Gold Plating

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Applications

Gold is one of the most noble metals and is also counted among those with the best electrical properties. These combined features make gold a logical choice for electronic interconnection applications. Naturally, the relatively high price of this metal restricts its use to those applications where its unique properties make its use essential.

Much of the technology associated with gold plating of electronic contacts and semiconductor devices has been directed toward minimizing use of the amount of metal per component, while striving for maintenance of deposit performance. A very significant reduction in gold consumption has resulted from efforts in the following areas:

- Reducing deposit thickness to a minimum;
- Reducing waste by ensuring uniform deposit thickness;
- Eliminating unnecessary deposition by greater use of selective deposition.

Equipment design and process formulations have developed together to significantly improve the efficient use of gold over the two decades. Increased plating speeds and improved parts handling have been ancillary benefits derived from this work.

The ability of pure gold to form a low temperature eutectic with silicon is a property still employed on critical or sophisticated silicon chip carrier devices. Newly developed bonding techniques, such as silver-filled epoxy bonding, has enabled the use of plated silver in place of gold in the vast majority of semiconductor applications.

Deposits of gold containing small quantities of other metals, such as nickel or cobalt, have been the exclusive finish for low-load electrical connectors for approximately three decades. Recently, proposed alternatives based on palladium require a thin gold over-flash in order to have equivalent performance.

The birth of the electronics era marked the end of almost a century during which the only applications for gold plating were decorative ones. However, this use still accounts for more than 10 percent of plated gold today.

Processes

Gold is applied to the surfaces of electronic components in one of four ways: (1) by electroplating; (2) by thermal decomposition of a screen-printed paste (thick-film technology (3) by vacuum deposition or thermal decomposition of a metallo-organic compound (thin-film technology); or (4) by mechanical rolling to form a strip stock from which components can be stamped or punched (inlay materials).

Electroplating accounts for the greatest consumption of gold among these techniques, since it is generally more versatile than the others and offers more precise control of the precious metal used. The plating solutions employed usually contain potassium gold cyanide, $KAu(CN)^2$, sometimes referred to as PGC. Solution conductivity and buffering are supplied by salts such as citrates and orthophosphates, depending on other solution components and the deposit properties desired.

Pure gold deposits are utilized for bonding applications and these are usually produced from solutions with pH values between 5.5 and 8.0. It is common practice to employ certain semi-metal elements to promote fine deposit grain size. However, brightening agents, which would significantly contaminate the deposit, should never be used. Typical grain refining additives include compounds of trivalent arsenic (As^{III}), thallium (TI^{2+}) and lead (Pb^{2+}) all at concentrations below 20 mg/L (20ppm). Thallium is prohibited from use in certain wire-bonding applications, due to subsequent fatigue failure of the wire bond.

Any thermal bonding procedure requires a gold deposit of high purity (usually 99.9 percent or more), which is free of porosity. The use of nickel pre-plates and a pure gold strike assist the plater in achieving these deposit requirements.

Since potassium gold cyanide is stable in solution above a pH value of 3.1, use can be made of solutions with pH values between 3.5 and 5.0. In this pH range, controlled co-deposition of small quantities of transition metals such as cobalt, nickel or iron is possible. Gold deposits, containing 0.1 to 0.3 percent by weight of one or more of these metals, undergo a dramatic transformation. Their structure becomes lamellar rather than equi-axial, and they contain measurable quantities of carbon, nitrogen and potassium, as well as the transition metal itself. The result is a massive improvement in wear resistance, enabling these gold deposits to provide durable contact surfaces. Since they are relatively hard (130 to 200 Knoop at a 25-g load), they are referred to as “hard gold deposits,” and the plating solutions that produce them are called “acid golds,” due to their relatively low pH range. The material that is included in hard golds has been dubbed “polymer.” Although its identity remains unsolved, it undoubtedly plays a significant role in the excellent sliding wear resistance observed.

