Selecting the Right RoHS compliant Finish

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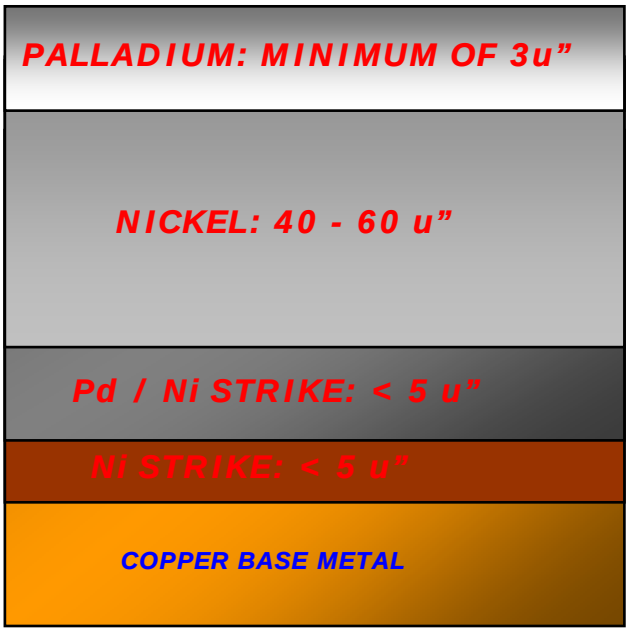
As the RoHS deadline approaches there is continued discussion about Lead(Pb)-Free finish selection for leadframe based packages. The majority of integrated circuit (IC) manufacturers will use tin (Sn) as their replacement for tin-lead (SnPb) in post-mold plating operations. A few component suppliers have opted to use nickel-palladium-gold (NiPdAu) preplated as a Pb-Free finish option. Other options exist including tin-bismuth (SnBi) and tin-copper (SnCu), but Sn and NiPdAu appear to be the choices for the majority of IC manufacturers. Certainly there are pros and cons with both Sn and NiPdAu finish. This article will review TI's component finish history and the decision process that led to our strategy.

More than 20 years ago IC package lead pitch was decreasing to below 50 mils (0.050"). At that time, TI's primary component finish was SnPb solder applied by a solder dipping process. Solder dipping is a good finishing process but does not work well when component termination finish is less than 50 mils. TI engineers knew that TI would either have to make a significant capital investment in solder plating equipment or develop a preplated technology that would not require plating after the mold encapsulation process.

NiPd

TI devoted significant resources and time to develop the NiPd leadframe plating structure in the mid to late 1980s. The result of the work was a structure that utilized copper (Cu) base metal, two strike layers (Ni and NiPd), a Ni layer (40-60microinches), and finally a palladium layer with minimum thickness of 3 microinches (Figure 1)



In this system the palladium serves as an oxidation barrier to keep the Ni from oxidizing prior to soldering. High-temperature assembly processes (wire bonding, die attach cure, mold cure) were optimized so that no negative impact would be encountered either to those processes or to final product solderability.

This structure served TI well as it allowed for assembly of very fine pitch components with no post-mold plating operation. Removal of post-mold solder plating or dipping operation meant that all chemicals and waste associated with this process could be eliminated from the assembly process. Also, removal of an entire process step in the assembly operation meant that the floor space and manpower could be utilized for other operations.

Introduction of a new plating technology into the electronics industry did require significant work to demonstrate solderability and reliability. TI understood that it would be impossible to introduce a new finish technology if it was not a "drop-in" replacement for SnPb components. Customers simply would not accept a new finish option if it meant that they had to change their assembly process.

Prior to, and during, the introduction of NiPd finish, TI performed multiple studies in the areas of reliability, solderability testing (steam age, wetting balance, and surface mount method), board mount visual appearance, and solder paste compatibility. Our multiple studies were documented in the Palladium Lead Finish User's Manual (http://focus.ti.com/lit/ml/sdyv001/sdyv001.pdf) for ease of access.

