# What's Your PCB IQ?

*Marissa Oskarsen & Chrys Shea, Printed Circuit Girls and Geeks*

## Quiz #4
## PCB Final Finishes

Take The Printed Circuit Girls and Geeks' 10-Question Pop Quiz on PCB Final Finishes.

**Questions:**

1. What is the best overall PCB final finish?
    a. Organic Solderability Preservative (OSP)
    b. Electroless Nickel – Immersion Gold (ENIG)
    c. Electroless Nickel –Electroless Palladium – Immersion Gold (ENEPIG)
    d. Immersion silver (ImmAg)
    e. Immersion tin (ImmSn)
    f. SnPb Hot Air Solder Levelling (HASL)
    g. Pb-free HASL
    h. None of the above

2. What is the key consideration in selecting a surface finish?
    a. Price
    b. Volume
    c. Finest pitch component
    d. All the above

3. Which surface finish has the poorest stability through multiple reflow cycles?
    a. OSP
    b. ENIG
    c. ImmSn
    d. ImmAg
    e. ENEPIG

4. Which surface finish is the overall most robust?
    a. OSP
    b. ENIG
    c. Pb-free HASL
    d. ImmAg

5. Which potential failure mode is *not* associated with ImmAg:
    a. Planar microvoids (aka "Champagne" voids)
    b. Creep Corrosion
    c. Black Pad

d. Trench Etch
e. None of the Above

6. True or False: Black Pad can be seen with the naked eye?

7. True or False: Creep corrosion can be seen with the naked eye?

8. True or False: ImmSn surfaces are prone to tin whiskers?

9. True or False: surface finishes that have demonstrated champagne voids, SMIA, creep corrosion or black pad can be returned to the board fabricator for rework?

10. True or false: In addition to metals and organometallics, polymers now work as PCB surface finishes?

**Answers:**

1. h. None of the above. If there were a perfect finish, this would be a super-simple, one question quiz. Every final finish has its plusses and minuses, and it's up to the engineer to understand how the different finishes' attributes apply to their product configuration and assembly process. The chart below should help.[1]

| Surface Finish | Cost | Corrosion Res | ICT | Hole Fill | Fine Pitch | Cosmetics | Comments |
|---|---|---|---|---|---|---|---|
| Imm Silver | Low | Poor | Good | Mod | Good | Poor | Good surface finish for soldering and testing, tarnish & creep corrosion are the weaknesses |
| HT OSP | Low | Mod | Good | good | Good | Mod | Requires pasting of test pads/vias. Not all OSP's are created equal. Evaluate carefully |
| LF HASL | Mod | Good | Good | Good | Mod | Good | Phenolic laminate recommended. New equipment required. Flatness is better than SnPb HASL |
| Imm Tin | Mod | Good | Good | Mod | Good | Mod | Solderability/hole-fill may be a problem on double sided PCBs. Shelf life. |
| ENIG | High | Mod | Good | Good | Good | Good | Galvanic driven creep corrosion can occur if Cu is exposed. Ni-Sn interface is brittle with LF. Black pad issues remain. |
| ENEPIG/ AG | High | Good | Good | Mod | Good | Good | Expensive coating and more plating steps. Evaluate cost/reliability. No black pad issues. |