It should be noted that while pure gold deposits have a density approaching that of the wrought metal (1 9.3 g/cm^3),

hard gold deposits have a density approximately 10 percent lower. In most cases it is sufficient to assume a density between 17.3 and 17.7 g/cm^3. When deposition has occurred under extremely high current density (usually in excess of 200 A/ft^2, it may be necessary to measure deposit density. Figures as low as 16.3 g/cm^3 have been observed. Suitable corrections should be made for density when calibrating X-ray fluorescence and beta backscatter thickness measuring instruments; otherwise, erroneous thickness readings will result.

It is often necessary to solder gold plated components and it is important to note that gold dissolves in molten solder, the bond forming between solder and the substrate metal, usually copper or nickel. Whenever possible, gold thickness should be minimized in the area to be soldered. A maximum thickness of 20 µin. (0.5 µm) is best. Also, pure gold dissolves more readily than hard gold.

Dewetting is the most common form of failure when soldering gold-plated parts. This is most often due to a passive nickel surface beneath the gold layer, but can also be due to excessive impurities co-deposited with the gold film. Organic breakdown products formed during solution operation can cause poor soldering. Plating solutions should be carbon-treated regularly to remove detrimental organic substances.

The only viable gold plating solutions that are cyanide-free are based in sodium gold sulfite, $Na_3Au(SO_3)_2$. However, these alkaline solutions work best if preceded by a cyanide-based gold strike. They produce bright, hard deposits but lack the wear resistance offered by acid gold processes.

Decorative gold plating has benefitted from many of the developments introduced by the electronics industry. Hard gold deposits have provided durable decorative finishes on articles such as watches and eyeglass frames. One application has benefitted from the development of deposits from sulfite-based gold solutions—that of bathroom fixtures and fittings. These solutions withstand contamination from the hollow castings so prevalent in this industry. Cyanide-based gold solutions are destroyed by this contamination much sooner.

Post-plating

Gold is virtually the ultimate in corrosion protection, so post-plating treatments of this type are not normally employed. Special care should be taken in rinsing after gold plating in order to minimize gold losses due to drag-out of plating solution. It is common practice to employ at least two static rinses after gold plating prior to any running water rinses. These static water tanks are equipped with means for recovering dissolved gold by electrolysis or ion exchange. Subsequent high-purity hot and cold water rinses remove salts from the surface of the gold deposit.

Post-plating heat treatment is rare, but it should be noted that hard gold deposits cannot be heated above 250 °C (485 °F) without risk. The "polymer" content of these deposits decomposes at elevated temperatures. Pure gold deposits can be heated to temperatures in excess of 500 °C (932 °F), provided they are plated over a suitable barrier layer, such as nickel.

Environmental Status

Gold is not a threat to the environment. It is also collected with great care because of its value. After the gold is removed from the plating solution, quantities of cyanide and base metal impurities associated with gold plating are easily treated by traditional chlorination, followed by high pH precipitation of metal hydroxides prior to discharge. Ion exchange resins collect gold as the cyanide complex and must be handled as hazardous waste after gold has been absorbed on them.

Health Impact

Gold metal is not considered toxic; however, many of the chemicals utilized in gold plating solutions are potentially hazardous. Normal precautions should be observed. Particular attention should be paid to routine protection of the skin, since operators seem to suffer more frequent dermatological reactions to gold cyanide solutions than to almost any other cyanide-bearing material.

Metallic brighteners used as solution additives, such as nickel salts, may be hazardous. Solutions containing more than 0.1 percent by weight (1 g/L) arsenic are considered to be carcinogenic.

Trends

Improved design of electronic components, aimed at selective gold plating solutions and equipment, is already a well-established practice in the electronics industry. New additives for acid gold solutions allow much higher deposition speeds to be attained improvements from 3 to 15 µin./sec or 4.5 to 22.5 µin./min. are typical.

A growing number of connectors are being designed so that traditional hard gold can be replaced with a similar thickness of either pure palladium or palladium-nickel (80 percent Pd-20 percent Ni), plus a thin top layer of gold, usually only 2 to 5 µin. thick. In some specific cases, those novel deposit combinations are outperforming hard gold. P&SF