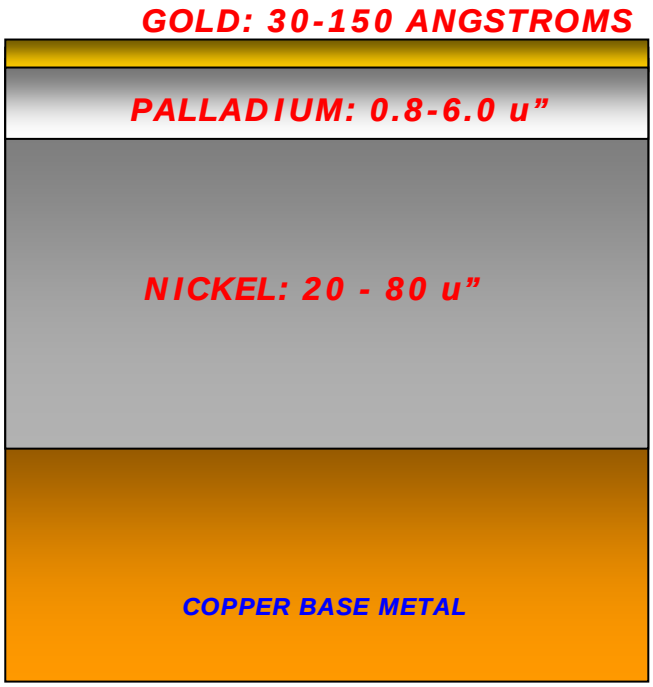
Starting in 1989, and continuing in the early 1990s, TI converted its internal assembly operations to use of NiPd finish for all leadframe packages. For leadframe manufacture, NiPd finish was qualified at TI's internal leadframe plating facility in Attleboro, Massachusetts. TI then qualified five major lead-frame plating houses for the manufacturing of NiPd finish.

It was during this same timeframe (late 1990s) that the price of palladium spiked from the low $100s/ounce to over $1000/ounce. With the minimum of 3 microinches Pd plated on the surface of the NiPd leadframes this spike in Pd pricing did impact lead-frame cost. TI was already committed to the NiPd finish. The dramatic rise in Pd pricing meant that we would have to develop new ways to limit precious metal usage so that we could minimize exposure to fluctuations in Pd pricing without compromising product performance.

Once again TI went back to the "drawing board." TI developed designs and plating methods that would allow it to maintain the 3u" of Pd in the soldering areas but minimize Pd content across the non-functional regions of the lead-frame. This focus on process optimization allowed TI to greatly reduce the sensitivity to fluctuations in palladium pricing upon lead-frame cost.

NiPdAu

As stated, TI developed and introduced the NiPd structure into the market starting the 1989. Subsequently, in the early 1990s, Japanese lead-frame suppliers introduced an alternative version of this finish utilizing nickel-palladium-gold (NiPdAu). The NiPdAu structure used thinner Pd (0.8u" versus 3u" in NiPd) with a flash (angstroms thick) of gold on top of the Pd. Certainly, TI noticed this development. Figure 2 shows the typical NiPdAu structure introduced.



The thinner Pd and addition of Au allowed for quicker dissolution of the Pd and thus improved wetting balance times. The work to optimize plating operations had reduced the exposure to swings in Pd pricing and allowed TI to continue to successfully utilize NiPd finish through the end of the 1990s.

For NiPdAu lead-frame production, TI qualified our internal lead-frame manufacturing operation. Externally, TI qualified 7 major lead-frame plating houses to manufacture NiPdAu finish. As with NiPd plating line qualifications, every external plating house qualified to produce NiPdAu lead-frames went through a rigorous plating line qualification.

Pb-Free

In the late 1990s, the component industry took notice of the legislation requiring removal of Pb from electronic products. TI found itself in a unique position with a Pb-Free finish (NiPd) already in use for the majority of our lead-frame based packages. Along with use of a Pb-Free finish, TI certainly would have to investigate and implement new material sets (mold compound, die attach, etc) that could withstand the higher temperature requirements of Pb-Free reflow.

