

# Soldering Immersion Tin

**Rick Nichols and Sandra Heinemann**  
Atotech Deutschland GmbH  
Berlin, Germany

## Abstract

The stimulating impact of the automotive industry has sharpened focus on immersion tin (i-Sn) more than ever before. Immersion tin with its associated attributes, is well placed to fulfill the requirements of such a demanding application.

In an environment dominated by reliability, the automotive market not only has very stringent specifications but also demands thorough qualification protocols. Qualification is ultimately a costly exercise. The good news is that i-Sn is already qualified by many tier one OSATs.

The focus of this paper is to generate awareness of the key factors attributed to soldering i-Sn. Immersion tin is not suitable for wire bonding but ultimately suited for multiple soldering applications. The dominant topics of this paper will be IMC formations in relation to reflow cycles and the associated solderability performance.

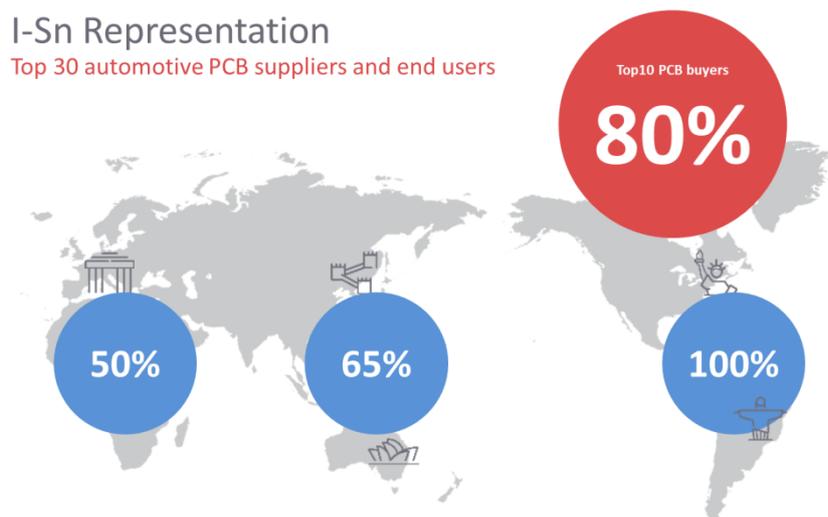
Under contamination free conditions, i-Sn can provide a solderable finish even after multiple reflow cycles. The reflow conditions employed in this paper are typical for lead free soldering environments and the i-Sn thicknesses are approximately 1  $\mu\text{m}$ .

## Introduction

Immersion tin is enjoying a continued upwards trend in terms of market share and sales in the market. This is directly related to the growth in automotive electronics. The reader only needs to take a look at various reports and market synopsis to confirm these conclusions [1,2].

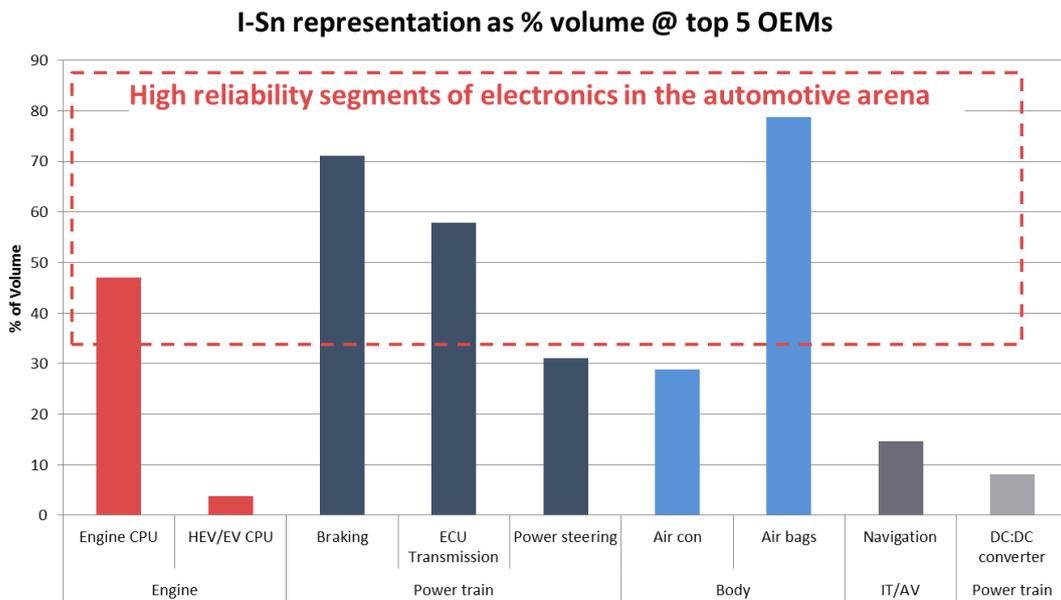
Safety in numbers is a significant consideration in the electronics business. A representative reference list for a process is as, or more, important than the technical capabilities touted by the chemical suppliers.

