BENEFITS OF INERT GAS SOLDERING FOR PRINTED CIRCUIT BOARD ASSEMBLY PROCESSES

Dr. Jerry Wu
Air Products China
Shanghai, China

Gregory K. Arslanian
Air Products and Chemicals, Inc.
Allentown, PA

Emily Tan
Air Products Malaysia
Prai, Malaysia

ABSTRACT:
This review of inert atmosphere for the electronics assembly processes will look at the benefits and attempt to close the gap on some of the misconceptions of using inert gases for electronics assembly. We will look at the reasons for using nitrogen and the cost benefits that come with the use of this inert atmosphere gas. As part of this review we will be explain the needs assessment and when you should use an inert atmosphere for your assembly process. Case studies will be provided to demonstrate the benefits of an inert atmosphere in the electronics assembly process area.

KEY WORDS:
Printed circuit board assembly processes, inert atmospheres, lead-free solders, defect reduction

INTRODUCTION

With the advent of higher density microelectronics packaging that is required to satisfy the functionality of the newest generation of integrated circuits the manufacturing concerns of the microelectronics process engineer have increased. This new generation of packages includes BGA's, flip chip technologies, stacked or 3D packages, and fine pitch chip scale components. The introduction of "no clean" flux chemistries in solder reflow and wave soldering processes to eliminate the need ozone depleting cleaning agents has required changes in how assemblies are processed. With the introduction of lead free solder alloys, several other process issues are evident. The many challenges of assembling printed circuit boards require that the process engineers use new process technologies, equipment, and materials.

By the end of the day the engineer needs to establish a process that reduces costs, increases productivity and improves customer satisfaction. The primary interconnect method of components to the printed circuit board is via soldering. Solder joint quality is largely dependent on the degree of wetting between solder and the materials to be joined. Lead-free solders have a higher melting point than the traditional lead based alloys. The delta is approximately 34^0C for the tin/copper/silver alloys. When printed circuit boards are soldered in air, the metal alloy systems used in electronic assembly processes are subject to oxidation. Tin oxides form rapidly in an air environment and these oxides inhibit wetting of the molten alloy to printed circuit board lands and component leads which can result in soldering defects. The use of nitrogen as a process gas provides an inert, reduced oxygen soldering atmosphere. By eliminating the formation of solder oxides, wetting is promoted and soldering quality is improved.

ASSEMBLY PROCESSES

Many soldering defects occur due to poor wetting of the filler metal with both the component and substrate. Defects most affected are those related to nonwetting, bridging, and insufficient solder. By using inert atmosphere one can typically expect a significant decrease in this type of defect. This defect reduction can result in higher first pass yields, reduced labor for rework, and increased production rates.

The advantages to using inert atmospheres in microelectronics assemblies are summarized below:

Reflow Soldering

- Reduction in Soldering Defects
- Improvement of First Pass Soldering Yields
- Reduction in Labor Costs and Increase in Production Rates
- Elimination of Metal Surface Oxidation
- Increase in Solder Joint Strength
- Implementation of Low Residue, No-Clean Soldering
- Expansion of Process Window

Wave Soldering

- Dramatic Reduction in Solder Dross Formation
    - ♦ Reduced equipment maintenance = reduced labor costs
- Reduction of Operator Exposure to Lead-Containing Materials
- Increase in Wetting Force, Decrease in Wetting Time
- Reduction in Overall Soldering Defects
- Enhanced Performance of Low Solids Flux Chemistries
- Expansion of Process Window

INERT ATMOSPHERE ASSEMBLY PROCESSING

Manufacturers of microelectronics assemblies can improve product quality while reducing the overall process costs because nitrogen soldering atmospheres prevent solder alloys from oxidizing. This results in an improvement in soldering performance and a reduction in soldering defect rates. Nitrogen atmospheres complement no-clean soldering by inerting these oxygen sensitive processes. This in turn reduces the need for costly rework. In the case of BGA's and flip chip technologies improves wetting, increases first pass yields, eliminates the need for cleaning of flux residues in a restrictive area and the difficulties of rework.

By using no-clean soldering technology, process engineers can eliminate post-solder cleaning steps. No-clean inert atmosphere soldering is an environmentally friendly process using no solvents and eliminating cleaning equipment, which results in an increase in available floor space, and more importantly, an overall decrease in processing costs.

The use of inert atmosphere soldering technology allows the process engineer to effectively deal with the new packaging technologies while enhancing the process window, reducing costs, improving quality, and increasing productivity.

