, cost is an important factor; in recent years demand for dental

alloys has been heavily influenced by fluctuations in the prices of gold, platinum and palladium.

Europe is currently the world's principal market for high gold alloys, accounting for around two-thirds of platinum demand in the global dental industry. Most of this demand occurs in Germany, where dental practitioners and consumers have tended to be rather less price-sensitive than in other European countries.

The North American dental

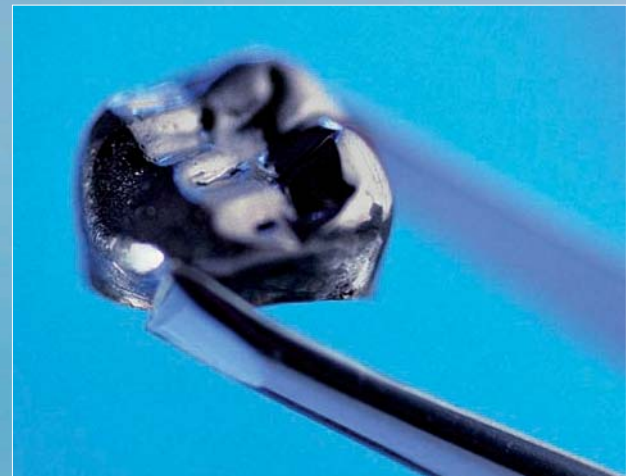


*Platinum has a long history of use in dentistry but demand has diminished in recent years as use of lower cost alloys and ceramic alternatives has risen.*

### Dental Alloys

*Platinum has a long and varied history of use in the dental industry, dating back to at least the early 19th century. In modern dentistry, however, platinum's use is confined to alloys used in bridges and crowns (prosthetic teeth). The latter can either be made entirely of precious metal alloy or from a porcelain crown bonded to an alloy core.*

There are two principal types of precious metal alloy used in dental restorations: low gold and high gold alloys. The latter have been used in restorative dentistry for many decades, and are typically at least 75 per cent gold (as high as 99 per cent in some cases). Most contain platinum as an alloying element: the platinum content can vary from 1 per cent to as much as 20 per cent. These alloys may also contain small amounts of silver,



sector uses only modest amounts of platinum in high gold alloys; products with a high palladium content have a dominant share of this market.

In both regions, the trend of platinum demand is downwards. Full ceramic crown and bridge systems (which do not have a metal core) are now starting to encroach upon the market for high gold alloys. At the same time, the price differentials between gold, platinum and palladium are encouraging a shift towards low gold alloys, which do not normally contain platinum.

Outside Germany and North America, consumption of platinum-containing dental alloys is minimal. The Japanese market is dominated by the Kinpala alloy, which contains 20 per cent palladium but no platinum, while in China and the Rest of the World region, the relatively high cost of restorative dental treatment means that the use of precious metal dental alloys remains small.

### **Automotive**

*The automotive industry is the single largest consumer of platinum, accounting for nearly half of all demand in 2005. Although most of this metal was used in autocatalysts, two other automotive applications, spark plugs and oxygen sensors, together consumed more than 130,000 oz of platinum in 2005.*

#### **SPARK PLUGS**

In a gasoline engine, power is generated by mixing air and fuel inside a combustion chamber (cylinder) and igniting this mixture with a spark generated by a spark plug. The plug also has an important secondary function - that of removing excess heat from the combustion chamber.

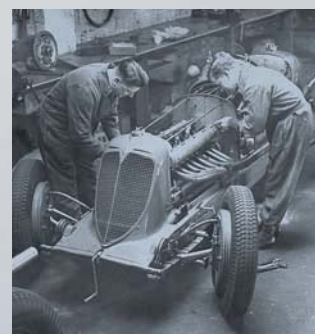
A correctly functioning plug helps to ensure clean and efficient combustion, thereby playing a significant role in meeting emissions limits.

Traditionally, most spark plugs had base metal electrodes. However, these electrodes are gradually eroded by the repeated cycles of firing, which widens the gap between them. Ultimately, this can lead to misfires, which increase pollution and can damage the catalytic converter.

The use of platinum-tipped electrodes largely eliminates this problem because platinum resists chemical and electrical erosion much better than base metal alloys. As a result, a platinum-tipped plug generally has an effective life of 100,000 miles or more, compared with around 30,000 miles for a typical base metal plug. This in turn allows for longer intervals between servicing and reduces costs: on many modern engines, replacing plugs is a difficult and time-consuming job.

Platinum plugs are now fitted as original equipment on all new vehicles in North America, where strict on-board diagnostic (OBD) and catalyst durability requirements have caused manufacturers to abandon the use of base metal plugs.

In Europe and Japan the use of platinum plugs is increasing: we estimate that currently around 25 per cent of new gasoline cars in Europe and around half of Japanese vehicles are fitted with platinum plugs. Diesel vehicles, which currently account for more than half of the European market, utilise glow plugs, which do not use platinum. The aftermarket has tended to lag behind, such that only around a third of all replacement plugs are platinum-tipped, but here too sales are increasing.



*Platinum-tipped spark plugs are increasingly fitted as original equipment as they last several times longer than their base metal predecessors.*

#### **OXYGEN SENSORS**

Oxygen sensors are less familiar to motorists than spark plugs, but the role they play in ensuring optimal engine performance and reducing emissions is no less vital. An oxygen sensor is an indispensable part of a modern vehicle's closed-loop engine management system, which controls the air-fuel mixture that is fed to the combustion chambers.

