

Other Platinum Group Metals

Rhodium

The market for rhodium in 2000 was characterised by strong consumer demand and tight physical availability, which combined to force the price up from \$1,000 at the beginning of the year to just over \$2,000 at the end of December, having touched \$2,600 in August. This was despite record shipments of the metal from Russia.

Autocatalyst

Demand for rhodium in autocatalysts rose in all regions. Additional rhodium was needed to meet tougher emissions standards in Europe, Japan and the USA, while several automakers increased rhodium loadings to help them minimise the growth in palladium demand that was also occurring last year. It seems likely that many companies may follow this trend in future years as they try to reduce their dependence on palladium.

In Europe, the introduction of Euro III standards in January 2000 resulted in heavier average loadings of rhodium in autocatalysts. Further increases can be expected in future as a higher proportion of vehicles is built to meet the Stage IV legislation that will come into effect from 2005. In Germany, the largest car market in Europe, the government is already providing tax incentives for vehicles meeting the tighter regulations.

Japan also saw the introduction of more stringent emissions legislation in 2000, although the new standards were not enforced until October. Many auto makers chose to fit catalyst systems capable of meeting the new limits ahead of the deadline and this helped boost demand for rhodium. Several of the

major Japanese auto companies are making strenuous efforts to reduce their consumption of palladium and some have already begun to use higher loadings of rhodium and platinum to help them meet their objective. We believe that some companies may have added to their stocks of rhodium during 2000 in the expectation of higher use of the metal in future years.

The high price of palladium has also led US auto makers to consider adopting a strategy employing more rhodium and platinum to meet their own tougher domestic emissions standards. New legislation coming into force in North America over the next few years bears most heavily on hydrocarbon emissions, for which palladium is particularly effective as a catalyst. However, the addition of rhodium to palladium-only catalysts helps minimise the overall pgm loadings used. There is circumstantial evidence here too that auto makers increased their stocks of rhodium in anticipation of increased future use.

Imports of rhodium by the USA in January 2000 rose dramatically, with no less than 161,000 oz of the metal being imported from Russia. As this coincided with a period when the rhodium price was rising sharply we conclude that most, if not all, of the metal was not seen by the market at large but was acquired by one or more auto companies either directly from Almaz or through an intermediary.

The amount of rhodium recovered from the processing of scrapped autocatalysts rose last year by 20 per cent to 78,000 oz. Over half the increase came from catalytic converters removed from cars scrapped in North America, where

Rhodium Supply and Demand

'000 oz

	1999	2000
Supply		
South Africa	410	457
Russia	65	290
North America	18	16
Others	8	3
Total Supply	501	766
Demand		
Autocatalyst: gross	509	793
recovery	(65)	(78)
Chemical	34	35
Electrical	6	6
Glass	35	42
Other	9	9
Total Demand	528	807
Movements in Stocks	(27)	(41)



rhodium levels in autocatalysts increased significantly in the early years of the 1990s.

Other

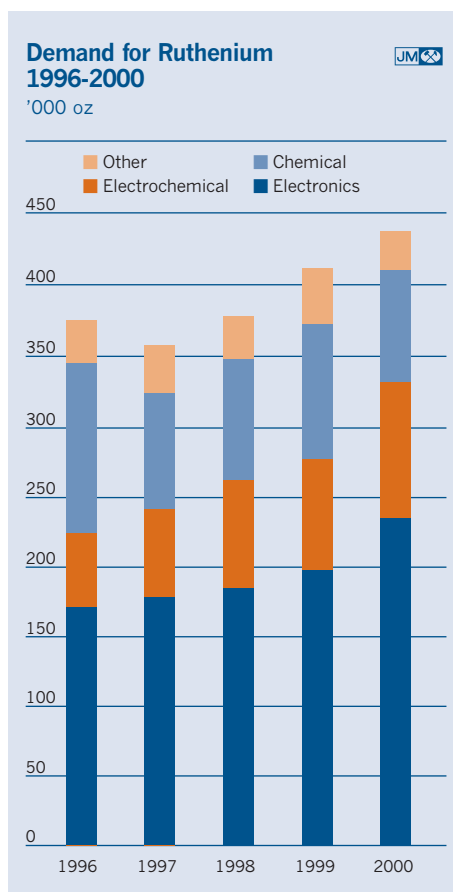
Demand for rhodium in other applications rose by almost 10 per cent to 92,000 oz last year. Sales to the glass industry were particularly strong, with rhodium demand increasing by a fifth to 42,000 oz, largely as a result of investment in new plants to manufacture the high quality, thin glass used in liquid crystal displays (LCDs). Equipment made from rhodium-platinum alloys is used to control the flow of molten glass during the production process. The wider application of LCDs in computer screens and in other consumer electronic devices such as mobile phones