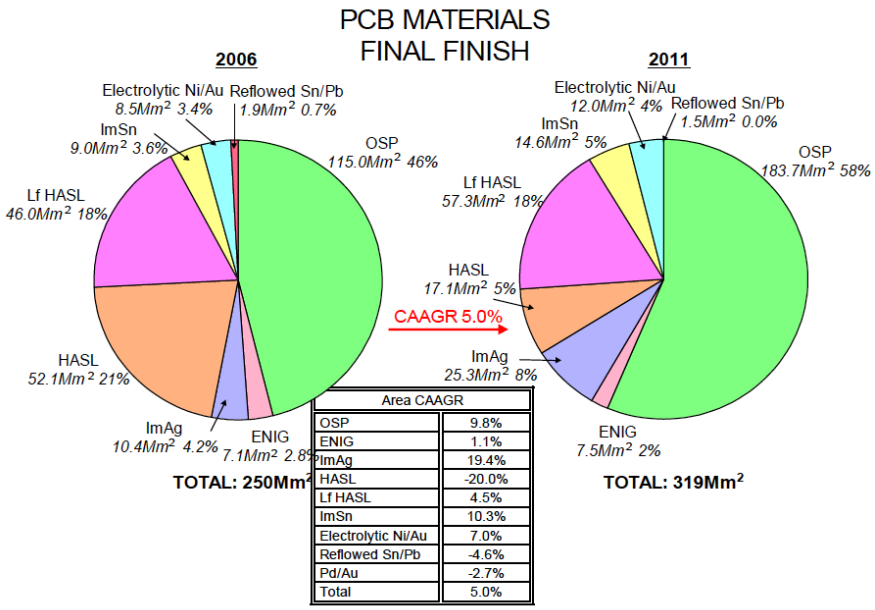
*Courtesy of Mike Carano, OMG Chemicals*

2. d. All the above. While we all like to begin with price (sigh! *purchasing*…), all that quickly changes once you consider volume. OSP is the cost leader (simmer down there, purchasing folks!) ***except*** when considering small or domestic builds; in those cases lead free HASL is your winner on price. But, Pb-free HASL has bad coplanarity and is not recommended in fine pitch assembly. What do we consider fine? Any device with 0.5 mm (20 mil) pitch or smaller. Even if it's only one component, HASL is not a good option because it will cause yield problems at assembly.

   Other considerations include shelf life, your contract assemblers' processing preferences, and product requirements such as wire bond capability or drop shock resistance. The ultimate decision is based on a combination of factors that include production volumes, economics and technology.

3. c. The solderbility of ImmSn decreases during storage and after the 2nd reflow due to copper-tin intermetallic compound growth through the tin layer.

   If you guessed OSP, it's probably because you had a bad experience with it. OSP also deteriorates during storage and in reflow, but not all OSP's are created equal, so please don't be so quick to judge. The good folks at OMG Chemicals have upgraded the coating to enhance its humidity and oxygen resistance, and have improved the microetching process too, helping this inexpensive surface finish become the world's most popular. OSP makes up 58% of all PCB finishes produced globally, as illustrated in the chart below.




| Area CAAGR | |
|---|---|
| OSP | 9.8% |
| ENIG | 1.1% |
| ImAg | 19.4% |
| HASL | -20.0% |
| Lf HASL | 4.5% |
| ImSn | 10.3% |
| Electrolytic Ni/Au | 7.0% |
| Reflowed Sn/Pb | -4.6% |
| Pd/Au | -2.7% |
| Total | 5.0% |

*Source: Prismark*

4. b. All printed circuit snobs got this one right (I can say this because I am a self- professed PCB snob). And the answer is not ENIG just because we love this shiny precious metal so much that we adorn ourselves with it on a daily basis. It's actually because ENIG averages a shelf life of about 24 months! Two years is a long time to sit on a shelf and still solder like a champ. No other finish even comes close. What are the typical shelf lives of other finishes, ***if*** they're stored properly?

   - SnPb or Pb-free HASL: 18 months
   - ImmAg: 12 to 16 months
   - OSP: about 6 months

