The Effect of Powder Surface Area and Oxidation on the Voiding Performance of PoP Solder Pastes

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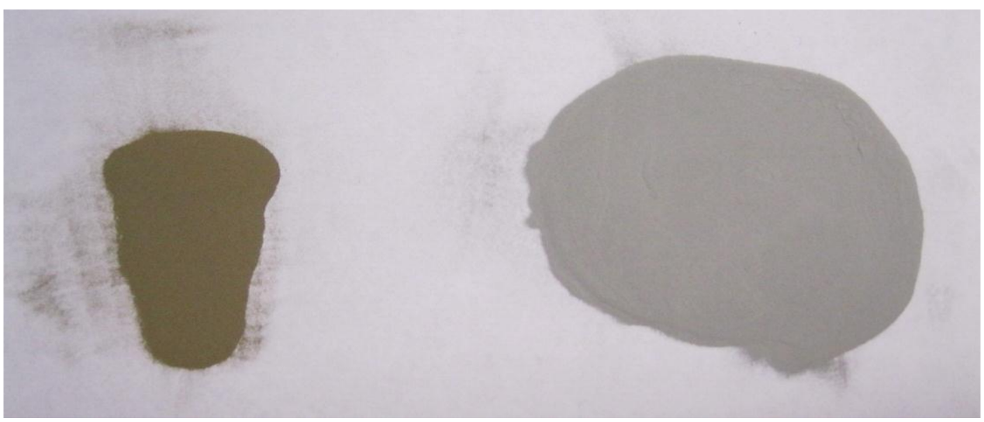
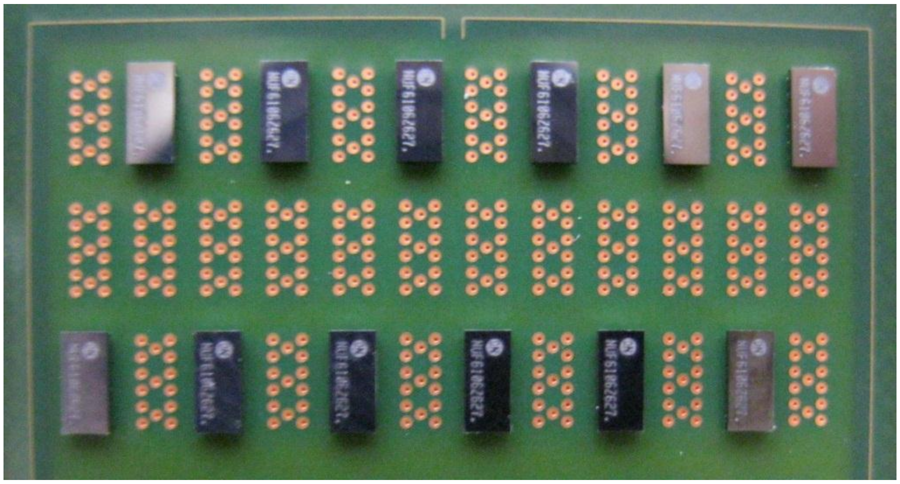
Introduction:
With the miniaturization of components in the semiconductor industry, the need for specialized solder pastes with finer powder mesh sizes for package-on-package (PoP) assemblies has become imperative and increasingly more common. As the powder mesh size decreases (smaller diameter powder), more surface area of powder within the paste is exposed and, therefore, more susceptible to oxidation. The flux vehicle of the solder paste consequentially has more oxides to remove in order to allow for proper coalescence to form a good solder joint. The intent of this paper is to evaluate whether the decreased powder mesh size and increased oxide content of the powder in the PoP pastes affects the voiding performance of the materials, and to what degree.

