

# PALLADIUM

## AUTOCATALYST

Autocatalyst demand for palladium edged up by just 20,000 oz to 3.81 million oz in 2005. Given the metal's persistent and substantial discount to platinum, such a slow rate of growth might appear surprising. However, although North America auto manufacturers increasingly phased out platinum-based catalysts in favour of palladium-based systems, average palladium loading levels continued to decline. European demand for palladium was also adversely affected by thrifting, as well as by a further fall in sales of gasoline light vehicles. It was only in Asia that auto industry purchases of palladium increased, notably in South Korea and China.

### Europe

In 2005 European auto industry purchases of palladium fell below 1 million oz for the first time since 1996, dropping 10 per cent year-on-year to 990,000 oz. Demand was affected by the continuing decline in production and sales of gasoline light vehicles and by the ongoing thrifting of palladium loading levels on catalysts. The introduction of the first diesel after-treatment systems containing palladium had a negligible effect on metal demand last year.

Car companies and catalyst manufacturers made further progress in reducing the average palladium content of gasoline vehicle catalysts in 2005. This was achieved despite the advent of Euro IV emissions legislation, which applied to all new light vehicle models from the beginning of the year. Technical

advances in catalyst design and manufacture, together with increased use of close-coupled catalysts, have enabled substantial reductions in metal use over the last few years.

Close-coupled catalysts are fitted near to the engine manifold and so very quickly reach their effective operating temperature after the vehicle is started. The rapid 'light-off' of the catalyst enables more

effective control of emissions at lower metal loadings.

The Western European light vehicle market was relatively flat in 2005, with total new vehicle sales little changed from the year before. However, sales of diesels continued to rise, accounting for almost one out of every two new light vehicles purchased. Production and sales of gasoline vehicles consequently declined, which had a direct effect on demand for palladium.

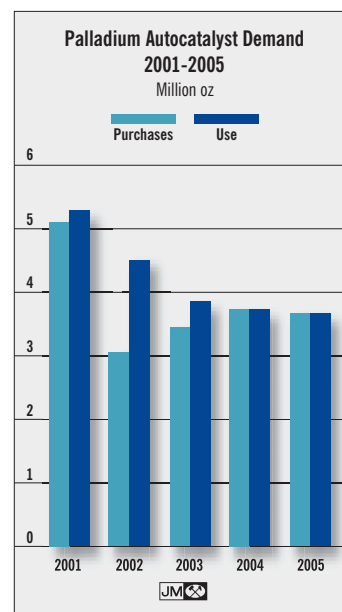
The first catalyst systems for light duty diesel vehicles containing a proportion of palladium in place of platinum entered production during the second half of 2005. Although platinum-palladium after-treatment systems for diesel vehicles are expected to become more widely adopted over the next few years, their introduction did not have a material impact on demand for either metal last year.

### Japan

Japanese autocatalyst demand for palladium expanded by 4 per cent to 660,000 oz in 2005. This was largely a result of a 3 per cent rise in light vehicle production as the Japanese auto industry benefited from both increased domestic and export sales.

