Palladium and its Alloys – A Revival?

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This paper will aim to serve two functions, 1) to disseminate the latest information about palladium with respect to its pricing, availability, market drivers, etc. Following on from this, we aim to update the audience and readership on our continuing and expanding story of a unique, ammonia-free, halide-free palladium system by illustrating some recent field trial and material property data.

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Here we go again! The metal markets are ruining budgets, estimates, forecasts, etc. Gold, rhodium and platinum are all up, palladium is down. Particular emphasis will be placed on gold and palladium in this paper. In Figure 1, which details the average metal prices[1] over the period from late 2000 through February 2005, the reader can see how crazy the precious metal arena can be.

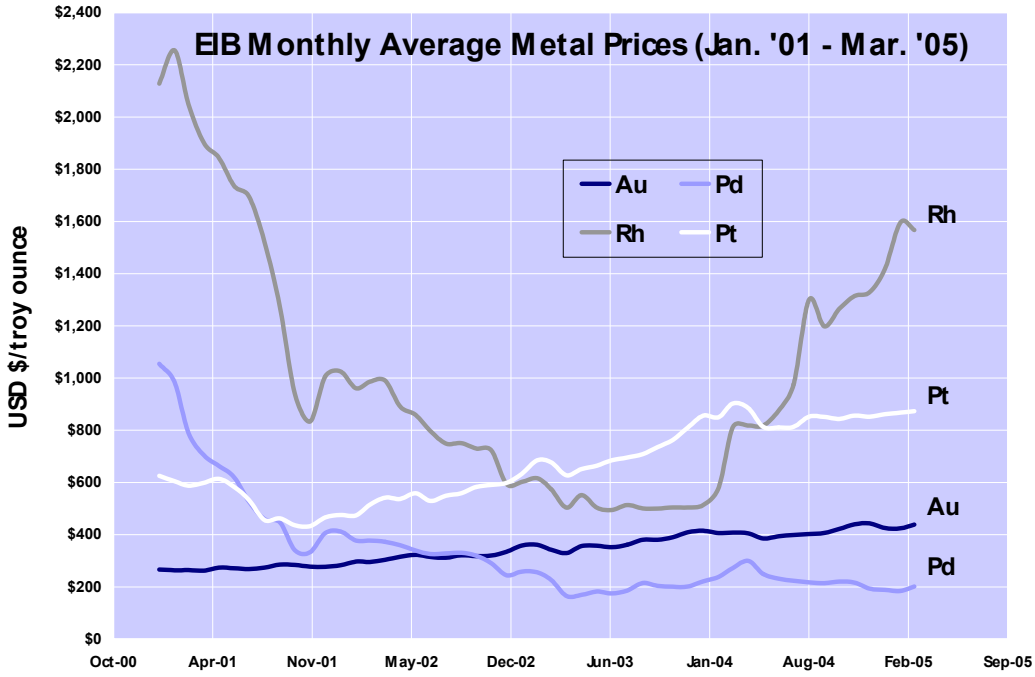

Figure 1 – Historical performance of Palladium, Gold, Platinum and Rhodium (2000-2005)

If we focus simply on gold and palladium and redraw Fig.1 with a narrower range of dates, i.e., Sept. 2002 through the middle of Mar. 2005, the separation (and consequent value proposition) becomes very clear. See Figure 2. Recently, the separation has resulted in a pure metal, ounce for ounce savings in excess of $200. Later, when this is combined with the density difference and we factor typical annual consumption figures, the magnitude of the potential cost savings can be overwhelming.

As part of this paper, an effort was made to consolidate the opinions and guesstimates from the chief metal supply houses[2] as to where they felt precious metal prices would trade over the next few months. This was also carried out to give the readership a feel for the likelihood of a reversal of gold and palladium pricing and a return to the 2001 situation.