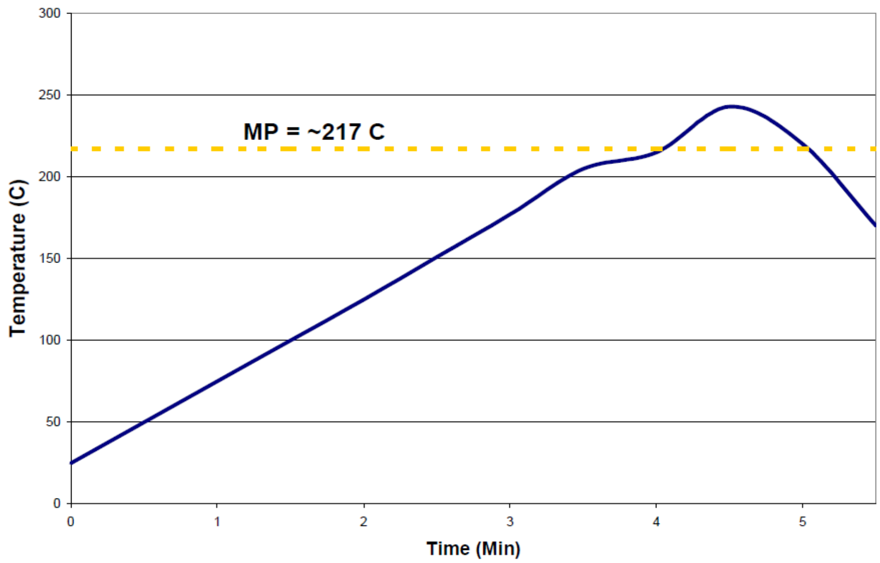
Procedure:
A single PoP solder paste flux vehicle was used for this testing to keep the results consistent. A single batch (lot) of flux was also used to help eliminate variability. The alloy used for this testing was 96.5Sn/3.0Ag/0.5Cu (SAC305). Mesh sizes tested for this experiment were Type 3, Type 4, Type 5, and Type 6. Each of these powder mesh sizes were mixed with the PoP solder paste flux vehicle in both fresh and oxidized forms. Oxidation of the powder was achieved by subjecting the powder to a 160^{o}C oven for a period of 24 hours. This gave us eight solder paste configurations to test. The following image displays an example of the oxidized powder (left) compared to fresh powder (right).



The components used for this testing were CSPs with fifteen 0.012” diameter bumps. These bumps were SAC305 to match the alloy of the solder paste. The PCB used was a test vehicle with 0.010” diameter pads with 0.004” diameter via holes. Pads with vias were chosen as a worst case scenario due to their tendency to trap air and cause voids, though PoP components are seldom placed on pads with via holes. Two boards were assembled for each solder paste configuration, for a total of 16 boards. Each board had 12 CSPs placed in the configuration shown in the image below.



Processing of the test boards was performed at the Rochester Institute of Technology Center for Electronics Manufacturing and Assembly lab. Components were dipped in the PoP solder paste and placed using a Siemen's S-27 placement machine with a rotary style dipping tray. The dip depth was adjusted to 0.009" (75% of the bump height). The dwell time for both the component dipping and the component placement was set to 1.5 seconds. The PCBs were then reflowed in a Heller 1700 7-zone oven with the following reflow profile:

