

# PALLADIUM

## AUTOCATALYST

World demand for palladium for use in autocatalysts increased by 3.9 per cent in 2006, to a total of 4.02 million ounces. Although demand fell in Europe, due to lower sales of gasoline vehicles with palladium catalysts and also due to thrifting of precious metal, it was up in all other regions. New legislation in a number of countries was one contributory factor. More important was the cost-driven move to switch from platinum-rich catalyst formulations to ones containing more palladium for gasoline-fuelled vehicles.

## Europe

Palladium demand in the European market fell in 2006 to 865,000 oz. The market share of diesel vehicles continued to grow, rising above the 50 per cent level. As overall production levels of light duty vehicles grew only slightly, the number of gasoline cars and commercial vehicles fitted with palladium-based catalysts was reduced.

The auto makers have the option of using different mixes of the platinum group metals in many of their vehicles' exhaust systems, particularly those with spark ignition engines. With the palladium price substantially below that of platinum, this strategic trend of balancing individual metal requirements and minimising total precious metals costs has been ongoing for several years.

The introduction of new emissions legislation typically requires development of new catalysts and is the ideal opportunity for companies to replace previous

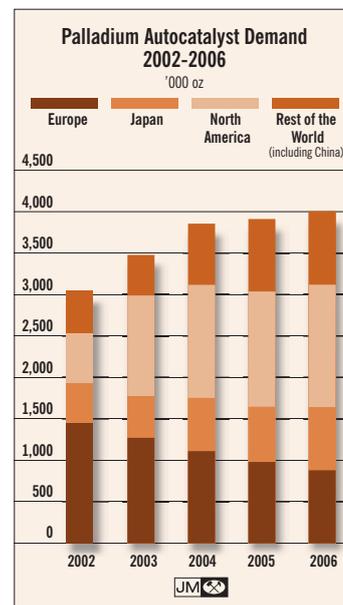
platinum-based catalysts with palladium-based ones. The new Euro IV rules which came into use in early 2006 therefore drove this change more quickly than in previous years, increasing the number of palladium catalysts being manufactured at the expense of the number of platinum formulations. In much of Europe, palladium loadings also rose in order to meet these new stricter regulations.

Palladium Demand: Autocatalyst '000 oz		
	2005	2006
Europe	975	865
Japan	660	795
North America	1,430	1,470
Rest of the World		
China	165	220
Other	635	665
<b>Total</b>	<b>3,865</b>	<b>4,015</b>
<b>Autocatalyst Recovery</b>	<b>(625)</b>	<b>(800)</b>

However, metal loadings were reduced in the German market. Many vehicles sold in Germany prior to 2006 already met Euro IV limits in order to qualify for domestic tax incentives. The German car groups were therefore able to thrift metal from formulations used previously, reducing their metal usage. With Germany accounting for a higher than expected proportion of European sales in the final months of 2006 due to impending consumption tax increases, this amplified the effect of thrifting, forcing palladium demand below our previous estimates.

The early stages of a move toward palladium use in diesel catalysts marginally buffered this falling demand from gasoline vehicles. Palladium had not been used in any significant quantities in diesel catalysts prior to 2006, so growth here has been from a very low baseline.

In this application, palladium is used as a replacement for some of the platinum in a more conventional formulation. Although palladium does not exhibit good activity in the oxygen-rich exhaust of a diesel engine, when mixed with platinum it can be used to maintain catalytic activity and to enhance thermal stability at a reduced overall cost (at current price differentials between these two metals).