is expected to double demand for LCD glass and most of the major manufacturers have begun, or are planning, significant expansions in their production capacity over the next 2-3 years. Demand in other applications that use rhodium was similar to that of 1999.

Ruthenium & Iridium

Continuing strong growth in the electronics industry was the main driving force behind increased demand for both ruthenium and iridium during 2000. Total consumption of ruthenium rose by 7 per cent to reach 439,000 oz, while the use of iridium increased by 30 per cent to 127,000 oz, driven by a dramatic 180 per cent growth in demand for crucibles for crystal growing.

The principal application for ruthenium in the electronics industry is in thick film pastes used in the manufacture of resistors. These components are incorporated into the majority of electronic products and manufacturers have therefore benefited from the global expansion in, for example, the markets for computers and mobile phones. Last year there was a 35 per cent increase in the production of resistor chips and networks, although the resulting rise in demand for ruthenium was somewhat lower, at 19 per cent, due to the continuing trend towards



miniaturisation of electronic components.

During 2000 there was an explosive growth in the demand for mobile phones with worldwide production of these devices growing by almost 50 per cent. This in turn generated a comparable need for lithium-based crystals, which are used in surface acoustic wave (SAW) filters to prevent signal interference between individual phones. These crystals are grown in iridium crucibles and, in order to meet demand, there was a significant increase in production capacity during the year which led to an almost threefold rise in iridium usage in this application. Demand was also lifted by increased use of yttrium aluminium garnet (YAG) crystals in industrial applications, such as laser cutting, and medical procedures, including cosmetic surgery.

Within the chemical sector, both iridium and ruthenium are used in the production of speciality and bulk chemicals. For iridium, the most

significant source of demand is the Cativa process for acetic acid production. This employs an iridium catalyst promoted with ruthenium, in contrast to traditional routes based on rhodium or base metals. The need for replacement catalysts for the plants currently operating with Cativa technology supported demand for both metals during 2000.

Ruthenium is a more versatile, and less expensive, catalyst than iridium and is used in a wider range of chemical processes. In recent years demand has been augmented by the Kellogg Advanced Ammonia Process (KAAP) which employs a ruthenium catalyst for the production of ammonia in place of the traditional iron based system. This process generated demand during 2000 for a new plant that is due for completion in Trinidad in 2002. Ruthenium catalysts are also used in the production of a number of speciality and fine chemicals; investment in new processes in this sector had increased in 1999, but demand softened slightly in 2000.

The electrochemical sector accounts for a significant proportion of total demand for both ruthenium and iridium. Electrodes coated with either ruthenium or a mixture of ruthenium and iridium are employed in a number of electrochemical processes. The most important of these is the chlor-alkali process which is used to produce chlorine and caustic soda from brine.

Ruthenium Demand by Application

'000 oz

	1999	2000
Chemical	95	79
Electrochemical	80	97
Electronics	197	235
Other	39	28
Total Demand	411	439



Iridium Demand by Application

'000 oz

	1999	2000
Automotive	34	14
Electronics	21	59
Electrochemical	18	19
Other	25	35
Total Demand	98	127



Demand for both metals rose during 2000 following increased consumption of the two end products, a trend that is expected to continue for the foreseeable future due to the myriad uses for each. The use of iridium, in particular, continues to benefit from a shift away from pure ruthenium to mixed ruthenium-iridium coatings.

