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Pd Grows Stronger as a Substitute for Gold

Precious metal electrodeposits have found numerous applications in electronic manufacturing by utilizing a unique property in a specific area to gain an advantage—where value far outweighs material cost. Corrosion, chemical, and contact resistance; electrical conductivity; hardness and eutectic alloy formation are distinctive features that have been crucial in the success of countless technology advancements.

A precious metal is an extremely expensive commercial element. Its price is quoted per troy ounce or per gram, and can vary widely based on several factors: Availability, inflation, and industrial demand. Metals that fall into this classification are gold (Au), silver (Ag) and elements in the platinum group. The latter elements are grouped together because they are found in the same ores. They include iridium (Ir), palladium (Pd), platinum (Pt), osmium (Os), rhodium (Rh) and ruthenium (Ru).

Table 1
Cost/Property Data—High-density Metals[1,2,3]

	mp	Density, g/cc	% IACS	ER μΩ/cm	Cost, $ Tr.oz.	Cost, $ gm.
Au	1063 °C (1945 °F)	19.3	73.4	2.19	384.00	12.35
Pt	1662 °C (2836 °F)	21.45	21.45	10.6	411.00	13.22
Ir	2452 °C (4449 °F)	22.5	—	4.9	60.00	1.93
Os	2700 °C (4900 °F)	22.57	—	9.5	N/A	

Table 2
Cost/Property Data—Medium-density Metals

	mp	Density, g/cc	% IACS	ER μΩ/cm	Cost, $ Tr.oz.	Cost, $ gm.
Ag	961 °C (1761 °F)	10.49	108.4	1.59	5.33	0.17
Pd	1552 °C (2836 °F)	12.02	16	10.8	137.00	4.41
Rh	1966 °C (3571 °F)	12.44	—	4.51	330.00	10.61
Ru	2500 °C (4530 °F)	12.2	—	7.6	29.00	0.93

Capitalizing On a Unique Property

Currently, only gold and silver have found widespread use in electronics. The latter has the highest conductivity and lowest electrical resistivity of all metals, which guarantees an excellent surface in static pressure and slow-speed switch contacts. These properties are beneficial in thick film conductors. On PWBs, however, silver is rarely used because, under certain humidity and voltage conditions, it has a tendency to migrate across and through the body of insulation, producing low-resistance leakage paths.

The numerous unique properties of gold (*e.g.*, chemical and corrosion resistance, low electrical resistivity, high conductivity and eutectic alloy formation with silicon, germanium and tin) have been instrumental in propelling the electronics industry to its current lofty position. Gold finds applications in component, hybrid, and PWB manufacturing.

Replacing Gold

With the end of the cold war and a resurgence in commercial electronics (resulting from recent advancements in component technology), material costs are an ever-increasing factor in coping with price-sensitive markets. Many of the unique properties of gold are also found in most other precious metals.

A careful study of silver and platinum-group metals indicates that only palladium possesses the potential to compete with gold for a greater use in electronics. For electroplating applications, medium-density elements (*e.g.*, Pd, 12 g/cc) have a distinct advantage over heavy-density metals (*e.g.*, Au, 19.3 g/cc) when considering cost per given thickness.

Of the high-density metals, only gold has found widespread application in the electronics industry. Properties such as eutectic alloy formation are utilized for bonding—

Table 3
Solubility in Tin/Lead

	Temp °C	°F	Dissolution Rate µm/sec	µin./sec
Au	232	450	3.0	117.9
	252	486	4.3	167.9
Pd	232	450	0.35	1.4
	273	525	0.16	6.2

for example, 97 Au/3 Si (mp 363 °C/685 °F); 88 Au/12 Ge (mp 356 °C/673 °F); 80 Au/20 Sn (mp 280 °C/536 °F). Gold's chemical resistance makes it an excellent etch-resist metal, and solderability is preserved by protecting the surface from oxidizing. Low electrical resistivity and high conductivity are valuable properties for a contact surface.

The use of noble metals heavier than gold has been limited by cost considerations, electrical properties, and by the fact that electrodeposited coatings are thinner for higher-density metals.

Cost factors have restricted the use of rhodium to only those applications where hardness is crucial for a contact surface. Ruthenium finds very limited use as a hardener for alloys employed as electrical contacts where extreme wear resistance is essential.

Palladium is currently being investigated as a lower-cost alternative to gold. During October 1995, the price of gold was 2.62 times greater than palladium. In addition, a density difference (19.3 vs. 12.02 g/cc) provides an even greater advantage with regard to cost per plating thickness.

Properties promoting palladium include cost, chemical resistance, low solubility in solder, and bonding possibilities similar to gold (*e.g.*, aluminum/gold wire bonding).

Interest in palladium and palladium/nickel coatings on PWBs as an alternative to HASL was prompted by the urgency for flat pads, and a precise volume of solder when bonding ultra-fine-pitch components. The ability to serve as a metal etch resist and provide a surface wire bonding could be valuable in expanding the market for PWBs.

The main concern of soldering to gold is brittleness, resulting from excessive gold/tin intermetallic when the gold content of the fillet exceeds 3 percent. It does not appear that embrittlement from intermetallic formation presents a problem for palladium because of its low solubility in tin/lead. This is illustrated by the data in Table 3.[4]

In 1980, when the price of gold reached $875 and speculators predicted it would surpass $1,000, palladium was a strong candidate as a lower-cost alternative. As the price of gold settled to lower values, desire for replacement diminished. In today's price-sensitive market, however, palladium resurrects itself.

Conclusion

With its decided cost advantage, its ability to function as a metal etch resist metal, preserve solderability, and offer a viable coating for wire bonding, palladium is a formidable contender in the gold alternative market. *P&SF*

References

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