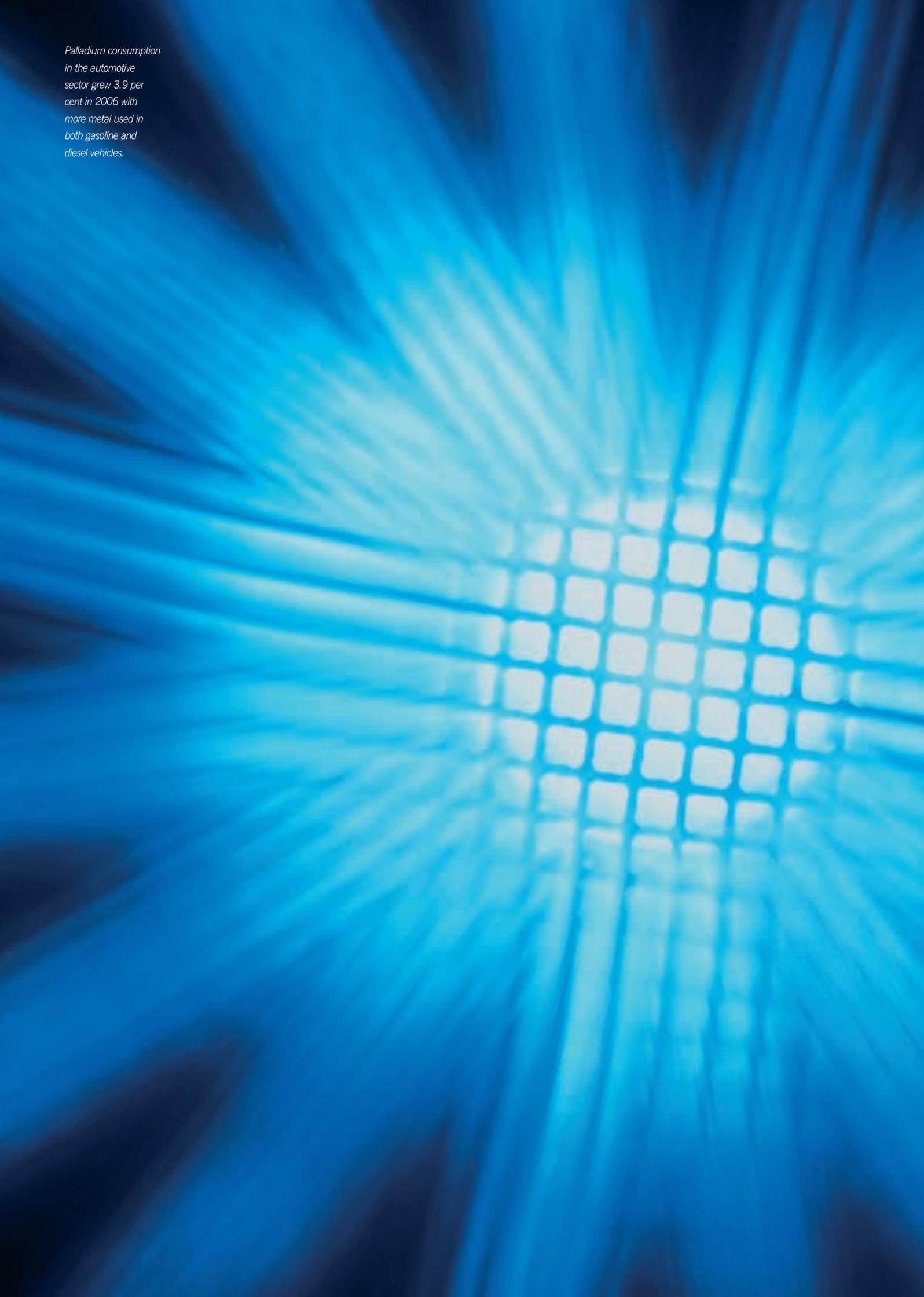
*Although the North American autocatalyst market continues to be the most important in terms of palladium demand, the fastest growth in metal usage in 2006 was seen in Asia.*

## Japan

Japanese automotive palladium demand climbed from 660,000 oz to 795,000 oz in 2006. Although domestic light duty vehicle sales were little changed from the year before, annual production in Japan rose strongly, increasing by 5 per cent. With most of this additional output destined for export markets, much of the growth in manufacturing was from comparatively large vehicles, boosting the average amount of palladium required per car.

These trends were accompanied by a continuation in the shift from platinum-based three-way, or gasoline,

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catalysts to their palladium-based analogues as the Japanese auto makers sought to reduce exposure to the more expensive metal. Record platinum prices may have accelerated this switching process to a degree but were only partly responsible for driving palladium demand 20 per cent higher over the year.