In Figure 1, it is demonstrated that i-Sn is established as the 'safety in numbers' final finish for the automotive industry. I-Sn is present in many of the top 30 automotive PCB manufacturers and in 80% of the top 10 end users.



**Figure 1: The presence of i-Sn in the automotive global arena [2]**

Figure 2 is a representation of i-Sn at the top 5 automotive OEMs for each segment [3]. It is evident that i-Sn is utilized for high reliability automotive applications such as engine CPUs, braking and air bags.

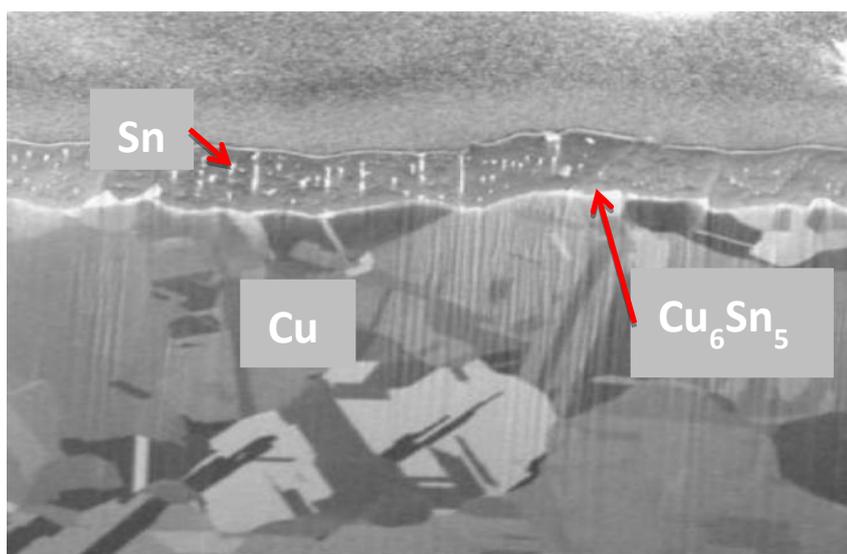


**Figure 2: Representation of i-Sn according to automotive segments versus top 5 Automotive OEMs [3]**

### IMC formations

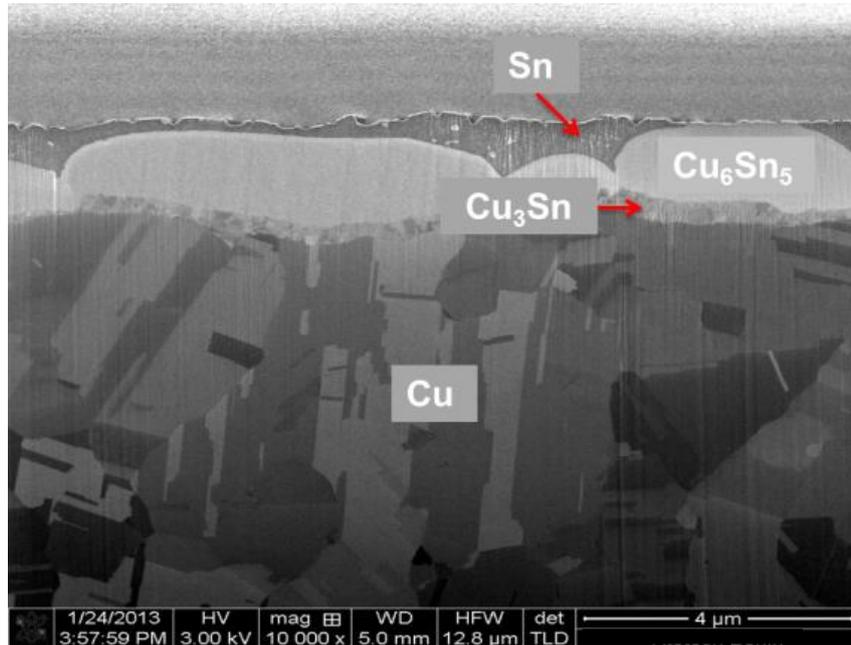
The formation of the intermetallic compound (IMC) is of great concern in the industry. This is because the solderability and wettability can be impacted by the IMC formation related to the remaining pure tin. The growth of the IMC is a reflection of its production viable shelf life. The primary function of a surface finish is to protect the integrity of the copper conductor and maintain utilization performance until the panel is populated.