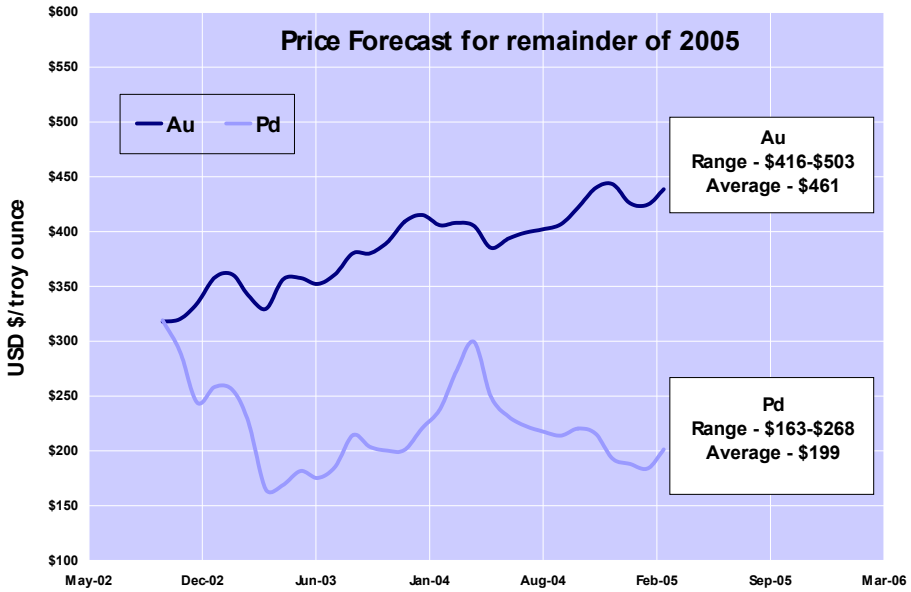

Figure 2 – Palladium and Gold pricing since Nov. 2002 along with expert predictions for the balance of 2005.

Beyond a simple illustration of precious metal pricing charts, I would like to give the reader a feeling of the fundamentals behind the current trends, i.e., supply and demand. First, let us examine the components that represent the largest contributors to gold supply. The data is illustrated graphically in Figure 3. As one can clearly see, mining still provides the largest volumes of material to satisfy market demand.[3] The countries that make up this mining component are broken out and illustrated in Figure 4.[4] One of the aspects that is worth noting is that as opposed to the sources of new palladium, where production sites and countries are narrowly distributed, gold enjoys widespread production facilities.

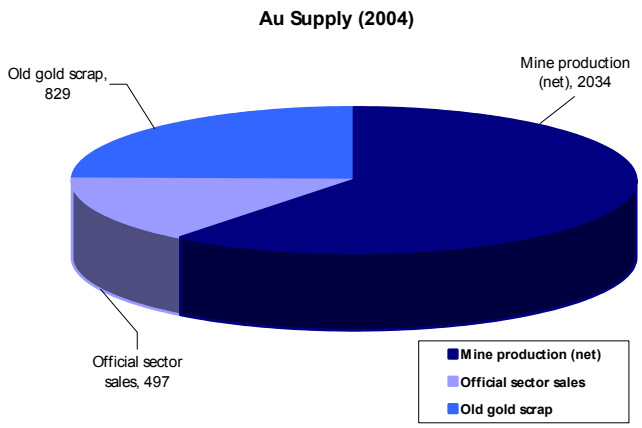

Figure 3 – Sources of Gold supply in 2004. Units are tonnes. Data courtesy of – www.gfms.co.uk.