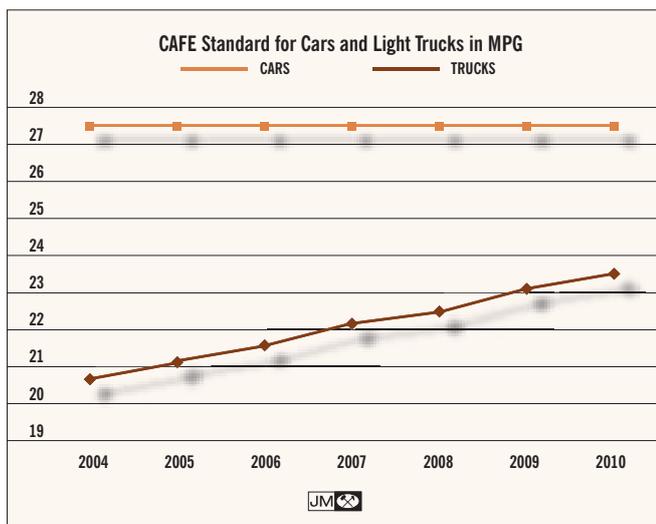
### North America

1.47 million ounces of palladium were purchased for use in the North American automotive market during 2006, 3 per cent more metal than was used the year before. North America is primarily a gasoline-engined vehicle market where light duty diesel vehicles only represent a tiny percentage of sales. This focus on gasoline cars and trucks provides the auto makers with considerable freedom of choice between using platinum or palladium catalytic systems.

Due to the current price advantage of palladium compared to platinum, the vehicle manufacturers therefore continued switching many of their catalyst requirements to palladium technology during 2006, albeit at a lower pace than had been the case previously. Total palladium demand for this market has now risen to more than one and a half times the amount of platinum used.

However, North American production weakened in 2006, with light duty vehicle production falling by 2.3 per cent to a total of 16 million cars and trucks. Additionally, US consumers have been buying progressively smaller vehicles. Although the strength

*American fuel economy has historically been lower than in other regions. However, recent proposed changes to CAFE standards should start to address this.*



of this trend can be overstated (engine sizes remain larger than in any other region), it is leading to lower catalyst volumes and hence to lower pgm content on average. These trends have counterbalanced the change in metal used, limiting growth in palladium demand in 2006 to only 3 per cent.

Over the longer-term, the US Federal Government appears increasingly likely to impose tighter CAFE (corporate average fuel economy) rules on cars and light duty trucks. This could have two possible effects on palladium demand: it could accelerate the move to smaller engines, which typically use less pgm for exhaust aftertreatment, or help promote diesel technology in which platinum is the main precious metal catalyst component.

### China

As in many other sectors in China, the dominant influence in the autocatalyst market was simply that of economic growth. Domestic automobile sales rose by a weighty 34 per cent to 4.2 million in 2006. This extremely strong growth boosted palladium consumption, which rose by a quarter, or 55,000 oz, to 220,000 oz.

There were numerous changes within the marketplace, in particular relating to taxation. The Chinese Government has introduced higher taxes on larger cars in an attempt to limit its requirements for fuel imports. Despite strong overall growth in vehicle sales, the number of sports utility vehicles made and sold actually fell in 2006. A reduction in the consumption tax on cars with engines of below 1.5 litres capacity has, as yet, had little impact at the other end of the market.

With platinum prices far above those of palladium, there was an incentive to use palladium as the metal of choice for new catalyst formulations. The resulting increase in demand for this metal was therefore greater than for platinum.

### Rest of the World

Autocatalyst demand for palladium also rose in the Rest of the World region, to a historic high of 665,000 oz, 30,000 oz more than in 2005. The major automotive groups have for several years been

investing in production facilities near to areas of consumer demand rather than meeting this demand by exporting. This has led to a continuing increase in the volumes of vehicles manufactured outside the three main regions. Again, the difference between relative pgm prices has also encouraged a certain amount of replacement of platinum on gasoline vehicles with palladium. Finally, every year sees new emissions legislation somewhere around the world, with 2006 no exception.

The Russian autocatalyst market provides a good example of all three trends. The major global auto companies are investing in Russian plant capacity and increasing output there. With plentiful local supplies of this metal, most catalyst formulations used in the Russian autocatalyst market are palladium-based, something we expect to continue as Euro III rules are introduced in 2008.