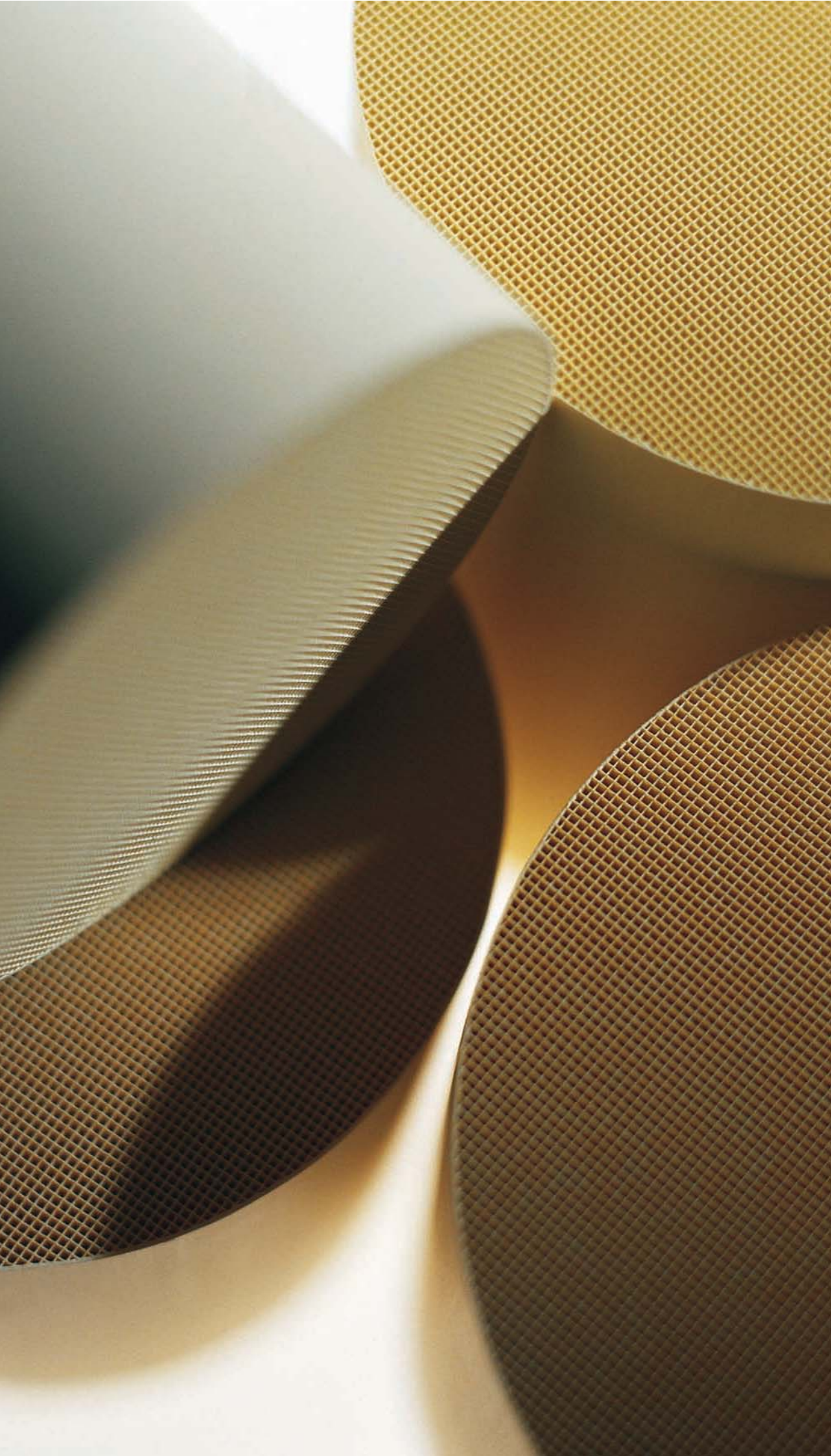
Palladium demand was also supported by the rising proportion of vehicles manufactured to increasingly stringent emissions standards. Within Japan a growing number of cars and light trucks were produced to ultra-low emissions vehicle standards, and legislation in the major Japanese export markets of Europe and North America continued to tighten.

Japanese auto makers have not, in general, made very significant changes to their use of platinum and palladium in response to movements in the prices of the two metals. Some have initiated a gradual change in favour of palladium-based formulations on new models but to date the impact on metal demand has been relatively minor.



