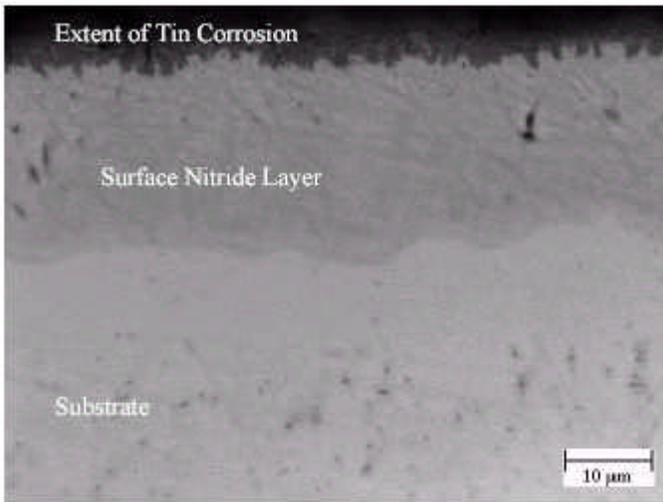




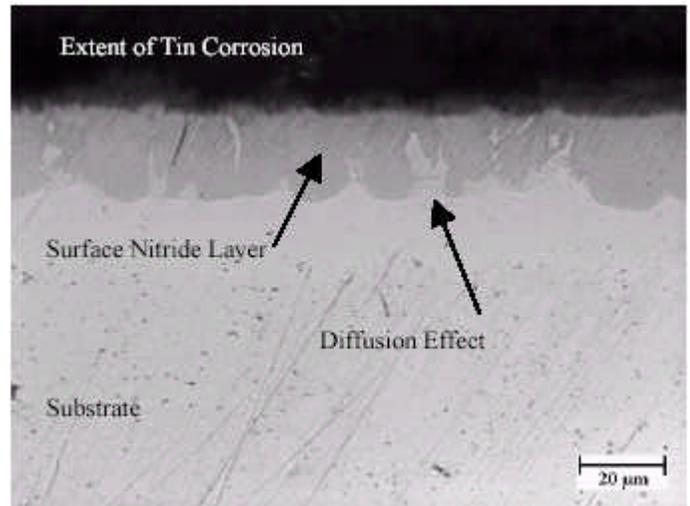
**Figure 12**  
**Titanium Samples**  
**No evidence of wetting**

Figures 6, 7, 8, 9, and 10 show the ability of the Melonite. QPQ Nitriding process to protect the underlying substrate of the stainless steel and carbon steel materials. Macroscopically, all coated samples showed very little wetting except in the area that was scratched. The unprotected 304 and 316 stainless steels had significant wetting on all samples. Plain carbon steel samples were tested as a possible “lower cost” material for solder unit internal components. Plain carbon steel exhibited good resistance to corrosion when protected by the Melonite coating. Results indicate that coated plain carbon steel will give equivalent corrosion protection to the stainless steel materials. Samples were examined microscopically to determine if any corrosion effects could be found.



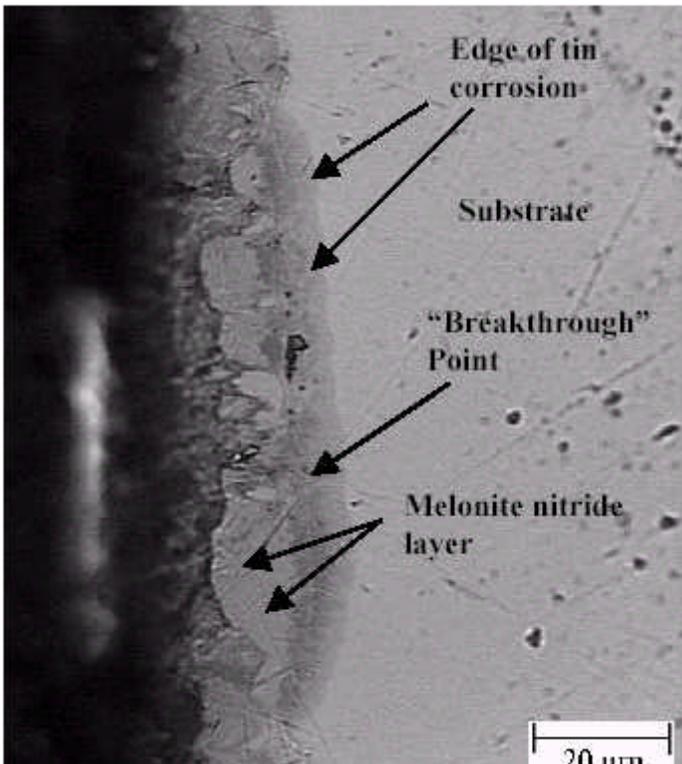
**Figure 13**  
**100X Light Microscope Image of Melonite**  
**Coated 304 SST**