### Autocatalyst Recovery

The estimated weight of palladium recovered from the recycling of catalytic converters grew by more than a quarter in 2006 to 800,000 oz. The bulk of this material was collected in North America where an efficient infrastructure for collection and processing of used catalysts has existed for a number of years. The significant growth in the amount of palladium being reclaimed is largely due to the increased amount of the metal which was used in the US autocatalyst sector in the middle of the 1990s.

Recovery volumes have also benefited to a limited extent from the high prices of other commodities including steel. The economics of the recycling of such auto components are heavily dependent on the price received for materials other than precious metals. The increase in value of the entire exhaust and aftertreatment system has therefore helped to raise the number of catalysts being removed from end-of-life vehicles and recycled.

European autocatalyst recovery also increased, reflecting the new legislation covering this area and, again, the amount of palladium fitted to vehicles in the previous decade. The volume of metal being reclaimed also increased marginally in Japan and the Rest of the World region but remains much lower than in Europe and North America.



### JEWELLERY

**Net global purchases of palladium by the jewellery sector decreased by 435,000 oz from their 2005 peak to 995,000 oz in 2006. A fall in Chinese demand was the major contributor to this decline, with 440,000 oz less palladium purchased in 2006 than the year before. Outside China, palladium remains a much less important jewellery metal but interest in its use is increasing.**

Palladium consumption from the Chinese jewellery sector fell by 37 per cent in 2006, with net demand of 760,000 oz. 2004 and 2005 saw a ramp-up not only in palladium sales but, perhaps more importantly, in stocks of raw materials and finished jewellery held by manufacturers, wholesalers and retailers.

It is therefore, perhaps, unsurprising that demand fell in 2006, as the requirement for injections of further metal into the supply chain diminished, for the time being at least. Although large quantities of palladium were imported into Hong Kong early in 2006, we believe that little of this metal has entered the jewellery sector and that it was instead sold as a medium-term investment.

Another factor in the lower level of palladium purchases was increased recycling of palladium. The first palladium jewellery products seen in the Chinese market were made from a 95 per cent palladium alloy, Pd950. However, current production focuses very heavily on Pd990, taking advantage of the Chinese consumer interest in metal purity, something which

*The weight of palladium recovered from scrapped catalytic converters soared by 175,000 oz in 2006.*

is also seen in relation to gold. Although some Pd950 pieces can still be found in shops, many retailers have returned this metal for refining and remaking into newer product, depressing headline demand by an estimated 120,000 oz.

Manufacturing volumes fell dramatically in the second half of the year, having been healthy for the first few months, again suggesting that much of the previous demand had been used to fill pipeline stocks. Quite large amounts of material also returned in the form of unsold pieces for remaking into new jewellery, as mentioned above. However, even taking this metal into account, the volumes of palladium jewellery manufactured in China fell substantially over the last six months of 2006.

There were also a number of consumer issues which coloured the end customer's view of palladium jewellery. For example, a Chinese television report on palladium jewellery focused on some occasions where it had been misrepresented as the more expensive platinum. With quality problems such as discolouration and brittleness having been frequent in some of the original palladium jewellery sales, consumer perception is therefore not universally positive towards this material.

As yet, palladium does not have a clear market positioning and this has made its marketing particularly challenging. However, this does not indicate a simple picture of low consumer interest in this metal.

In many provincial or secondary cities, sales are healthy, with palladium's lower price making it an



*The processing of palladium jewellery requires modification of the techniques used to manufacture platinum jewellery.*

attractive option (although product availability differs widely between cities and towns of similar sizes around the country).

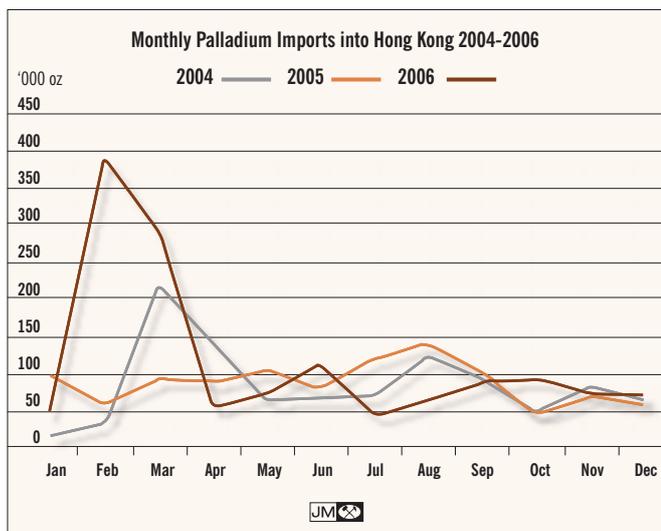
Diamond-cut metal-only pieces constitute a large proportion of the jewellery for sale. These are relatively hard for most consumers to distinguish from other white metals except on price and therefore compete with platinum and with white gold. A certain amount of gem-set jewellery is also available which typically competes directly with white gold.