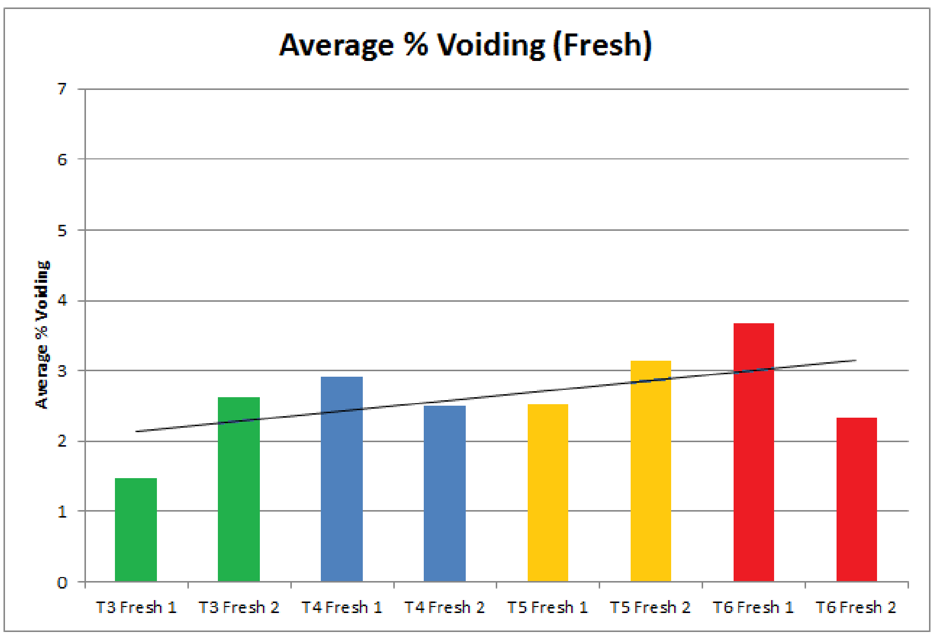


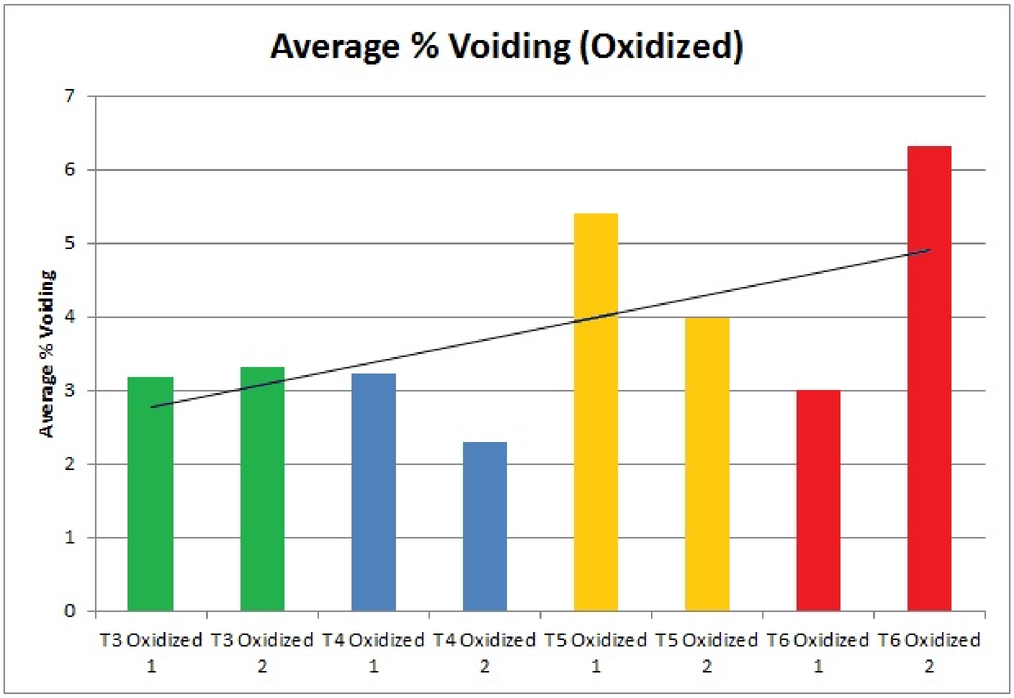
Voiding analysis was conducted utilizing a VJ Electronics X-ray machine programmed specifically for the CSPs used on this test vehicle.

Results:

The following chart and graphs show data for the number of voids and percentage of voids measured for the boards analyzed.

	# Voids			% Voiding		
	AVG	STDEV	MAX	AVG	STDEV	MAX
T3 Fresh 1	0.59	0.58	3	1.46	1.69	7.26
T3 Fresh 2	0.81	0.54	3	2.62	2.13	9.29
T3 Oxidized 1	0.97	0.51	4	3.19	2.09	9.01
T3 Oxidized 2	1.14	0.74	5	3.32	2.48	12.37
T4 Fresh 1	0.86	0.39	2	2.90	1.95	7.89
T4 Fresh 2	0.89	0.56	4	2.50	2.03	8.32
T4 Oxidized 1	0.91	0.44	2	3.23	2.18	8.81
T4 Oxidized 2	0.85	0.57	3	2.31	2.10	13.49
T5 Fresh 1	1.02	0.59	4	2.51	1.69	8.11
T5 Fresh 2	0.90	0.34	2	3.13	1.74	13.38
T5 Oxidized 1	0.95	0.17	1	5.40	2.09	11.37
T5 Oxidized 2	0.96	0.29	2	3.99	2.09	9.20
T6 Fresh 1	0.88	0.33	2	3.67	1.87	8.73
T6 Fresh 2	0.77	0.38	2	2.33	1.55	8.61
T6 Oxidized 1	1.00	0.38	3	3.01	1.37	5.71
T6 Oxidized 2	0.95	0.29	3	6.31	2.27	12.98





It was our theory that the more oxidation that was present within the powder, and the finer the mesh size, the more voiding that would be present. This would be due to increased outgassing because of the additional oxides being removed by the flux during reflow. Though the trend lines for the graphs above agreed with this speculation, the data is somewhat unclear. The average voiding percentage did not exceed 7% even in the worst-case-scenario solder paste (oxidized Type 6).

Future testing is required to help eliminate variables, which were not taken into account in this experimentation and that may have had an effect on the results. Solvent content is most likely the largest contributor to voiding of a solder paste. Since the solvent content has more of an effect than oxide content, it is difficult to sort out what results were affected by solvent content, and what were affected by oxides. A future test would be to bake the boards prior to reflow to burn off the solvents in the paste. This would make it easier to analyze the voiding in comparison to oxidation alone.

Another variable in this testing was the heating of the powder in order to oxidize it. It is unclear whether the oxidation of the powder was consistent throughout the containers of powder. For example, the powder on top may have oxidized more than the powder at the bottom of the container. This could be eliminated in future testing by spreading the powder out in a single layer to oxidize it more uniformly in the oven.

It was initially believed that because there was more exposed powder surface area per cubic unit of volume of paste with a finer mesh size, the oxidation quantity would be higher, therefore creating more voids during reflow due to outgassing. However, the grain structure of the powder is different for the different mesh sizes of powder due to the manufacturing process. This also may have an effect on the voiding of the material.