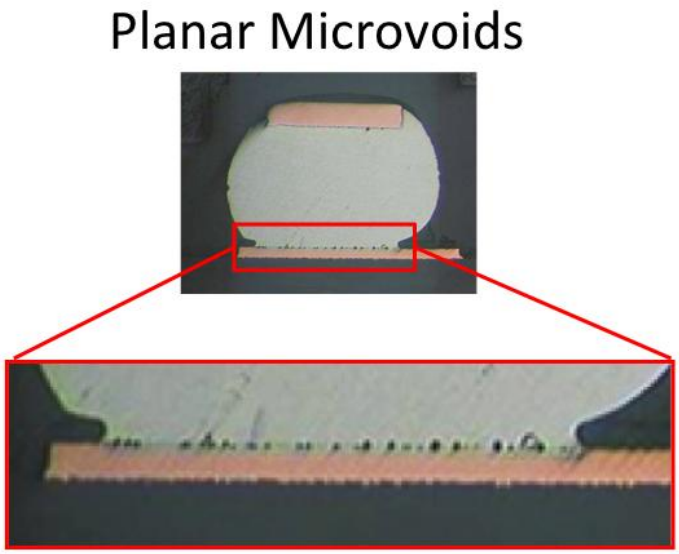
   I know my estimates might not necessarily agree with the manufacturers' spec sheets, but these numbers are based on personal experience, not marketing materials.

   ENIG's shelf life, along with other factors like its flat surface and easy wetting, make it the overall most robust. But like any other finish, it has certain drawbacks, too. Like the dreaded *black pad*.

5. c. Black pad. It is associated with ENIG finishes. More on that later.

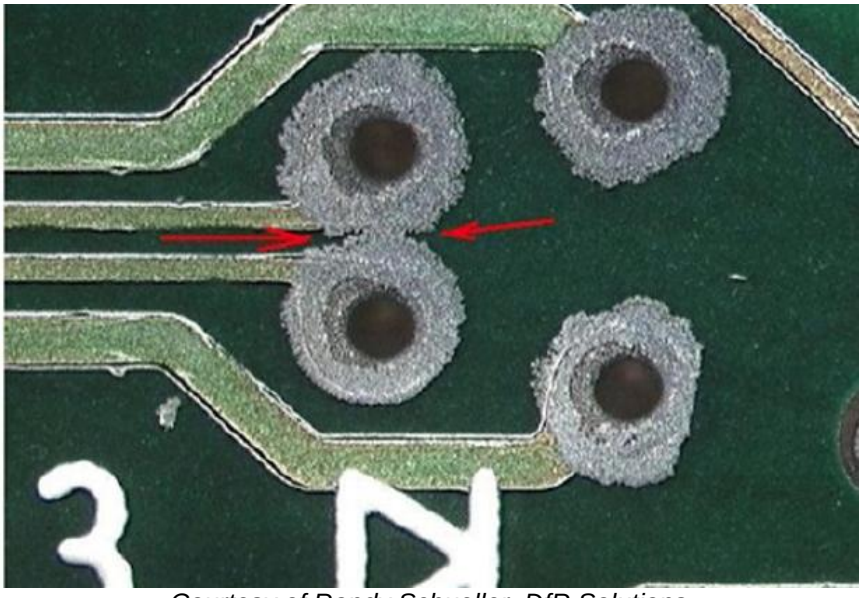
   Ok, so what are planar microvoids? I prefer their other name, *Champagne voids*. Who doesn't like a bit of the bubbly? Customers, that's who! When their product's reliability is compromised by this condition they might actually need a drink, and we can guarantee it won't be champagne…

   **Champagne voids** are a layer of small pockets of air/gas located right above the intermetallic compound region of the solder joint.[2] This layer is weak and fails when stressed. Under magnification, the fractured surface appears to have little bubbles, like the ones that nucleate in the bottom of a champagne glass. The bubbly champagne is much prettier though, and the reliability issues associated with this type of voids are way more troubling than your average hangover.