In the major cities, particularly Beijing and Shanghai, availability of palladium products is low and the consumer promotion of palladium as a jewellery metal at the end of 2006 appears, so far, to have had relatively little impact on either the amount of stock being held or on sales in these cities.

Although these trends combined to depress demand for new metal in China in 2006, the underlying strength of the market is still difficult to gauge. Palladium jewellery is now being actively promoted and marketed and may be establishing itself in a secure market niche. Looking further into the future, the degree of consumer acceptance remains somewhat uncertain and will be key to the prospects for this developing market.

In North America, a number of manufacturers have investigated palladium and a wide range of other materials, such as tungsten carbide, as alternatives

*Hong Kong import statistics can act as a guideline to the total volume of palladium shipped into China. We estimate, however, that Chinese jewellery purchases fell despite very high shipments in early 2006.*



Palladium Demand: Jewellery '000 oz		
	2005	2006
Europe	35	40
Japan	145	130
North America	20	40
Rest of the World		
China	1,200	760
Other	30	25
<b>Total</b>	<b>1,430</b>	<b>995</b>



to gold and platinum, as a consequence of high prices for these metals. Although product availability is currently still limited, an increasing number of companies are offering ranges of palladium products, particularly for men's wedding rings, and demand for palladium has consequently started to grow.

Although palladium has only a low market penetration in Europe, industry interest in this metal has also been slowly building, as in North America. Much of the European demand for palladium in 2006 was for use in white gold and other alloys where it is a minor component. Palladium purchases for this use remained flat. However, the number of palladium jewellery products available increased in 2006 and early 2007.

There are very few reports of any palladium jewellery being sold in Japan and its use is restricted to an alloy component in platinum and white gold jewellery. The decline in purchases of platinum by manufacturers, largely due to greatly increased levels of recycling of jewellery scrap, has accordingly depressed demand for palladium.

## CHEMICAL

**Total usage of palladium in the chemical sector was almost flat in 2006, rising by just 5,000 oz to 420,000 oz. Demand is composed of contributions from the production processes of a number of basic feedstock chemicals, including hydrogen peroxide, nitric acid, purified terephthalic acid (PTA) and vinyl acetate monomer (VAM). We have upgraded our estimates for both 2005 and 2006 demand to account for the construction of a European polymer manufacturing facility in 2006.**

One of the most important process catalyst uses of palladium is in the manufacture of hydrogen peroxide. Supported palladium catalyses the hydrogenation stage of the anthraquinone process traditionally used to make hydrogen peroxide. This chemical is used in many bleaching processes and is cleaner than other alternatives. With environmental concerns constantly increasing, demand for hydrogen peroxide is rising,

increasing the demand for palladium in this application in all regions.

Palladium is also used as a catalyst in making purified terephthalic acid (PTA) and in the manufacturing of vinyl acetate monomer (VAM). Both of these chemicals are common building blocks in the polymer industry and are used in the manufacture of products as varied as paints and fabrics. With global economic growth of just below 4 per cent in 2006, requirements for these commodity chemicals continue to grow, leading to high rates of replacement for catalysts already in use and to addition of manufacturing capacity around the world.

The economics of palladium demand for nitric acid production are somewhat different and depend on the price differential between palladium and platinum. Nitric acid is manufactured for use in fertilisers and in explosives, two applications which showed good growth in 2006, increasing the volumes of nitric acid produced. The platinum gauze which is used as the catalyst in the nitric acid process slowly degrades and palladium catchment gauzes are employed to capture platinum lost from the gauze for recycling. With platinum prices high, many manufacturers have made greater use of these catchments, boosting net palladium demand by 10 per cent.