As solderability is the key concern of this paper, multiple soldering steps must be evaluated. Only the non soldered side is considered in an evaluation of the IMC. In Figure 3, the as-received condition (ASR) is shown. Approximately 1  $\mu\text{m}$  immersion tin is plated on copper. The ASR condition means directly after plating. The IMC is not yet visibly apparent and therefore solderability is of no concern. This is why results shown in this paper benchmark test conditions against ASR conditions.



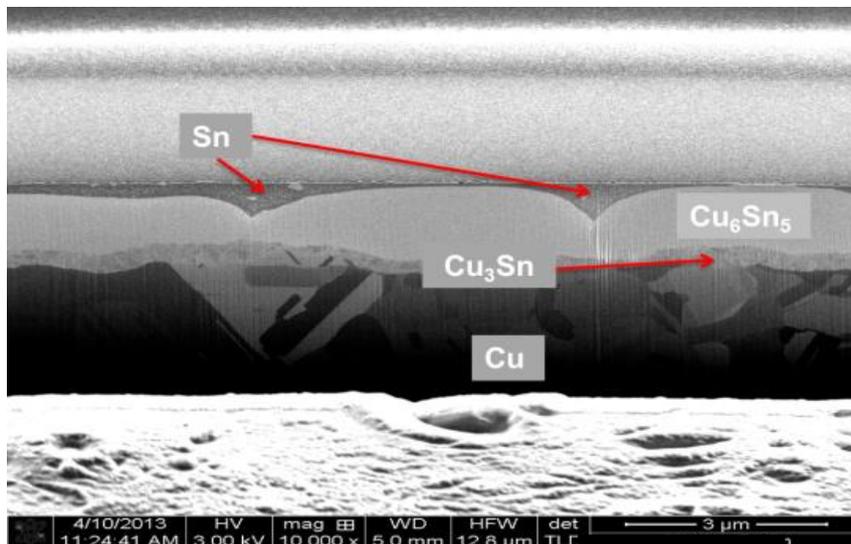
**Figure 3: As received i-Sn deposit on copper (FIB)**

In production, solder paste is only applied to 80% of the feature area to guarantee acceptable wetting. After the first reflow cycle two distinct IMC types are generated, (Figure 4). There is a copper rich ( $\text{Cu}_3\text{Sn}$ ) IMC and a less copper saturated ( $\text{Cu}_6\text{Sn}_5$ ) IMC. The ‘scallop’ formation is the  $\text{Cu}_6\text{Sn}_5$  IMC. The growth of the  $\text{Cu}_6\text{Sn}_5$  IMC is inhibited by the copper rich IMC which limits the copper migration. This formation is expected under normal conditions.