In the majority of oxygen sensors the sensing element consists of a ceramic bulb coated on both sides with a thin layer of platinum, the outside of which is exposed to the exhaust gases. The voltage generated by the sensor is determined by the

amount of oxygen in the exhaust: a high voltage indicates that the air-fuel mixture is too rich (there is too much fuel and not enough air), a low one that the engine is running too lean. This voltage is monitored by the onboard engine management computer, which adjusts the proportion of air to fuel to ensure that the average is close to the optimal ratio of 14.7:1. The sensor ensures that the autocatalyst works efficiently and that emissions leaving the engine are minimised.

All catalyst-equipped cars have at least one sensor mounted in the exhaust system upstream of the catalytic converter; in countries where strict OBD legislation is in place (such as the USA), vehicles are also fitted with one or more sensors downstream of the autocatalyst in order to monitor emissions. A large vehicle may therefore have as many as four sensors. The average number of sensors per car has grown steadily in recent years as a result of tightening OBD legislation, and this has generated proportionate increases in platinum demand.

### **Biomedical Uses**

*Biomedical, the third largest of platinum's other application categories, encompasses uses varying from anti-cancer drugs to devices used in cutting-edge treatments for heart and brain disease. We estimate that a little over 100,000 oz of platinum was consumed by this sector in 2005.*

#### **ANTI-CANCER DRUGS**

The first platinum-based anti-cancer drug, cisplatin, has been in use for nearly three decades and has revolutionised the treatment of certain diseases, particularly testicular

cancer. The chemical compound itself had been known since the mid-nineteenth century but its ability to inhibit cell division (and thus its potential utility in the fight against cancer) was discovered by chance in 1965; the development and approval of the drug took over 10 years, and cisplatin was first approved in 1978. Despite the subsequent development of other platinum compounds with less severe side-effects, the drug is still in widespread use, especially in the treatment of testicular, ovarian, bladder and lung cancers.

More recently, two other platinum-based drugs have come onto the market. The first, carboplatin, was approved in the late 1980s and is currently the most widely used of all the platinum anti-cancer compounds. It indicated for the treatment of a similar range of cancers to cisplatin but is considerably less toxic. A second drug, oxaliplatin, was first approved in Europe in 1996 and in the USA in 2004 and is principally used to treat advanced colorectal cancer. In the last two years oxaliplatin has been rapidly adopted by oncologists and its use has now overtaken that of cisplatin.

Other platinum compounds with anti-cancer activity have been discovered, but most are still in the

very early stages of development. However one potential new drug, satraplatin, is currently in Phase 3 trials (the final stage of clinical evaluation which, if successful, may lead to the approval of the drug). It is thought that an application for European approval could be made as early as 2007.

#### **MEDICAL COMPONENTS**

Platinum components are a critical element of many biomedical devices, particularly those which are implanted permanently into the body or used in minimally-invasive surgical procedures. The metal has many qualities which make it an ideal choice for medical applications: it is among the most biocompatible of all metals; it conducts electricity well; it is hard and resistant to corrosion, yet workable enough to permit the machining of tiny, complex components; and it is radiopaque (visible under x-ray).

The two largest uses for platinum components are in angioplasty, a treatment for blocked arteries, and

*Micro-machined platinum components have numerous surgical applications, whilst platinum-based drugs are widely used in the treatment of cancers.*



in devices such as pacemakers and implantable cardioverter defibrillators (ICD) that are used in the treatment of cardiac arrhythmias (irregularities in the beating of the heart). Platinum marker bands enable surgeons to track the position of guidewires and catheters within the body, whilst pacemakers and ICD are usually connected to the heart by platinum-tipped electrodes.

Recent medical trials have improved doctors' ability to identify people at risk of fatal arrhythmias. As a result, there has been rapid growth in the number of patients implanted with an ICD – up by around 20 per cent in 2005. This application has consequently been the largest single contributor to recent growth in biomedical demand for platinum.

### ***Turbine Blades***

*In 2005, more than 50,000 oz of platinum were used in the manufacture of turbine blades, making this the fourth largest of the metal's other applications. Platinum is used both in the casting of blades and in coatings required to increase their longevity in the very harsh operating conditions of a modern gas turbine engine.*

Turbine blades are manufactured via investment casting, which enables the production of very complex cast shapes with, in some cases, hollow cores. The process involves the creation of a disposable wax mould or form that is subsequently coated with a ceramic material. The wax is then removed by melting and the ceramic shell is fired. Molten metal (often a titanium-based superalloy) is then cast into the shell.

Blades destined for use in the hottest part of a turbine engine



*The use of platinum pinning wire and platinum-aluminide coatings are essential in the production of blades used in modern high-temperature turbines.*

often have a hollow core, which functions as an internal cooling vent. This is formed by fixing a ceramic core inside the ceramic shell using platinum "pinning wire". The pinning wire holds the core in place while the blade is cast, before melting into the alloy and thus remaining permanently within the blade.

Platinum is universally used for pinning wire as its high strength and rigidity ensures that cores are held securely during casting, and it does not adversely affect the structure and integrity of the blade.

The efficiency of a gas turbine is related to its running temperature.

In the quest for ever greater fuel efficiency, turbines are becoming hotter: the gases from the combustion chamber in a modern aero-engine may enter the high pressure section of the turbine at temperatures of over 1,500°C. In order to extend the life of the blades used in the high pressure section of the engine, a platinum aluminide coating is usually applied. This provides protection from oxidation and allows the blade to operate continuously for as long as 20,000 hours before it requires repair or replacement. It is usually possible to strip and reapply the platinum coating once, after which the blade must be changed.

Demand for platinum in turbine blades is expected to rise steadily over the next few years as increasing demand for air travel stimulates sales of new aircraft. Not only will additional platinum be required for new engines, but the expansion of the world air fleet will also boost the recoating and replacement blade markets.