Conclusion:

Though initial testing indicates that voiding may indeed be effected by powder mesh size, additional testing is required in order to eliminate possible variables and form a definitive conclusion as to what degree oxidation and powder mesh size affects the voiding percentage within a solder joint.

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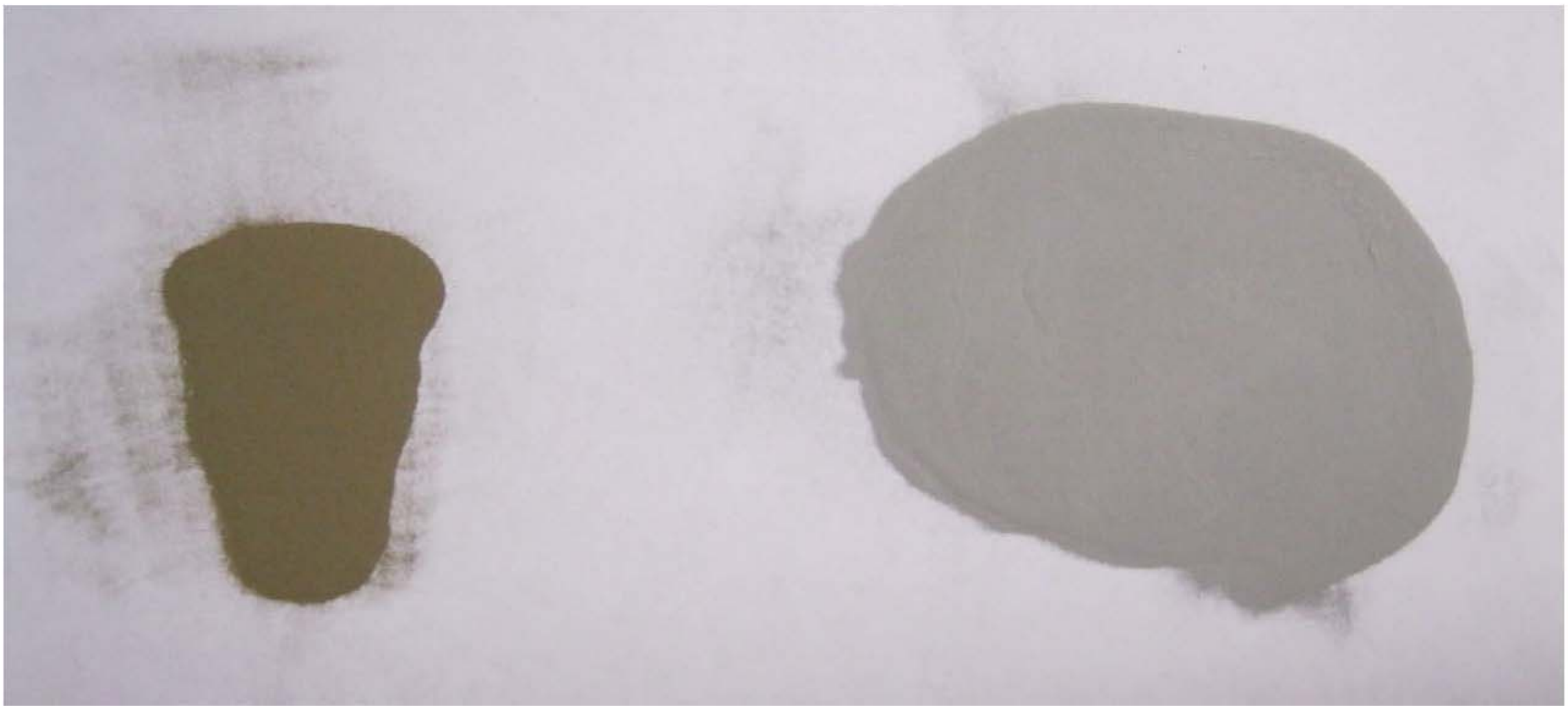
Introduction

- As solder paste powder mesh size decreases (smaller diameter powder), more surface area of powder within the paste is exposed and therefore susceptible to oxidation. The flux vehicle of the solder paste consequentially has more oxides to remove in order to allow for proper coalescence to form a good solder joint.