**Figure 4: IMC formation after 1 x reflow at 245°C (FIB)**

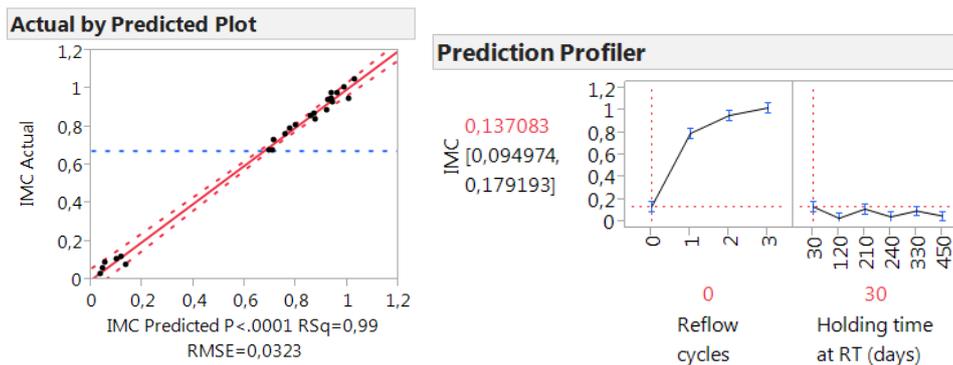
The most significant IMC formation occurs after the first reflow. In figure 5, it can be seen that the IMC formation does not change significantly compared to the first reflow. The key to solderability is presumed to be the presence of free tin. And as demonstrated in the figure: areas of pure tin are still available for soldering. At this stage the IMC may break the surface affecting wetting but the islands of pure tin ensure that solderability is maintained.



**Figure 5: IMC of unpopulated side after second reflow at 245°C (FIB)**

The development of the IMC under controlled storage conditions is very slow and is testament to the production viable shelf-life of i-Sn. This will be demonstrated later during the testing carried out to evaluate the practical factors that influence IMC generation. The factors considered in this test were thermal ageing by lead free reflow and holding time at room temperature (RT).

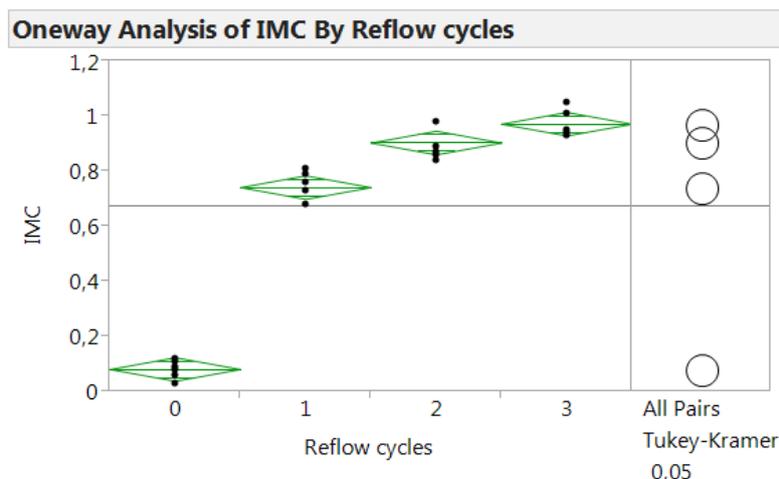
The measurements for the IMC were carried out using a combination of XRF and electrochemical measurements (e.g. coulometric stripping). The value for pure tin is a proportion of the bulk metal. The method above does not give a value for the shape of the IMC formation. This can only be assessed optically as shown in Figures 3,4 and 5.