*Purchases of palladium by auto manufacturers now closely reflect use of the metal on catalysts, excess industry stocks having been eliminated.*

Palladium Demand: Autocatalyst '000 oz		
	2004	2005
Europe	1,105	990
Japan	635	660
North America	1,445	1,430
Rest of the World		
China	105	150
Other	500	580
<b>Total</b>	<b>3,790</b>	<b>3,810</b>
<b>Autocatalyst recovery</b>	<b>(530)</b>	<b>(630)</b>



*Autocatalyst demand for palladium edged up by less than 1 per cent in 2005 as thrifting continued to reduce average loading levels in both North America and Europe.*

### North America

The North American auto industry purchased 1.43 million oz of palladium in 2005, a fall of 1 per cent compared with the previous year. The decline was less than we had previously forecast as switching from platinum to palladium catalysts by US auto manufacturers began to increase, a consequence of the persistently large disparity between the prices of the two metals.

Although an increasing proportion of vehicles manufactured were fitted with palladium-based catalysts, the average metal loading per catalyst continued to fall. The negative consequences of this thrifting on the consumption of palladium by the US auto industry once again outweighed the positive effects of switching.

The changing pattern of vehicle sales was also detrimental to palladium demand in North America last year. Record high gasoline prices (which exceeded \$3.00 per gallon in some states during the year) resulted in lower than anticipated sales of some of the largest SUVs and pick-up trucks, vehicles which tend to have large catalysts containing significant amounts of pgm.

Although total light vehicle sales edged upwards in 2005, North American vehicle production slipped as

imports gained market share. Furthermore, foreign brands accounted for a greater proportion of vehicle output within the region. Both factors had an adverse effect on demand for palladium as the best-selling transplanted models had, on average, lower palladium loadings than their US counterparts.

### China

Purchases of palladium for use in the Chinese autocatalyst sector jumped by 43 per cent to 150,000 oz in 2005, broadly in line with the growth in platinum consumption. The surge in pgm demand was a result of higher light vehicle production, tightening emissions limits, and an increase in the proportion of light vehicles fitted with catalysts.

The Chinese auto industry grew robustly in 2005, with production of light vehicles rising by 14 per cent to 5 million units, in line with strong growth in sales of both passenger cars and light trucks.

Emissions standards equivalent to Euro II were introduced nationwide in China in mid-2004, requiring the fitment of catalysts to all new gasoline light vehicle models. The phasing out of the manufacture and sale of older, Euro I compliant models was complete by mid 2005. The combined effect of these changes was a significant rise in palladium demand.

*Record high gasoline prices during 2005 hit US sales of many of the larger SUV models and pick-up trucks, which had a knock-on effect on palladium demand.*





*Recovery of palladium from scrapped autocatalysts climbed by 19 per cent to 630,000 oz last year.*

### Rest of the World

Autocatalyst demand for palladium in the Rest of the World climbed to 580,000 oz in 2005, annual growth of 16 per cent. This resulted in part from higher light vehicle production, notably in South Korea (up 12 per cent), India (up 8 per cent), South East Asia and South America. It was also a function of generally rising emissions standards, both in these regions and, in the case of South Korea, in the export markets of Europe and North America. There was also a noticeable acceleration in the switching from platinum-based catalyst systems to palladium products on gasoline vehicles by a number of Asian auto manufacturers.

### Autocatalyst Recovery

The weight of palladium recovered from scrap autocatalysts climbed by 19 per cent to 630,000 oz in 2005. The biggest year-on-year increase occurred in Europe; a combination of greater volumes of catalysts entering the recycling chain plus higher average palladium loadings on those catalysts led to a 50 per cent rise in palladium recovery to 165,000 oz.

Palladium recovery also continued to grow in North America, increasing to 390,000 oz. This was primarily a function of a rise in the number of vehicles manufactured in the mid-1990s, fitted with palladium-

rich catalysts, coming to the end of their lives. Recovery of the metal from scrapped catalysts in the Rest of the World region also increased but remained small in comparison.

In contrast, Japanese recovery of palladium from autocatalysts fell to just 30,000 oz last year. As with falling platinum recovery, this was a result of fewer end of life vehicles being recycled within Japan as the export trade in second hand vehicles and parts expanded.