Under magnification, the coated 304 SST sample shows (Figure 13) that the nitride layer remained intact and continues to protect the underlying material. Some pitting was observed on the surface of the nitride layer.



**Figure 14**  
**50X Light Microscope Image of Melonite**  
**Coated 316 SST**

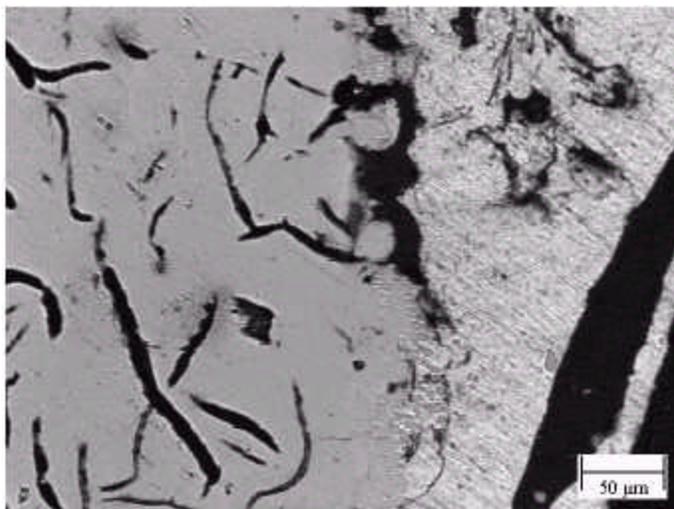
Figure 14 shows a close-up view of the 316 stainless steel sample after exposure to Sn-Ag solder. Visually, the samples did not show any signs of wetting or corrosion. Under magnification there appear to be “fingers” of material protruding into the nitride coating from the substrate side. These fingers do not appear on the baseline samples. It is suggested that the austenitic SST is diffusing nitrogen from the Melonite compound layer. Once extended to the surface, the Sn will attack and undercut the protective coating and eventually cause failure. [2] It is interesting that the 304 SST samples did not show the presence of these fingers that cause degradation of the protective layer. Further investigation needs to be done to determine if this phenomenon is only applicable on the 316 alloy. Given the theory proposed, similar diffusion in the 304 alloy samples would be expected. Higher temperature testing was conducted on the 316 stainless steel coated samples using temperatures of 250°C, 350°C, and 450°C. At the elevated temperatures none of the samples showed significant wetting [2]. Under microscopic examination the austenite diffusion phenomena was much more pronounced than the testing done at the lower temperature levels. Undercutting of the Melonite coating was observed for the 316 coated sample at 350°C (Figure 15)



**Figure 15**

**Image showing undercutting at 350°C exposure.**

This testing indicates that the service life of coated SST components is finite. The coating significantly improves the corrosion protection compared to noncoated stainless steel but will eventually degrade at some point in time. The Grey cast iron samples visually wet after two weeks of exposure. Light microscope images were taken of the 8-week exposed sample to determine the extent of the corrosion.



**Figure 16**

**Grey Cast Iron showing graphite flakes and "damming" action**

Microscopic images of the grey cast iron sample show a "damming" action created by the graphite flakes in the cast iron material (Figure 16). Since Tin will not dissolve the graphite flakes, less iron surface

area is available for attack by the Sn-Ag solder thus slowing the rate of corrosion to a very low level. Available corrosion data shows that cast iron will corrode at a rate of 0.25 mm/year when exposed to molten Sn at 300°C.[6] At this rate, we would expect many years of acceptable service life given the 10-12 mm thickness of these components. Titanium samples exhibited no effects of corrosion or wetting after exposure. This is expected as titanium forms a passive oxide on its surface and the titanium tin phase diagram indicates that titanium has no solubility in tin at the temperatures common to soldering [7]. Of all samples tested, titanium had the most resistance to corrosion attack.