In 1999, TI saw that most IC suppliers planned to convert their post-mold plating operations from SnPb to pure Sn. TI took notice and decided that the need to evaluate the primary Pb-Free finish options available was important in order to define future strategy. TI evaluated Sn and NiPdAu finish alongside our NiPd finish already in production. Evaluations showed that while Sn finish was producible and solderable, a significant investment in post mold plating equipment would be necessary. The work also showed that there was an enhancement in laboratory wetting tests with NiPdAu finish versus NiPd. Also, it was about this same time that the industry started whisker evaluations through consortia groups such as the National Electronics Manufacturing Initiative (NEMI). Component users, especially in high reliability environments such as telecom, military, and automotive sectors, noticed that their suppliers were planning conversion to Sn finish and started raising concerns about whisker growth. The concern over tin whisker growth, improved wetting performance with NiPdAu versus NiPd, customer preference for NiPdAu, and further reduced exposure to precious metal price fluctuation were the factors that caused TI to choose to convert our internal assembly sites from use of NiPd finish to NiPdAu finish. TI documented board level soldering evaluations which demonstrated good soldering performance of the NiPdAu finish (http://focus.ti.com/docs/apps/catalog/resources/appnoteabstract.jhtml?abstractName=szza026). This conversion of internal assembly operations from NiPd to NiPdAu finish took place in the 2000-2001 timeframe.

High-Temperature Requirements

After completion of the NiPdAu qualifications TI set out to qualify material sets (die attach adhesive, mold compound) capable of withstanding the higher temperatures of Pb-Free reflow. Starting in 2003, TI released packages qualified for 250C or 260C peak reflow, per J-STD-020B. TI worked closely with die attach and mold compound suppliers to optimize their materials for compatibility with the NiPdAu finish. Since the introduction of J-STD-002C, TI has qualified material sets capable of being rated for 260C reflow. In 2005, TI began introduction of “green” (Br-free/Sb-free) mold compounds. Once more this was an achievement which required significant collaboration between TI and suppliers to develop the materials. Each time an upgrade to materials was needed TI has partnered with suppliers to insure that new materials compatible with NiPdAu finish were successfully developed.

Subcon Built Product

TI’s strategy for internally built product had been set, however TI still had to address the minority of parts built at external assembly subcontractors. In 2001, TI contacted most of the external subcons. When asked, the majority of the subcons stated that Sn finish would be their primary offering. The subcons had found that this would be the easiest solution to implement similar to the strategy developed by other IC suppliers. However, TI understood that the potential for whisker growth would be a major concern for many customers.

In 2002, using inputs from NEMI whisker test plans TI devised a whisker test which used conditions of 51C/85RH. The units tested were all classified as "matte" tin finish per NEMI definition. The term matte refers to the grain size, thickness, and other plating factors of the tin finish. Use of matte tin finish was believed to be a mitigation factor for whisker growth. The TI whisker evaluation performed in 2002 (http://focus.ti.com/lit/an/szza037a/szza037a.pdf) showed whisker growth on several of the groups tested, even though they were built with matte tin. This result caused TI to further scrutinize the strategy for subcon built product. TI determined that it would be best to align the strategy with use of NiPdAu at external subcontractors wherever possible. In 2003 and 2004, TI partnered with most of the contracted external assembly subcontractors to qualify NiPdAu finish. Most TI external subcons are capable of producing NiPdAu finish components now.

In 2003-2005, TI performed whisker evaluations that included multiple finish options, beyond the work done in 2002. Finishes evaluated included SnPb, NiPdAu, matte Sn, SnCu, annealed matte Sn, and bright Sn. In this study, NiPdAu finish did not grow whiskers, as expected. Units finished with SnPb, matte Sn, bright Sn, and SnCu all demonstrated whisker growth in at least 1 sample. However, no whisker lengths were noted greater than the current industry technology acceptance criteria. Results of this study will be published by TI in 2H 2005.

Conclusion

TI is the leader in the use of preplated Pb-Free (NiPd, NiPdAu) finishes for lead-frame packages. TI developed and implemented NiPd finish in the late 1980s and converted to NiPdAu finish in 2000 and has over 50 billion palladium finish components in the field. NiPd and NiPdAu finishes are developed, proven technologies – not new. TI has demonstrated that palladium finish components can be manufactured in high volume operations and soldered in both SnPb and Pb-free soldering processes. Use of NiPdAu finish on TI internally built packages and most subcon built product has allowed TI to offer a whisker-free solution available for customers.