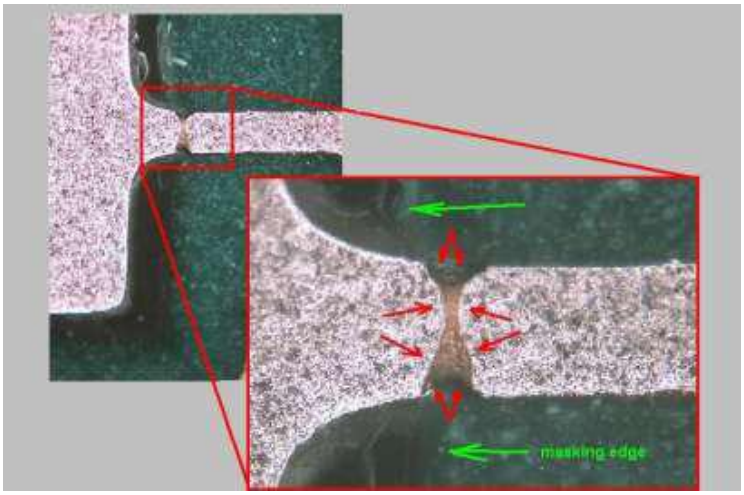

*Source: Intel*[3]

**Creep corrosion** happens when ImmAg finish is put into service in a humid, sulfur-rich environment.[3] A galvanic reaction between the silver finish and small areas of exposed copper under the edges of the solder mask produces copper sulfide. That's the corrosion part. When the $Cu_2S$ migrates radially out on the PCB and makes the areas around the pads and annular rings look like chia pets, that's the creepy part.



*Courtesy of Randy Schueller, DfR Solutions*

**Trench etch** is a fine example of the old adage “haste makes waste.” Also known as **Solder Mask Interfacial Attach (SMIA),** it is a result of too fast a silver deposition rate. The “trench” that is formed in the conductor is located at the edge of the solder mask and exposes copper, making it the perfect starting point for creep corrosion.




*Courtesy of Mike Carano, OMG Chemicals*

THIS IS IMPORTANT! While these three defect modes are associated primarily with ImmAg finsih, they are not common and should not discourage you from using it. It’s actually a really good finish; a great alternative to OSP is you want to improve PTH hole fill with lead-free solders. But just like OSPs, all ImmAg finishes are not created equal. Here are a few pointers for optimizing the performance of ImmAg:

- Because it is still growing in popularity, beware of shops that “offer” the finish but don’t apply it on a regular basis. Ask about their experience with it.
- Specify the type or brand of ImmAg you want on your PCBs. Don’t use a generic “ImmAg” call-out or the words “or equivalent” with your specification.
- Store your PCBs properly. Exposure to sulfur gas from kitchens, cafeterias, or industrial environments can cause them to tarnish faster and lose their solderability.
- Consider their end use. ImmAg might not be the best choice for an environment that’s high in sulfur and moisture.

6. False. Black pad is caused by a corrosive attack of the gold bath chemistry on the nickel. It happens inside the metal layers as shown in the cross section below, and cannot be seen by the naked eye, or even with your pocket-sized microscope. It can’t be diagnosed after soldering,

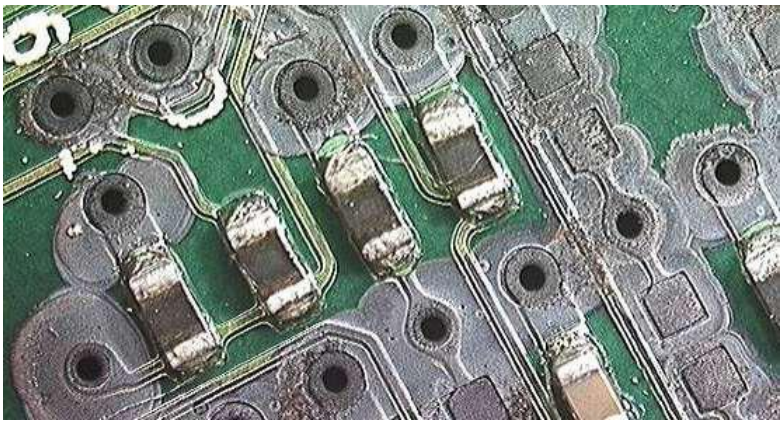
either. Joints formed on plating with black pad look fine visually and under X-ray. It is usually not discovered until the joints suffer massive brittle fractures, and unfortunately it manifests itself in the form of field returns when BGAs start popping off the board with little or no coaxing. If you've never been affected by it, you are fortunate, because it really is as bad as it sounds.