### JEWELLERY

**Purchases of palladium for use in jewellery soared by 54 per cent to 1.43 million oz in 2005. This was almost entirely as a result of the rapid expansion of palladium jewellery manufacturing in China, which accounted for 1.2 million oz of total jewellery demand last year. The majority of the remaining 230,000 oz was consumed in the production of platinum jewellery alloys in Japan and some white gold alloys, although small volumes of palladium jewellery were also produced in North America.**

The Chinese jewellery sector purchased 1.2 million oz of palladium in 2005, an increase of half a million ounces on the year before. Although retail sales of palladium jewellery grew, the surge in purchases of metal was driven primarily by companies throughout

the trade establishing and expanding stocks of finished jewellery. The majority of jewellery manufacturers had started production of palladium products the previous year, and most stepped up output markedly in 2005 to fulfil orders from a growing number of wholesalers and retailers across the country. The spread of palladium jewellery to stores throughout China last year was remarkably rapid; Shanghai and Beijing are now the only major cities where a significant proportion of retail outlets still do not stock palladium.

The concept of purity is a strong selling point for the jewellery buying public in China, especially in rural areas. Last year, 99 per cent pure palladium jewellery (Pd990) was introduced in addition to 95 per cent pure palladium products (Pd950). This made a significant contribution to the growth in metal demand as stores began building inventories of Pd990 items alongside their existing ranges of Pd950.

One of the primary attractions of palladium to the jewellery trade was the fact that it cost considerably less to finance metal inventories compared with platinum. This was a function of both the substantial price differential between the two metals and (given the large, readily available stocks) the very low lease rates for palladium.

Palladium holds a further advantage relative to platinum for jewellery manufacturers in the form of its much lower density, which means that almost twice the number of identical items can be manufactured from the same weight of metal. Assuming metal prices of \$900 for platinum (approximately the average price



in 2005) and \$225 for palladium, for a given level of investment a jeweller would be able to buy (or borrow) four times as much palladium and produce around eight times as many rings from it. Consequently, for many manufacturers output of palladium jewellery overtook platinum in terms of the number of pieces produced, and for some, palladium also overtook platinum in terms of the weight of metal used.

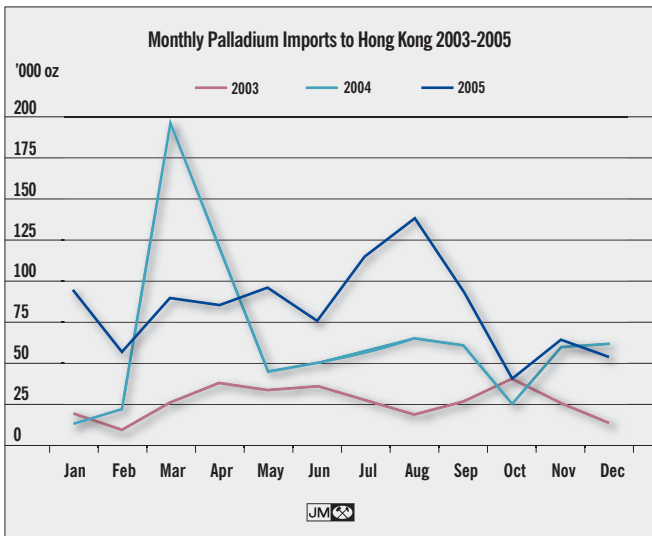
For the jewellery-buying public, palladium is seen to share many of the attributes that have made platinum so attractive: whiteness, rarity, purity, durability, and a good potential investment. It also offers less affluent consumers the opportunity to participate in the trend for white precious metal jewellery at a relatively affordable price. Its relative purity also gives palladium an important competitive edge over white gold, which contains at most 75 per cent gold.

The rally in the price of palladium from less than \$200 in September to almost \$300 in December was, in some respects, supportive of the expansion of retail sales of palladium jewellery, giving credence to the argument that it would be a sound investment and an appreciating store of value.