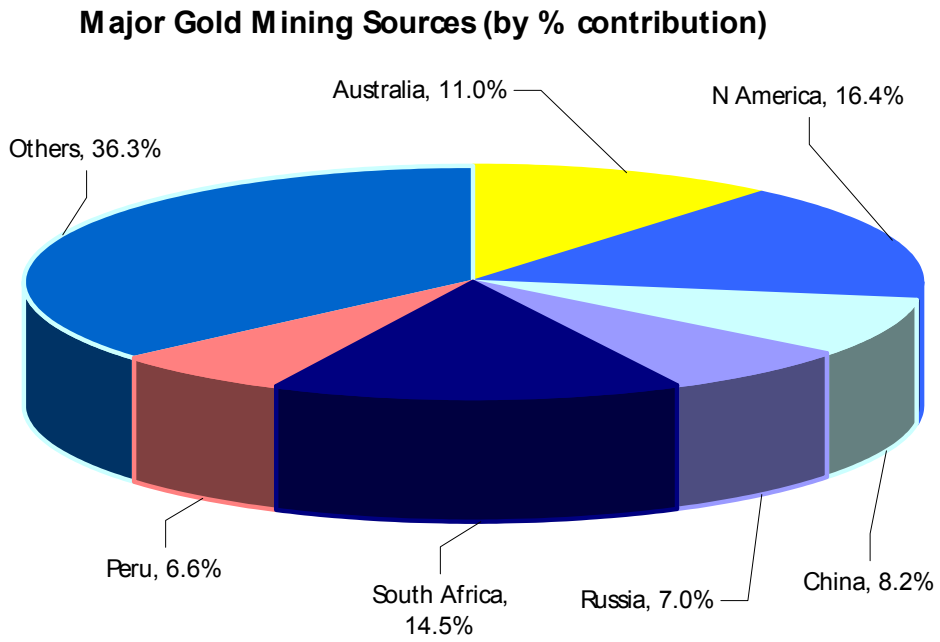

Figure 4 – Major gold mining countries. Data courtesy of World Gold Council (www.gold.org)

Switching to palladium, the supply of metal has always been questionable. This is, in no small part, related to the simple fact that 82% of the world's supply of the metal is controlled by Russia and South Africa. This is represented graphically in Figure 5.[5]

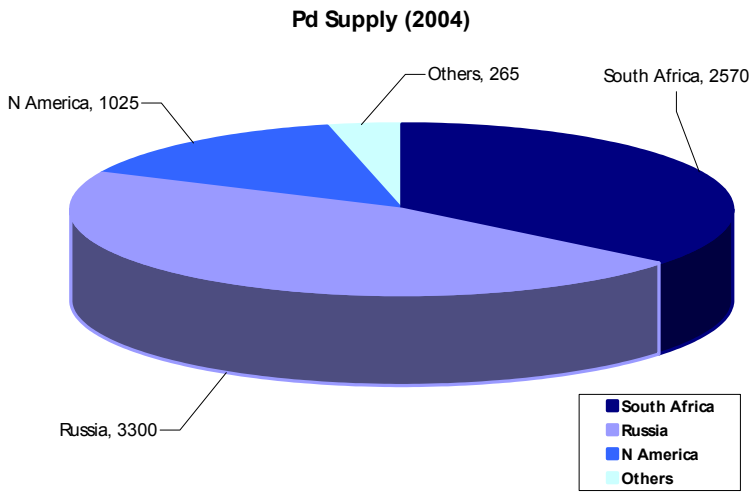

Figure 5 – Sources of Palladium supply in 2004. Units are tonnes. Data courtesy of Johnson Matthey.

On the demand side of the equation, gold consumption figures by industry or application are readily available.[4] Typically, jewellery consumes the largest portion of the available gold (ca. 77%), followed by bar & coin retail investment, then industrial demand and finally dental consumption. With respect to palladium, the demand is illustrated in Figure 6.[6] Automotive demand is in excess of 50% of the annual number.