**Summary of Test Results**

Based upon testing, field data, and experience better decisions can be made concerning the use of lead free solder in Wave Solder equipment. Up-front costs, maintenance costs, safety, and reliability must be considered when determining the best selection. Based upon corrosion resistance alone, titanium is by far the best material. The likelihood of being able to afford an entire Wave Solder unit manufactured entirely out of titanium is very low. It is estimated that the purchase price of a new Wave Solder machine with an all titanium solder unit would be double the cost of a regular unit. Unprotected stainless steel, either 304 or 316, is not suitable for long term use in tin-rich lead free solder. Samples of these materials are readily wet after a relatively short-term exposure to solder. On the other hand, when protected by the Melonite coating process the testing indicates that an extended life will result over the non-protected stainless steel. It is important to note that the nitriding coatings do not protect the stainless steel forever, they only delay the eventual corrosion. It is difficult to make predictions on the actual life, but from field experience, three to five years is not unreasonable when protected with a nitride type coating. For comparison, unprotected stainless steel has degraded to the point of failure after as little as 6 months of use. The key to a long life is to avoid scratching or damaging the Melonite protective coating. Once the coating is damaged corrosion of the substrate will be accelerated. Though not evaluated in this examination, we would expect similar results when ceramic coated stainless steel is used. Grey cast iron quickly wets with lead free solder but exhibits a damming action that slows the corrosion to a very low level.

Table 3 gives a summary of the recommended uses for the variety of materials under evaluation.

**Table 3 - Summary of Material Recommendations**

<b>Material</b>	<b>Pro's</b>	<b>Con's</b>	<b>Recommended Uses</b>	<b>Inspection Frequency</b>
<b>Titanium</b>	Extremely resistant to effects of Tin.	Very expensive. Impractical to manufacture many solder unit components.	Areas subject to frequent maintenance or cleaning.  Nozzle plates. Safety critical components.	Every two years.
<b>304 Stainless Steel</b>	Inexpensive.	Little to no corrosion resistance to lead free solders.	Exterior Hardware. Interior Hardware if corrosion resistant hardware in unavailable.  Not recommended for safety critical components.	Inspect monthly.
<b>316 Stainless Steel</b>	Inexpensive.	Little to no corrosion resistance to lead free solders.	Exterior Hardware. Interior Hardware if corrosion resistant hardware in unavailable.  Not recommended for safety critical components.	Inspect monthly.
<b>304 Stainless Steel Melonite/Nitrided</b>	Inexpensive. Good Resistance to Tin-rich solder.	Will degrade if scratched.	Internal Solder module components. Nozzles, ducts, impellers, pumps, etc.  Not recommended for safety critical components.	Inspect every 6 months.
<b>316 Stainless Steel Melonite/Nitrided</b>	Inexpensive. Good Resistance to Tin-rich solder.	Will degrade if scratched.	Internal Solder module components. Nozzles, ducts, impellers, pumps, etc.  Not recommended for safety critical components.	Inspect every 3 months*.
<b>Grey Cast Iron</b>	Inexpensive. Good Resistance to Tin-rich solder. Can be scratched.	Difficult to form for nozzle components.	Internal components in contact with non-flowing solder. Safety critical components (Main Solder pot).	Inspect thickness annually.

\* Due to the undercutting shown on the 316 samples tested a more frequent inspection is recommended.

## **Conclusion**

Tin-rich, lead free solder can be used in pre-existing and new wave solder machines if appropriate materials are used in the construction of the soldering unit. Older machines utilizing unprotected 304 or 316 stainless steel solder pots should not be used with lead free solder. Melonite or other nitride coated stainless steel is a cost effective material to use for the internal solder module components but care must be taken to not damage the surface coatings during maintenance. Melonite or other coated stainless steel is only recommended in safety critical areas when frequent inspections are made to identify degradation of the material. Due to the difficulty of such inspections, safety critical components such as the solder pot should be produced from titanium or grey cast iron but not stainless steel.

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