Not all brittle joint failures on ENIG finishes are due to black pad, however. They can be the result of incorrect reflow profile times or temperatures, oxidation of the nickel, or contaminants on the PCB surface. True black pad can only be diagnosed by cross-sectioning the solder joint and looking for the telltale saw tooth pattern shown in the micrograph below.


*Courtesy of Mike Carano, OMG Chemicals*

ENEPIG adds a layer of electroless palladium between the nickel and the gold. It prevents black pad and is a good alternative if you like ENIG, but it comes at a slightly higher price because of the added process steps and precious metal.

7. True. You can't miss it. No microscopy needed!!! Here's another creepy photo:



*Courtesy of Randy Schueller, DfR Solutions*

8. True AND False - it's a trick question. Tin whiskers can form on any solder joint or PCB surface because they relieve the stresses caused by an intermetallic region growing below the surface. Generally speaking, the thicker the tin, the more likely the surface to sprout hillocks or whiskers. Because the tin layer in the ImmSn finish is so thin, and also because some finishes have "anti-whiskering" coatings, it is likely that tin whiskers would form on other areas with thicker tin coatings before they would form on the PCB finish.

   Is it possible? Yes. Probable? No. Give yourself a point for getting this answer right.

9. False. They belong in the trash along with every vampire romance novel ever written. These rejects carry too big of a liability to be reworked and/or cannot be reworked because the underlying copper is affected by the problem.

10. True! A brand new treatment called SPF (Semblant Plasma Finish) is now available for use as a final finish over bare copper, or as a protective layer over existing finishes to extend shelf life and preserve solderability. It's a fluoropolymer that's plasma deposited in a vacuum chamber - and you can solder through it! Talk about a paradigm shift…this could change everything.

**How deep is your knowledge of surface finishes?** Give yourself one point for every right answer and deduct one point for every wrong answer.

**If you scored 8-10 you earned a gold PLATED medal**
Yes, plated! We are a printed circuit board distributor… we don't have big margins and this is all we can afford. But you still should be proud. This is

the most robust and expensive surface finish, and you deserve it because you understand that your specification will have a large influence on your products' quality, reliability and cost.

**If you scored 0-6 you earned a silver PLATED medal**
Basically, you're just a runner up to employee of the month. Slightly tarnished. Always number 2. But don't panic and pull a Tonya Harding! Remember, she didn't get a medal; she got international scrutiny instead. Don't worry though; you won't end up on celebrity boxing like she did. And not just because you're not famous, but because you have actual promise to succeed in technology. Keep taking the PCB IQ Pop Quizzes and soon you'll be able to earn that ENIG medal, and we'll take special care to make sure it doesn't have black pad.

**If you scored LESS THAN ZERO you earned a bronze PLATED medal**
Yep, bronze. Because it would fail as a surface finish...just like you did on this quiz! Your future is no brighter than the patina that's already forming on your medal. You need to either keep learning or start chatting up the right people about that opening in the marketing department.

*Special thanks to our friend Mike Carano at OMG Chemicals, our favorite expert on fabrication chemistry who helped us present this information to you.*

**References:**

1. Carano, M., "PCB Solderable Finishes" Workbook, APEX 2011 Professional Development Course
2. Yau, H.Y. et al, "A Study or Planar Microvoiding in Lead-free Solder Joints, Proceedings of APEX 2007
3. Arrigotti, G., "Planar Microvoids Intel Findings," IPC Committee Meeting 14-4, February 9, 2006
4. Schueller, R., "Creep Corrosion on Lead-Free Printed Circuit Boards in High Sulfur Environments," Proceedings of SMTA International, 2007