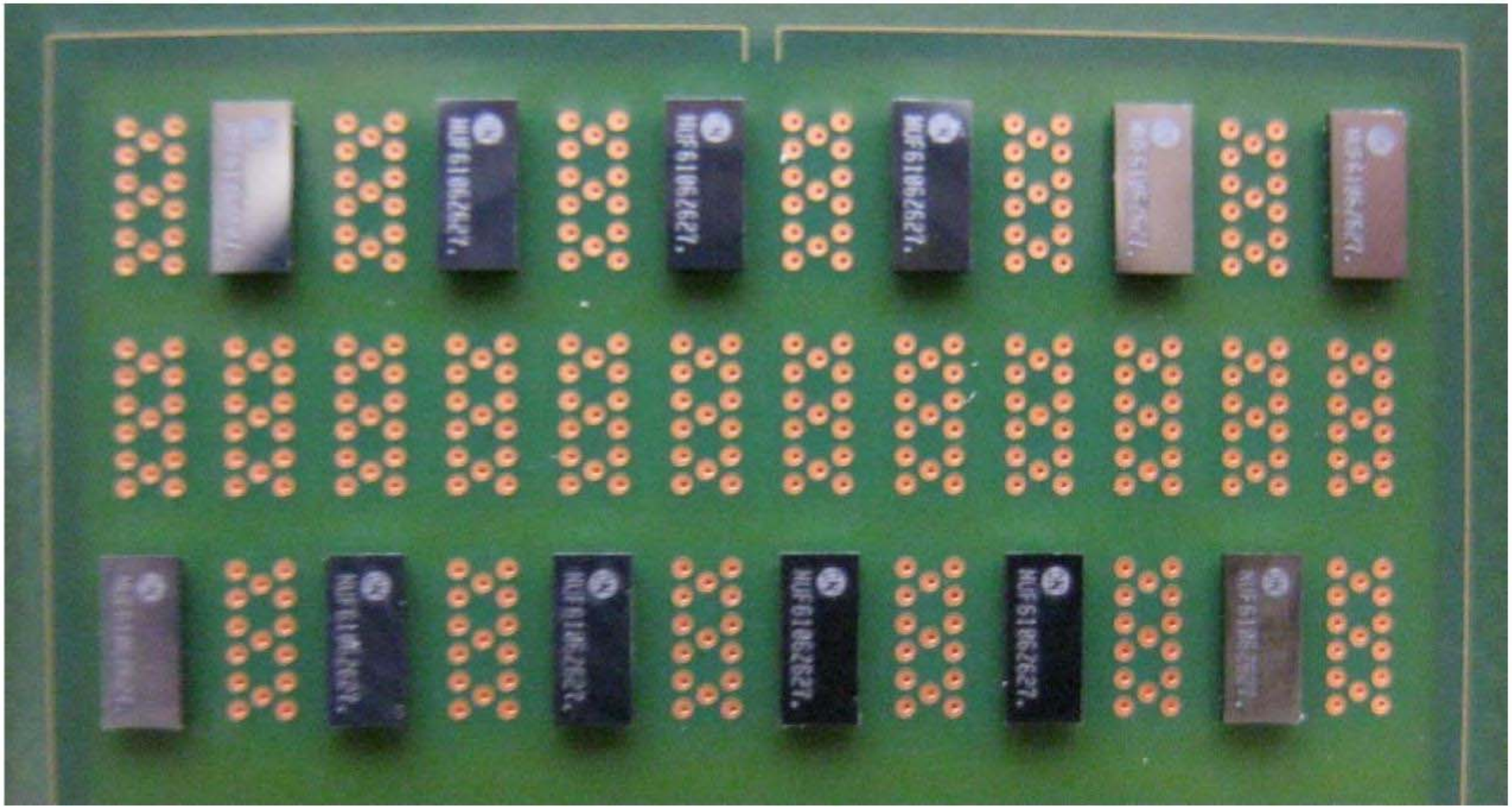
Procedure

- PoP solder paste flux vehicle with Type 3, 4, 5, and 6 powder mesh sizes (SAC305)
  - Each mesh size in fresh and oxidized form
- CSP Component
  - Fifteen 0.012” diameter bumps per component (SAC305)
- Components dipped in 0.009” paste depth with 1.5 sec dwell for dipping and placement