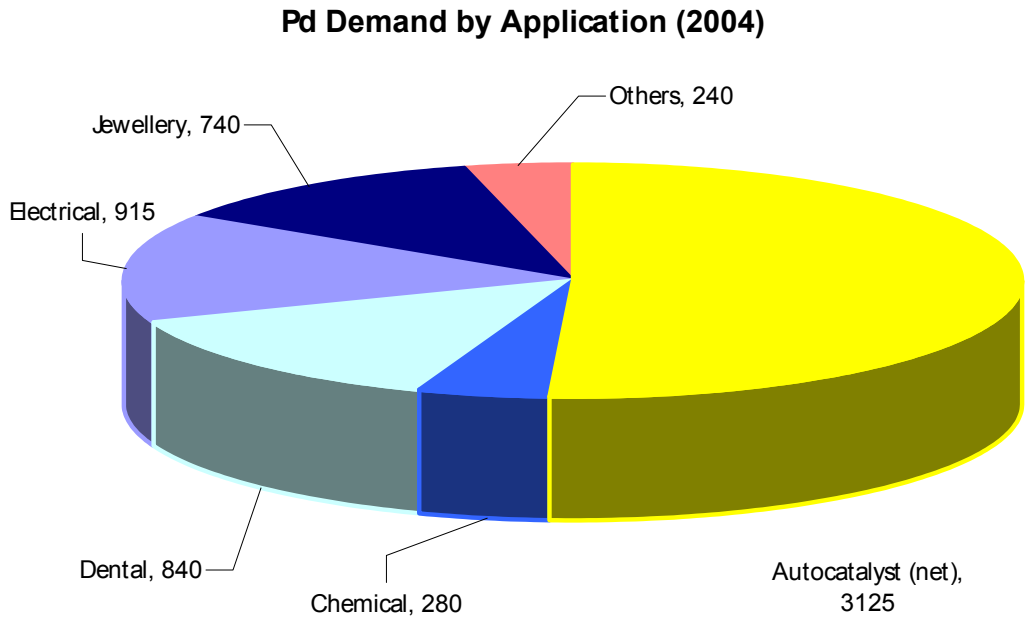

Figure 6 – Palladium demand by application in 2004. Units are tonnes. Data courtesy of Johnson Matthey.

On a consolidated basis, the palladium picture looks good for the consumer. The following in a list of some of the comments from the PGM experts[7] providing price support for palladium:

- Demand to improve to 6.14 million ounces
- US auto industry stocks falling, purchases rising
- Chinese jewelers introduce palladium products

However, the same experts[7] also offer the following comments to offset any optimism for higher prices:

- Mine output rising and large sales from stocks
- Market surplus to again exceed 1 million ounces
- Price subdued despite large investment by metal funds

A consolidated view of palladium supply and demand is presented in Figure 7. Over the past ten years, supply exceeds demand by 2,000,000 troy ounces.

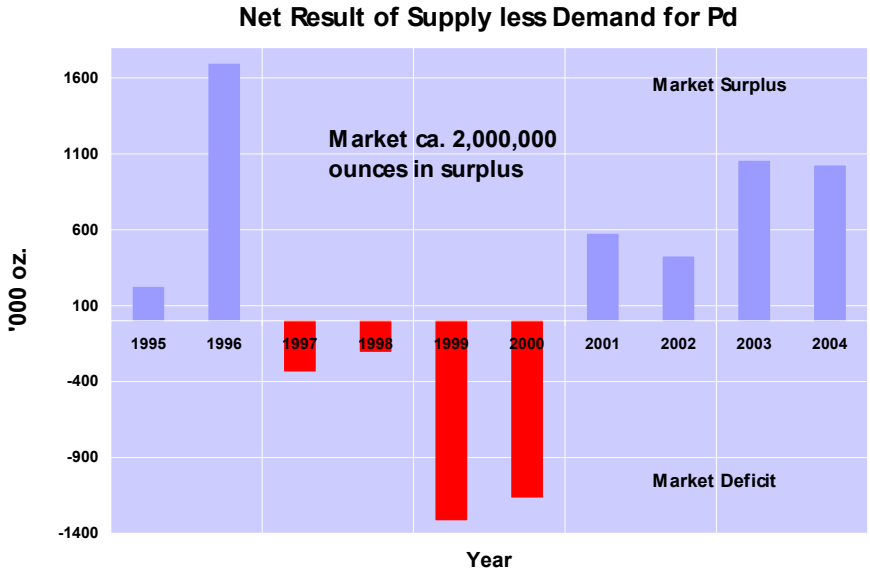

Figure 7 – Supply less demand result from 1995 through 2004. Data courtesy of Johnson Matthey.