Nevertheless, the level of sales completed from manufacturer through retailer to consumer was

*Some North American jewellery manufacturers became increasingly interested in palladium during 2005, although demand for metal was modest.*

*Imports of palladium to Hong Kong averaged almost 85,000 oz per month in 2005, up by more than 29 per cent on the previous year, whilst exports of metal direct to mainland China also increased significantly.*



uneven last year, palladium doing well in some areas but being received less enthusiastically in others. Where it sold best, typically in second and third tier cities in the central and western provinces, palladium appeared both to expand the overall level of precious metal jewellery sales and to take market share from yellow gold, white gold and platinum.

The relative absence of palladium jewellery in stores

Palladium Demand: Jewellery '000 oz		
	2004	2005
Europe	35	35
Japan	155	145
North America	10	20
Rest of the World		
China	700	1,200
Other	30	30
<b>Total</b>	<b>930</b>	<b>1,430</b>

in Shanghai and Beijing relates in part to the strong position that platinum has established in those cities. Platinum remains the jewellery metal to which young, middle-class consumers aspire, and leading retailers are wary of undermining the investments that they have made in promoting it.

Outside of China the main application for palladium in

jewellery is as a component of platinum jewellery alloys in Japan and, to a lesser extent, white gold alloys in Europe, where the use of nickel in jewellery is limited by legislation. In 2005, however, growing interest was seen in North America in Pd950 palladium jewellery and a number of manufacturers began trialling the production of limited ranges of products.

## CHEMICAL

**Investment in new chemicals plants in the Rest of the World region continued to generate strong sales of palladium in 2005, supporting demand at the historically high level of 320,000 oz. The construction of new production facilities for purified terephthalic acid in Asia remained one of the most important components of demand. In the mature markets of Europe, Japan and North America, little new plant construction was undertaken and palladium demand was therefore primarily replacement metal to cover losses in the production of various chemicals and pharmaceuticals.**

One of the main applications for palladium-based catalysts in the chemicals industry is in the production of purified terephthalic acid (PTA), a feedstock used in the production of polyester fibre and polyethylene terephthalate (PET). During 2005 construction of

significant new PTA capacity continued in several countries including India, Brazil, Mexico and especially China, where a number of new plants were either under construction or entered the planning stages. This reflected a shortage of local manufacturing capacity; China, for example, sourced less than half its PTA requirement from domestic production. The lack of captive PTA production has in turn resulted from the rapid growth in demand for polyester resin in those countries from their expanding textile industries.

Palladium is also a key catalyst in the production of vinyl acetate monomer (VAM), an intermediate product in the manufacture of a wide range of polymers used in industrial and consumer products such as paints, adhesives, coatings, textiles, acrylic fibres and packaging.

As with PTA, the market for VAM was strong in 2005, supported by robust economic growth in North America and Asia. Consequently demand for palladium-based catalysts from this sector increased on the back of high operating rates at existing plants and the construction of new capacity in China.

Purchases of palladium for use in gauzes for the nitric acid industry were broadly flat in 2005. Increased demand for palladium catchment gauze from North American nitric acid producers was offset by metal returned following the closure of plants elsewhere.

Palladium Demand: Chemical '000 oz		
	2004	2005
Europe	70	70
Japan	25	25
North America	85	85
Rest of the World	130	140
<b>Total</b>	<b>310</b>	<b>320</b>

## DENTAL

**Demand for palladium from the dental sector edged down to 845,000 oz in 2005, marginally lower than the year before. High gold prices encouraged a switch towards palladium-containing alloys in North America, but this was offset by an increase in the recycling of production scrap in Japan.**

Japan is the world's largest market for palladium-based dental materials. The Kinpala alloy (which has a palladium content of 20 per cent) dominates the market for reconstructive dentistry; the market is mature and there were no fundamental changes in alloy use in 2005. However, net palladium demand fell by 15,000 oz to 505,000 oz due to an increase in the

Palladium Demand: Dental '000 oz		
	2004	2005
Europe	80	75
Japan	520	505
North America	235	250
Rest of the World	15	15
<b>Total</b>	<b>850</b>	<b>845</b>



reprocessing of scrap. Japanese dental alloy companies have traditionally been slow to return production scrap for recycling. Recently, collectors have become much more active in this market, resulting in a shortening of the time between the sale of alloy and the return of scrap, and a consequent

increase in the amount of metal recovered.