**Figure 6: The statistical verification of testing**

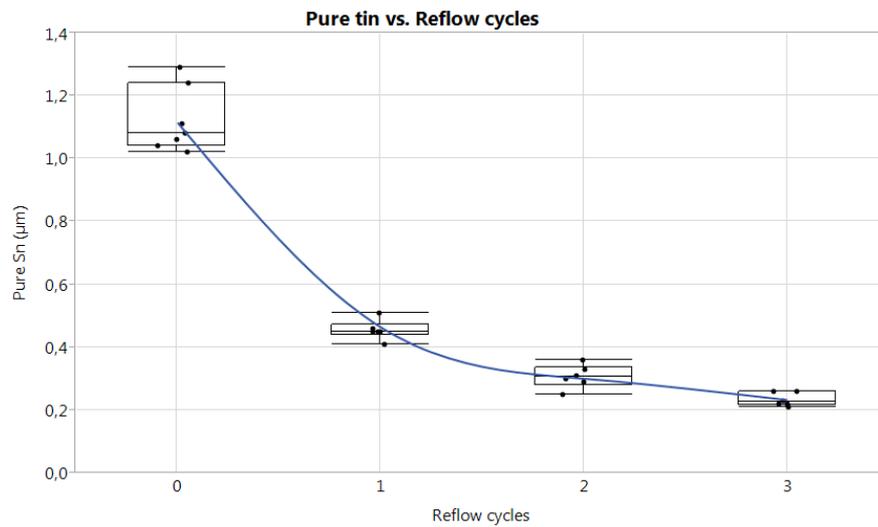
In Figure 6, it is proven that the tests are statistically significant and that the main impact on the IMC formation is thermal ageing by reflow cycles. The impact of holding time is insignificant, which is a demonstration for the good shelf life of i-Sn. For that reason, only the impact of the thermal ageing will be considered further.

A more detailed view of the impact of the lead free reflow profile, supports the notion that the copper migration into the tin is inhibited by the copper rich IMC (Figure 7). The most significant increase in the IMC is due to the first reflow cycle, whereas the increase in the IMC between cycles 2 and 3 is not statistically significant.



**Figure 7: IMC formation by thermal ageing (Reflow profile used is shown in the Appendix)**

Figure 8 on the other hand, demonstrates that pure tin is left over even after 3 lead free reflow cycles.



**Figure 8: Remaining pure Sn versus reflow cycles**

The next section will demonstrate the solderability potential for i-Sn after ageing. The testing does not directly correlate with the ageing conditions discussed in the previous section but is representative of production and includes 3 times reflow followed by selective wave soldering. This is considered as an extreme condition and will be the benchmark for the soldering performance after ageing. Typically, the automotive industry employs press fit assembly for high power lead frame components.

The conditions for this evaluation were to apply 3x reflow (see Appendix) and to selectively wave solder. The production selective wave soldering machine used Sn3Ag0.5Cu solder with a production low solids no-clean wave flux. The size of the solder nozzle was 18 mm inside, 20 mm outside. The solder pot temperature was 280°C and the soldering speed 6 mm/s. Two through hole dimensions were evaluated, these were of 0.8 mm and 1.2 mm in diameter at a board thickness of 1.5 mm.

Figure 9 is a typical result for the solder performance of the i-Sn even after multiple reflows. The PTHs are fully filled and the contact sides show excellent covered and potential filleting. With lead frame components the capillary action would further improve the performance.



**Figure 9: Result for selective wave soldering after 3 x reflow**

### Typical external causes for failures on i-Sn finishes

The main external causes for failures on i-Sn finishes can be attributed to the following general issues:

- Contamination of the copper tin interface
- Contamination of the tin surface
- Redeposition of volatiles from solder masks and fluxes.

Copper contamination is usually down to handling. The resultant failure is typically dewetting, whereby the solder covers the feature initially only to retreat on cooling after reflow. The alternative failure is non wetting. This is normally the result of heavy organic contamination. Copper contamination can result in an abnormal IMC formation.