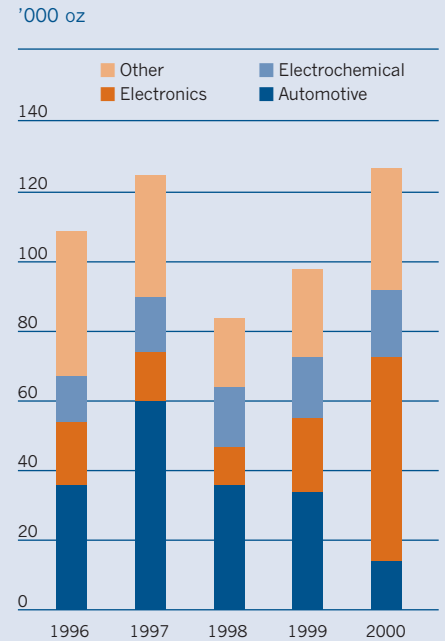
The adoption by Mitsubishi Motor Company (MMC) of an iridium based autocatalyst system on its gasoline direct-injection (GDI) engine has generated significant demand for iridium in recent years, with the system being fitted to vehicles sold in Japan and, with some modification, Europe. This catalyst, however, proved unsuitable for meeting the tighter emissions standards introduced in both these regions during 2000. As a result, MMC is now changing to a catalyst formulation that does not

use iridium and this led to a sharp drop in demand during 2000.

The use of iridium in spark plugs and medical applications increased during 2000. Iridium is a highly durable material and its incorporation into spark plug alloys imparts higher reliability and longer lifetimes, properties which are of particular interest to auto companies. Within the medical sector, iridium alloys are used in the form of electrodes attached to medical implants, such as pacemakers, and to catheters used to open blocked arteries.

Ruthenium demand for other applications fell slightly during 2000, mainly due to a decrease in the use of ruthenium-titanium pipe in off-shore drilling and geothermal projects. This can be attributed to a reduction in the number of such projects last year.

Demand for Iridium 1996-2000



Other PGM Supplies

Rhodium

Supplies of rhodium rose by more than 50 per cent to reach 766,000 oz in 2000. The previous year, shipments from Russia had been affected by restrictions on rhodium and platinum sales introduced under Clause 19 of the 1999 budget bill. The amendment of this clause in January 2000 paved the way for a sharp increase in rhodium exports from Russia; we estimate that sales by Almaz totalled 290,000 oz last year.

Much of this metal was shipped to North America, with US trade statistics revealing a massive import of 161,000 oz of rhodium from Russia in January 2000. This shipment alone exceeded Russian total sales in any year except 1997. As there was no obvious impact on market liquidity, with the price continuing to rise steadily throughout the early part of the year, it seems likely that most of this metal was acquired by auto companies, either directly or through an intermediary.

Supplies of rhodium from South Africa also rose sharply, despite a decline in platinum output last year. This was largely due to the sale of some rhodium from producer stocks. Increased mining from the rhodium-rich UG2 reef also had some impact on output; the rhodium content of UG2 ore is about twice that of the Merensky Reef.

World supplies of rhodium are expected to decline steeply this year. Russian production is estimated to be less than 100,000 oz per annum, and state stockpiles must therefore have been heavily depleted last year. In 2001, we expect that Russian exports will be closer to annual output. Meanwhile, South African supplies are expected to be similar to those of last year, with a rise in production offsetting a decline in sales from stocks.

Ruthenium & Iridium

Supplies of iridium were sufficient to meet consumer demand in 2000, and prices remained stable throughout the year. However, there was a significant shortage of liquidity in the ruthenium market, reflected in a rise in the price from \$46 in January to a peak of \$170 in August.

South African production of ruthenium declined, reflecting a fall in platinum output and a reduction in recoveries of minor pgm from residues. In addition, we believe that sales by South African producers were below the level of refined output last year. Meanwhile, Russian exports – which have typically totalled about 50,000 oz per annum in recent years – were negligible in 2000.