In North America, high gold prices have had a positive influence on demand for palladium in the dental industry. With gold prices averaging almost \$450 in 2005, there was a shift away from high gold alloys (which usually contain platinum rather than palladium) towards lower-gold content alloys which generally incorporate palladium and silver in varying proportions. As a result, North American dental demand rose by 15,000 oz to 250,000 oz.

European demand for palladium-based dental alloys occurs principally in Italy. This market tends to be price sensitive, and high prices for palladium and gold therefore had a negative impact on the use of dental alloys containing these metals. Total European purchasers of palladium softened to 75,000 oz.

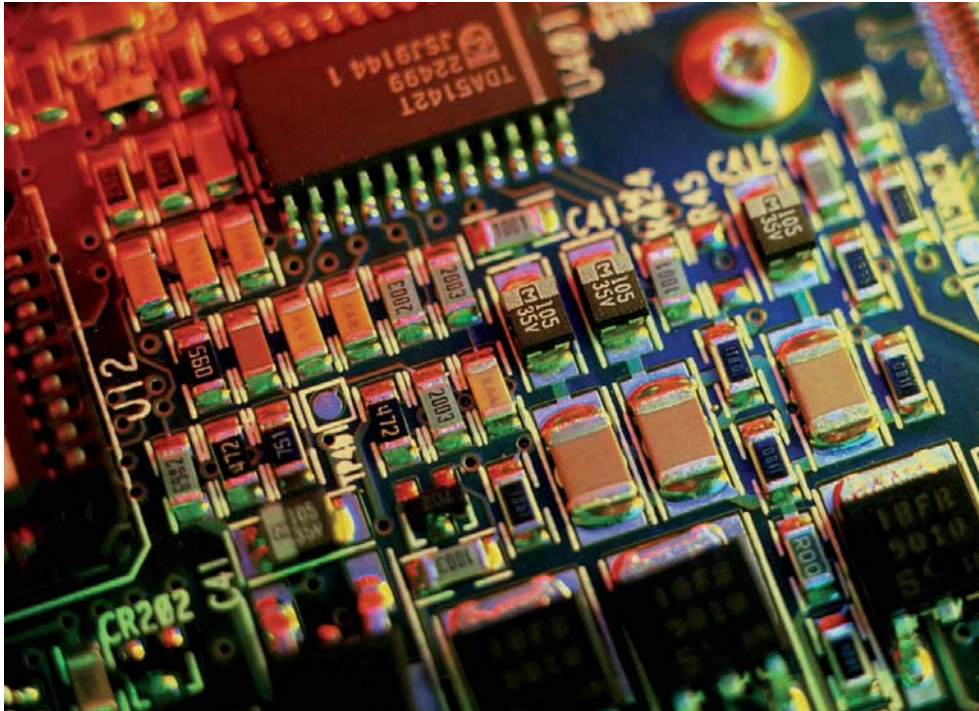
## ELECTRONICS

**Palladium usage in electronics rose by 5 per cent to 965,000 oz in 2005, supported by strong demand for consumer electronic devices and the increased adoption of palladium in the plating sector. This was partly offset by further substitution and thrifting of palladium in multi-layer ceramic capacitors (MLCC), the metal's largest single application in the electronics sector.**

World output of MLCC rose by an estimated 16 per cent in 2005, in line with strong sales of personal computers and mobile phones (especially those with an in-built digital camera) and greater use of electronic components in vehicles. On a geographical basis, the largest increases in production occurred in the Rest of the World region: China is now an important MLCC manufacturer (partly due to the relocation of production capacity from Europe and North America), and is the world's largest consumer of palladium for this application.