Palladium Demand: Chemical '000 oz		
	2005	2006
Europe	155	165
Japan	25	25
North America	85	80
Rest of the World	150	150
<b>Total</b>	<b>415</b>	<b>420</b>



## DENTAL

**Demand for palladium for use in the dental industry dropped 15,000 oz in 2006, to 800,000 oz. Purchases of metal in the Japanese market fell by 25,000 oz, while the North American market rose by 10,000 oz. European consumption remained flat. Historically, palladium has been widely used as a component of dental alloys for crowns and bridgework. In this area it traditionally competes for market share with gold. Although the palladium price rose significantly during 2006, it was outpaced by growth in the gold price and palladium therefore remained competitive.**

The Japanese market consumed 450,000 oz of

Palladium Demand: Dental '000 oz		
	2005	2006
Europe	75	75
Japan	475	450
North America	250	260
Rest of the World	15	15
<b>Total</b>	<b>815</b>	<b>800</b>

palladium largely in the form of Kinpala alloy (primarily palladium, gold and silver). This was a little below the 2005 figure. Usage depends heavily on the amount of subsidy paid by the government for an individual's treatment. Increasing palladium prices in the first half of the year pushed the cost of the dental alloys used above the level of this subsidy, leaving dentists to pay the excess, and causing demand to dip. The subsidy was finally increased for the last few months of the year. However, this rise did not match the increases in the alloy's price, leaving demand lower overall.

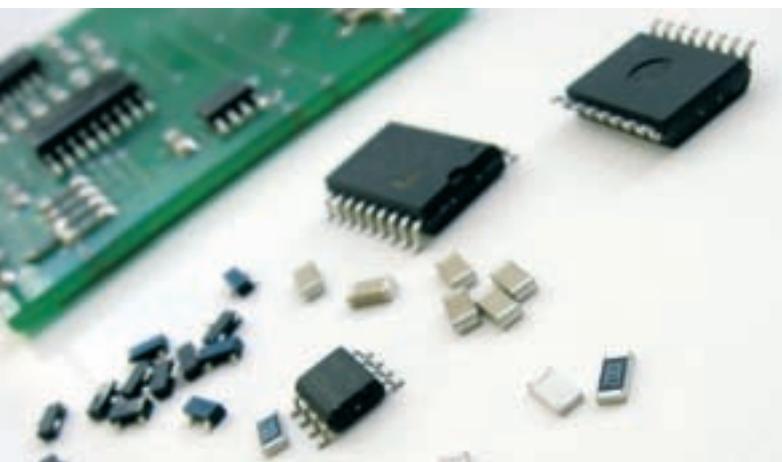
With no similar subsidy in North America for such dental treatment, demand is more influenced by simple price considerations. With the gold price almost double that of palladium for much of 2006, demand for the white metal was healthy and even rose marginally to 260,000 oz.

In the European dental sector, demand for palladium remained steady at 75,000 oz. Much of this metal is used in the Italian market, which is fairly conservative and with no price incentive to switch metal, palladium maintained its market share.

*Palladium demand in the electronics market continued its five year recovery. Sales of all kinds of devices continued to grow.*

## ELECTRONICS

**Demand for palladium in the electronics sector grew for the fifth successive year, to 1.07 million ounces (net of recycling). Despite this growth,**



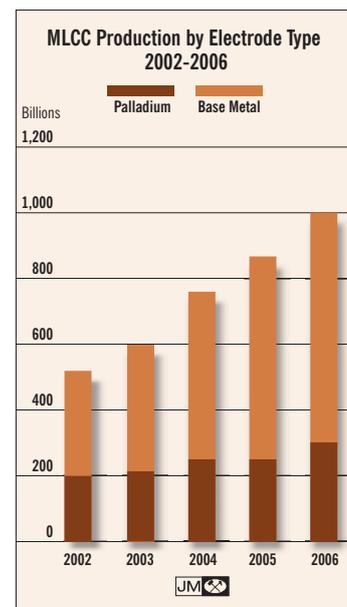
**overall consumption of palladium represents only a little over 50 per cent of its peak level in the late 1990s. Palladium is used in a number of electronics applications, from plating of components to its use in multi-layer ceramic capacitors, and competition comes from a number of different technologies and materials.**

Most importantly, palladium remains a key material in the production of multi-layer ceramic capacitors (MLCC), a passive component used in computers and other consumer electronics devices; annual demand for palladium for such capacitors is more than half a million ounces. Production volumes of all types of MLCC continue to grow at a great pace and exceeded one trillion in 2006. Nickel has been substituted for palladium in many types of MLCC in recent years. However, with plant utilisation rates high,

few manufacturers had the opportunity to switch any more production from palladium technology to nickel and some even added palladium MLCC capacity, increasing overall palladium requirements from this sub-sector for the first time in six years.