On the positive side, for precious metals as a whole, consumption in the electronics industry is on the rise again. Ever since the large correction in 2001, precious metal consumption has been steadily rising[7] and now stands at a figure close to the year 2000 number. See Figure 8.

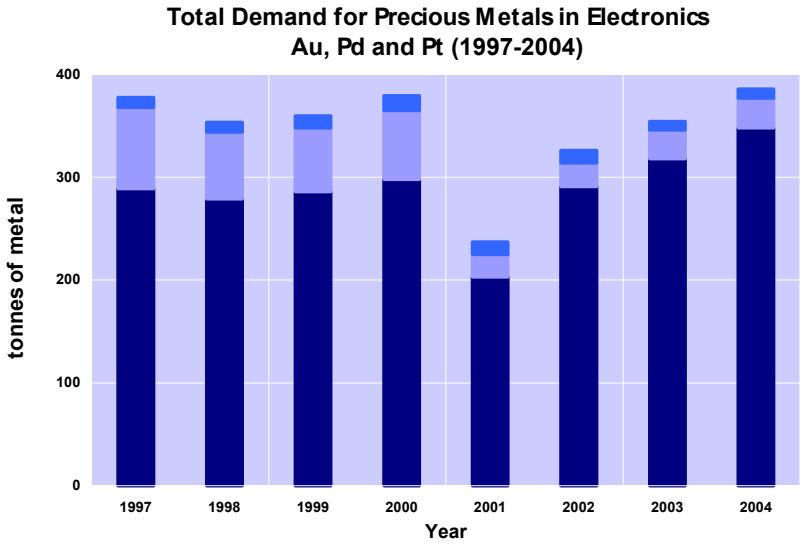

Figure 8 – Sources of Palladium supply in 2004. Data courtesy of Johnson Matthey.

Moving on from the macroeconomic situation, we need to examine the potential of palladium for electroplating applications. Herein, emphasis will be placed on:

- the ECONOMIC value
- the TECHNICAL value
- the ENVIRONMENTAL value

With reference to the economic value of palladium, the foregoing discussion on pricing has already demonstrated part of the proposition, i.e., on an ounce for ounce basis, you can capture almost $200, which depending on your annual consumption rates can generate enormous savings. A corollary to this originates in one of the fundamental material properties of palladium, namely – density. Table 1 illustrates the density differences between commonly deposited precious metal coatings.

Table 1 – Density differences between pure gold, nickel hardened gold, pure palladium and an 80/20 palladium nickel alloy.

Metal or alloy	Pure Au	Hard Au	Pure Pd	PdNi (80/20)
Density (g/cm^3)	19.3	17.3	11.9	10.8

Density combined with the current metal market conditions, i.e., Au - $425/troy ounce and Pd - $200/troy ounce, delivers the following proposition: on an equivalent thickness basis, a pure palladium alternative will cost 29% that of a pure gold alternative and an 80/20 palladium alloy solution will cost even less at 21%.

Armed with this information, Table 2 illustrates the potential metal cost savings associated with a switch to a palladium solution away from gold. Irrespective of the volume of precious metal going through your operation, the savings can be very large.

Table 2 – Potential cost savings in switching from gold to palladium.

Au consumption (tr. oz.)	$avings Potential with a Pd solution
500	$139,400.00
5,000	$1,394,00.00
50,000	$13,940,000.00
100,000	$27,880,000.00

The technical value of a palladium based solution has been well documented elsewhere.[8] Nevertheless, a couple of points worth noting are:

- The use of palladium in electronics is not new
- The use of palladium is well understood and documented (ASTM, Mil-Specs, etc.)
- It is a **proven** solution.