Demand for palladium in MLCC, however, dropped by around 4 per cent. Conductive pastes based on nickel rather than palladium were used in an estimated 70 per cent of all MLCC produced in 2005, up slightly compared with the previous year. In addition,

*MLCC production jumped by an estimated 16 per cent in 2005 but thrifting and miniaturisation continued to adversely affect demand for palladium.*



there was further thrifting of the palladium content of the palladium-silver pastes used in the remaining 30 per cent of capacitors. Furthermore, the ongoing miniaturisation of electronic components continued to adversely affect metal demand from the capacitor industry as the average size of MLCC declined.

Despite higher palladium prices there is no evidence that the pace of substitution increased in 2005. Although manufacturers adopted nickel technology for new production lines, most continued to operate their existing production facilities based on palladium. In particular, palladium has been retained for MLCC

with a low layer count (where it is not generally economic to shift to nickel) and in speciality high-performance applications (which are not price sensitive).

However, there are sharp variations between regions, with the adoption of nickel by the Japanese industry now approaching 90 per cent while in other regions nickel accounts for little more than half of capacitor production. In the latter areas, the uptake of nickel is likely to progress gradually, with almost all new production capacity using this technology.

Consumption of palladium by the plating sector rose by almost 30 per cent in 2005, outweighing the decline in demand from MLCC. There was increased substitution of gold by palladium in the plating of connectors, while there was also growth in other applications including the plating of palladium on circuit boards. In addition, there was further progress in the replacement of lead with palladium in copper lead frames .

Additional growth in demand for palladium in 2005 resulted from increased production of resistor chips and related components, particularly for use in automotive electronics. Use of palladium in hybrid integrated circuits was relatively stable.

As with all our demand numbers (with the exception of the autocatalyst sector) our estimates of palladium demand in electronics are net figures – that is they account for the recovery of substantial

quantities of metal from scrap. In 2005, we calculate that the amount of palladium recovered from electronic scrap was down around 6 per cent compared with the previous year. This decline reflects the impact of component miniaturisation and the thrifting and substitution of palladium that has occurred in recent years.

Palladium Demand: Electronics '000 oz		
	2004	2005
Europe	115	80
Japan	235	260
North America	185	195
Rest of the World	385	430
<b>Total</b>	<b>920</b>	<b>965</b>

## OTHER

**Private investors' enthusiasm for palladium coins and bars helped to maintain other demand for palladium at the historically high level of 300,000 oz in 2005, marginally up compared with the previous year. Consumption in a wide range of small applications, including catalysts for stationary-source pollution control, automotive oxygen sensors and brazing alloys, was little changed.**

Private investors in the USA again bought significant quantities of palladium in 2005, motivated by the perception that the palladium price has the potential to appreciate significantly in the wake of gold and platinum. Demand for investment products reached 220,000 oz, up 5 per cent on the previous year. Substantial quantities of palladium bullion products of all forms were purchased, including coins and one and ten ounce bars from a variety of sources. In November 2005, the Royal Canadian Mint began offering one ounce Maple Leaf bullion coins, of which 40,000 were produced and sold last year. A 2006 version of the bullion coin has also been issued, and this year no mintage limit has been announced.

The only other legal-tender palladium coin to be struck in 2005 was a half-ounce Panda from China, of which 8,000 were minted.

Demand for palladium in other industrial applications edged higher in 2005, with consumption of the metal in catalysts for control of stationary source emissions and in platinum alloys used in oxygen sensors increasing.

Palladium Demand: Other '000 oz		
	2004	2005
Europe	25	20
Japan	10	10
North America	230	250
Rest of the World	25	20
<b>Total</b>	<b>290</b>	<b>300</b>