Palladium usage in the plating of electronic components also fared well in 2006. This platinum group metal is an alternative to gold in this application and a sustained price differential between the two elements in favour of palladium encouraged use of the white metal where possible, boosting demand by 8 per cent. Palladium consumption in resistors also climbed by a similar percentage.

Environmental factors also had a significant effect on the uptake of palladium by the electronics industry in 2006. The pressure to move to cleaner manufacturing processes and to recycle a greater proportion of electronic products continues to grow all round the globe. In Europe, the Waste Electrical and Electronic Equipment (WEEE) directive came into force in 2006. This legislation has two aspects: first a reduction in the use of toxic metals such as lead (Pb) and, second, a requirement for greatly increased recycling rates. Other



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Palladium Demand: Electronics '000 oz		
	2005	2006
Europe	80	100
Japan	265	280
North America	195	190
Rest of the World	430	495
<b>Total</b>	<b>970</b>	<b>1,065</b>



countries are also considering implementing similar rules in the near to medium-term.

As a result of these limitations on the use of heavy metals, manufacturers are looking to phase out the use of Pb solders where possible. Knock-on changes to other components are often required in such

situations and palladium has found some use as an alternative plating material on lead frames for this reason. This effect was not seen simply in Europe but in other regions where goods for sale in Europe are manufactured.

The requirement for increased recycling rates also had some limited impact in raising the number of electronic and electrical devices recycled. Nonetheless, palladium and other platinum group metal content is very low in this waste stream, both in weight and in value terms. This in turn means that the economics of recycling these materials are less attractive than in the automotive industry. As a result, the volume of palladium reclaimed globally has been relatively low to date but is rising.

## OTHER

**Demand for palladium from other applications fell sharply to 140,000 oz in 2006, from 485,000 oz in 2005. A combination of stationary source emission control, titanium alloys and a range of other end uses contributed a slightly greater amount of demand than in 2005. However, the weight of palladium required for the production of physical investment products showed a dramatic year-on-year fall.**

Following a strong year in 2005 in which the physical investment market saw an off-take of 400,000 oz of palladium, 2006 was much weaker. Demand, which is almost solely due to the North American market, fell to 50,000 oz, a drop of 88 per cent. The increase in the palladium price over 2006 made initial sales more difficult and stimulated disinvestment of some products bought over recent years.

The performance of the gold price also impacted upon this market. As gold moved to record highs,

it received widespread publicity and investment demand focused on coins made from the more familiar metal. Palladium investment products are typically subject to a wider bid-offer spread than those in gold or silver, making it easier for investors to make a profit in these latter two metals.

A few new palladium products were introduced such as the 2007 Royal Canadian Mint Maple Leaf bullion coins and Great Bear/Little Bear series. However, with no other new coins being minted, opportunities for investment were limited. In these circumstances, palladium investment products were largely ignored and demand fell substantially.

A number of other applications accounted for small quantities of palladium in 2006. Stationary source emission control is a growing market, where regulations require the use of catalysts to minimise emissions from factories. After several quiet years, this sector is expanding once more and using palladium in some of the systems built.

High ruthenium prices encouraged the use of titanium alloys containing palladium in place of ruthenium for corrosion-resistant piping used in the petrochemical and other industries. Elsewhere, although palladium usage in biomedical applications has traditionally been insignificant, small but growing amounts of the metal are being used in anti-microbial coatings for catheters.

*The Royal Canadian Mint issued a set of new designs of the Ursa Major and Ursa Minor constellations in palladium late in 2006.*

Palladium Demand: Other '000 oz		
	2005	2006
Europe	20	20
Japan	10	10
North America	435	85
Rest of the World	20	25
<b>Total</b>	<b>485</b>	<b>140</b>