A chemical system is generally equipped with a pretreatment to remove contaminants on the copper surface. Generally these are adequate and non-wetting and dewetting are rarely caused by copper contamination. However tin surface contamination is common and often disregarded. The reflow equipment is in many cases a solvent derived volatile rich environment (fluxes and soldermask solvents) where re-deposition is possible. Exhaust levels depend on the reflow atmosphere ( $O_2$  or  $N_2$ ) but regardless, the environment is challenging. Additionally poor rinsing, poor soldermask applications and plugging operations can lead to surface issues.

### Conclusions

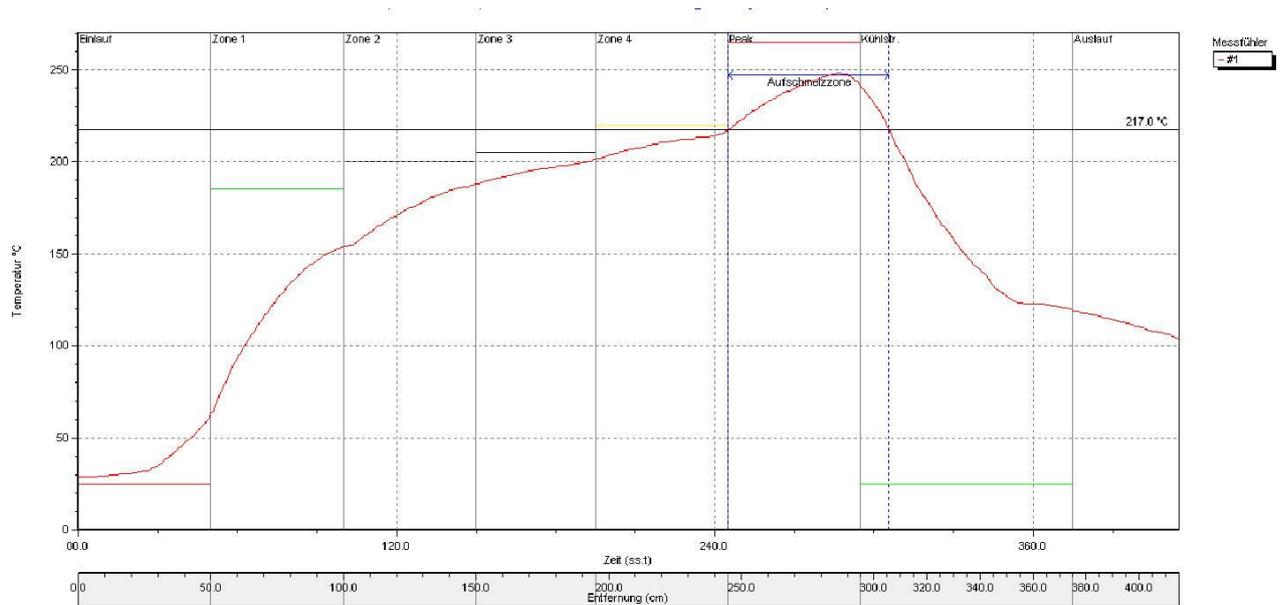
Whilst i-Sn can be shown to be a reliable final finish for soldering even after multiple thermal ageing tests that could feasibly be encountered in production, uncontrolled external influences can result in poor results. These are not only problematic to i-Sn final finishes and can be eliminated by good practice.

The production environment is a complex one where controls and good practice can help to ensure high yields. This paper proves that i-Sn can provide a reliable solderable finish with a long shelf life and a compatibility to realistically challenging production environments.

## References

1. Brian Swiggett, EMTC Conference, October 2014.
2. Dr. Hayao Nakahara, NTI Digest, August 2016.
3. Kiminori Miyata, Norie Matsui, et. al., Japan Marketing Survey Co., Ltd. October 2014.

## Appendix



**Figure 10: Reflow condition used: Peak temperature: 246°C, time over 217°C: 68 sec**