The advantages of palladium versus gold that are typically touted[8] are as follows: higher hardness, improved sliding wear, lower porosity, greater thermal stability and lower density. With particular reference to a palladium nickel alloy, the added comments are: high tolerance to wear and abrasion, low porosity, best available material for corrosion protection in mixed flowing gas environments, excellent resistance to traditional salt spray and CASS atmospheres.

On the environmental value proposition of a palladium based solution, here we are discussing the opportunity of the metal as a "Lead Free", "ABSOLUTELY WHISKER FREE" alternative. Whether the application is a traditional leadframe or a connector termination one, we have, with a trade-off on cost, the only tried and tested to solution to the WEEE lead free requirement. There are numerous, excellent papers published[9] on this subject by Abys et al. and Abbott et al.

With respect to palladium plating chemistries, a number of evolutionary steps have taken place. These are illustrated in Figure 9.

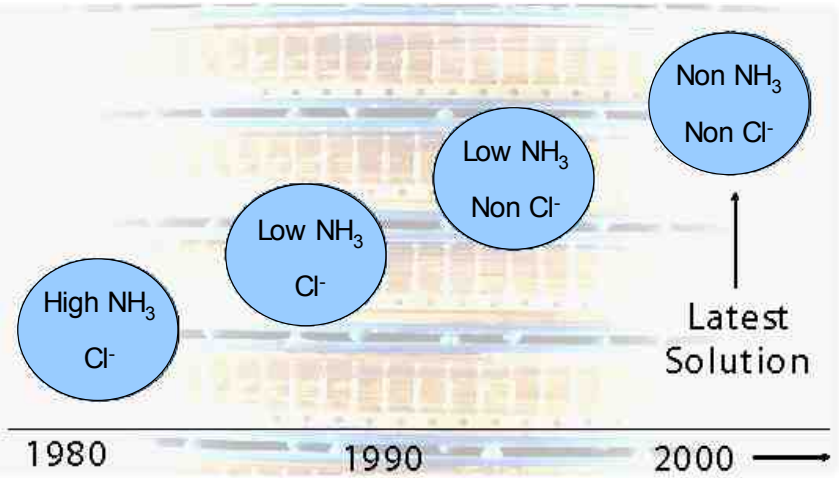

Figure 9 – Various generations of palladium plating chemistries.

The evolution from the original, high ammonia, chloride based palladium plating systems through to the latest non ammonia, non-chloride process has involved a number of intermediary steps. The low ammonia, non-chloride processes which were state-of-the-art through the year 2000-2001, possessed a number of limitations. The standard concerns were:

- Lack of conductivity
- Bath saturation – solubility of K_2SO_4
- Strong ammonia odor
- Systems too complex – 2 to 4 additives
- High consumption of ammonia for replenishment
- Copper alloy corrosivity

With these limitations in mind, the development team set about to design a novel palladium nickel electrolyte. Over the past two to three years, a family of products, based off of the proprietary salt, was developed:

- High speed palladium nickel (Pd at 20 g/L or at 7 g/L)
- Low speed palladium nickel for rack and barrel
- Pure palladium for leadframe applications

Since their launch into the marketplace, the processes are enjoying successes in the APAC region and in Europe. A number of papers[10] have been published elsewhere that provide details of the chemistry, the relevant operating conditions, etc. Since this abstract was submitted, a paper and presentation[11] was delivered which covers recent developments with respect to the system. Copies of these, along with other supporting information are available upon request from the authors.

Most companies are hesitant to shift back to palladium systems for a variety of reasons, not least because of a fear that the palladium price might return to the 2000-2001 levels. However, it is hoped that this consolidation of information, from a wide variety of sources, addresses some of these fears.

In summary, it is hoped that this paper gives the reader a feel for the current state of play with respect to the various precious metals, details on the supply and demand equations for gold and palladium and an outline of the economic, technical and environmental value of a palladium based solution to all your plating needs.

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11. Gonzalez et al., *Développement et application d'un nouveau procède de PdNi sans ammoniaque*, Swiss Electroplating Association (2005).

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