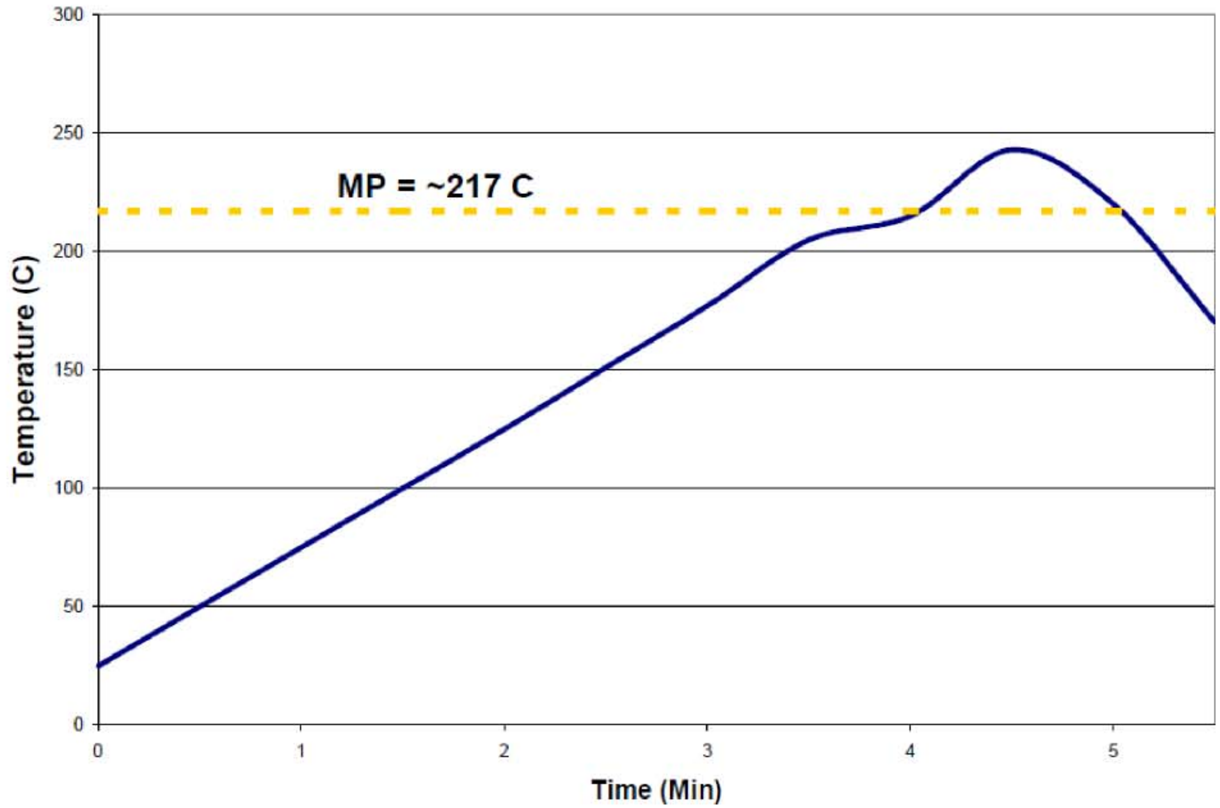
Oxidized Powder vs. Non-Oxidized Powder



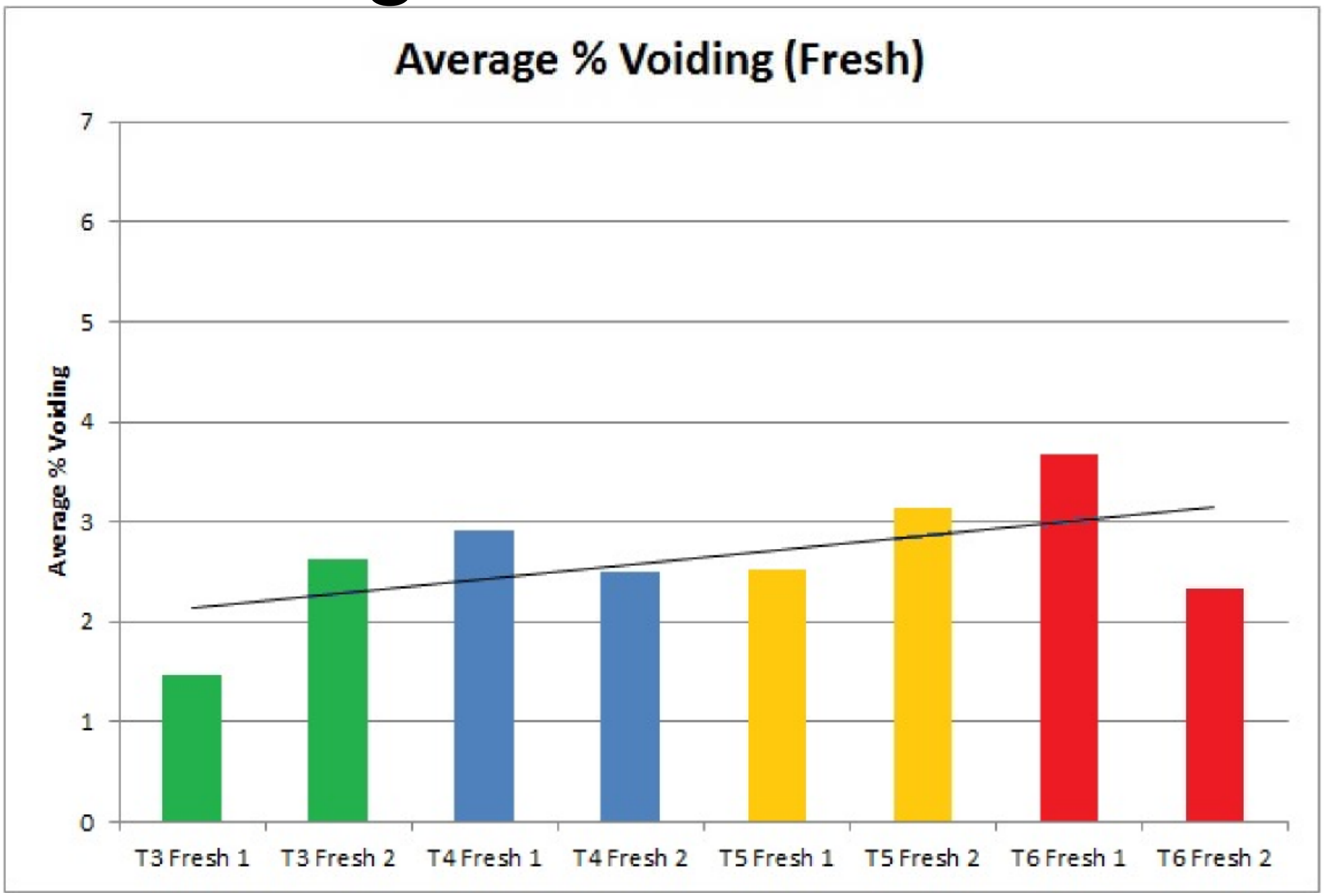
Test Board



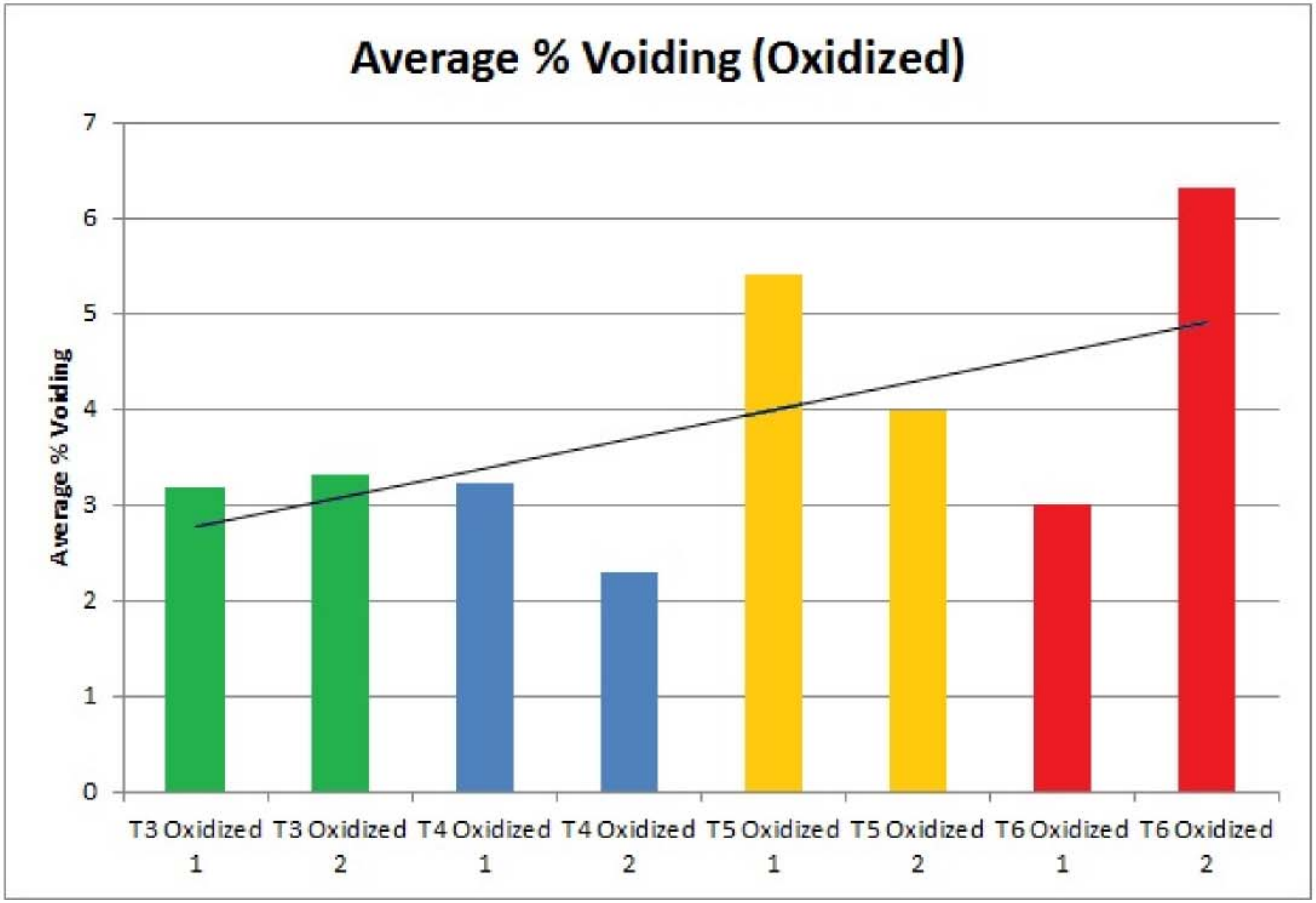
Reflow Profile



Voiding with Fresh Powder

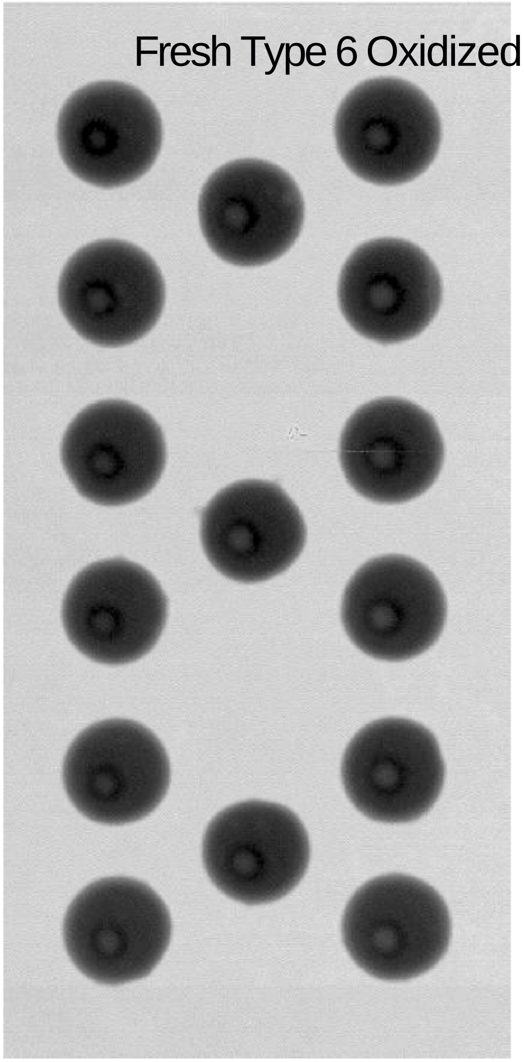


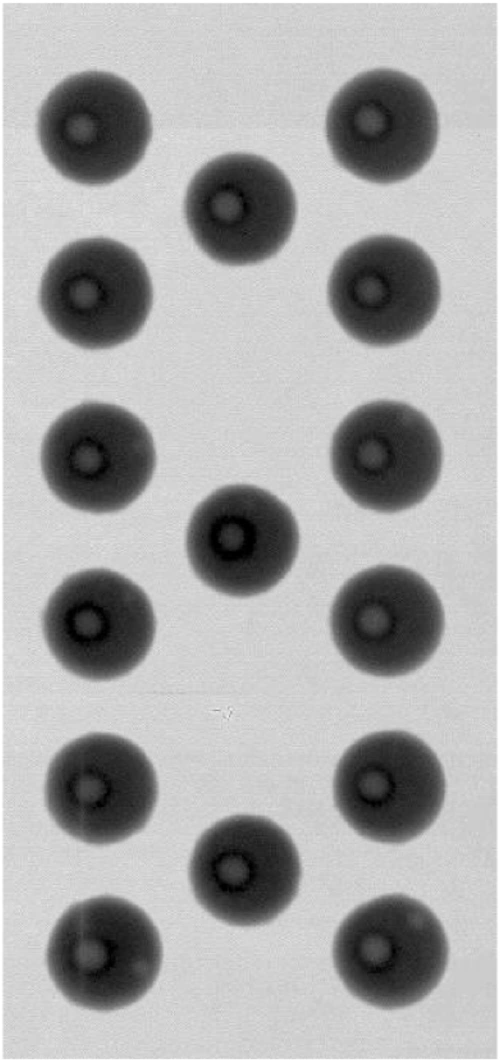
Voiding with Oxidized Powder



Voiding X-rays

Fresh Type 6 Oxidized Type 6





Conclusion

- All solder samples maintained <10% voiding
- Solder paste with oxidized powder exhibited more voiding than the same material with fresh powder
- Though the trend lines indicate an increase in voiding as mesh size decreases in both oxidized and non-oxidized form, the data does not give a clear indications as to what degree the oxidation level effects the voiding.

Future Testing

- More uniformly oxidized powder
- Boards baked after solder paste application to remove solvents
- Larger batches of solder paste to eliminate variability of hand mixing material

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Questions?