The use of an inert atmosphere in lead free soldering processes will beneficial for the following reasons:

a. Improved wetting of the higher temperature solder alloys
b. If RMA no clean flux chemistries are required, the flux residues will be softer, less polymerized and easier to probe during ICT.
c. Elimination of flux residues.
d. If no residue is desirable and the use of a low residue or ultra low residue flux is required, then nitrogen will reduce the chance of new oxide formation.
e. In wave soldering, less dross formation, improved wetting, reduced microdross on wave, reduce shorts.
f. Higher temperature processing, greater oxidation of the components especially at "toe" area of leads, increased oxidation of pads and plated through holes that will be used if 2nd reflow and wave solder is required in assembly.
g. Nitrogen will allow for increase in belt speed due to improved wetting, reduce the time board and components see higher temperatures.
h. Flip chip and chip scale packaging will require nitrogen to improve wetting due to the fact that less aggressive fluxes are used because of underfill issues, such as delamination of the underfill from the chip and board due to flux residue.
i. If using OSP coated boards, nitrogen will assist in preventing oxidation of unused pads and plated through holes for other operations.
j. Nitrogen will assist in simplifying the process and give a wider process window.
k. The use of nitrogen will allow for lower processing temperatures

Inert atmosphere soldering using nitrogen or any other inert gas, such as argon or helium will reduce the amount of oxygen in the reflow furnace or in an inerting cover for a wave solder system. The use of nitrogen over the other gases mention above is mainly driven by cost. Nitrogen or any inert gas does not react with the metal oxides that are formed to reduce them. Inert means "non-reactive" at the soldering temperatures in printed circuit or IC packaging assembly processes. Only hydrogen or a blend of hydrogen with nitrogen is reactive and will remove oxides; however caution must noted that higher temperatures are required to reduce the oxides.

There has been some discussion that nitrogen improves the heat transfer over that of air, however since nitrogen makes up 78% of air and its molecule weight is almost equal to air, there is no difference. When using nitrogen in the solder assembly processes, one must understand that you are mixing the nitrogen with air since a reflow furnace and a wave solder machine are not air tight.

The use of nitrogen in a reflow furnace is a balance between the system which is an open tunnel, the exhaust rates to remove the flux vapors and the nitrogen flow rates into the furnace. This is complicated more by the convective force required to achieve the proper heat to the active soldering surface. Recent research has shown that oxygen levels in the reflow zone of 1000 parts per million (ppm) or lower will provide for a reduce oxygen environment to improve wetting of the solder to create reliable solder joints. One must remember that you cannot achieve the low level of oxygen that is in the incoming nitrogen due to the above reasons. The nitrogen will assist in reducing the oxygen levels by diluting them to a level that will improve wetting.

The industry's push back to the nitrogen supplier has been that the cost does not justify the benefit and we will only use inert atmosphere processing if our customer demands it and will cover the cost. The manner in which a nitrogen supplier approaches this rationale is dependent on understanding the total cost of ownership to the prospective customer.

There are numerous factors that need to be quantified to provide the proper solution to a potential customer. The following are some of these factors.

Product type
The product that is being assembled is key to determine what benefit nitrogen will bring to the assembly house. It is obvious that if the product is of low value and is single sided with minimal complex components, then the benefits may not be very high and probably a very poor fit. However if the product that are being assembled are of high value, doubled sided, with complex components and require multiple processing in reflow and wave, then there is a higher likelihood that the benefit of using nitrogen will be seriously investigated and with a higher probability of usage.

First pass yield
First pass yield is a key quality matrix for assembly houses. This initial visual inspection is done after the boards have completed their reflow or wave solder processes. The ability of the inspector to pick up defects and if the there is flux residue that will inhibit the ability of the inspector to determine if there defects, then the inspector will err to the side of caution and tag the board as requiring rework. If the board is not defective, then the cost of assembly will increase due rework and re-inspection of the board. Nitrogen processing will reduce the amount of flux residue and provide a cleaner solder joint surface to inspect.

Defect types
There are several types of defects that are observed during the assembly of printed circuit boards. They range from cold solder joints to bridging of leads to poor wetting. Some of these defects can be reworked quite simply, however if the pitch of the component is very tight, then the rework is more difficult. At times the rework causes damage to the pads on the board, such as pad lift and this is not a repairable problem and in most cases the board and its components will be scraped. Nitrogen inerting will improve the wetting of the solder in both reflow and wave assembly processing to reduce the opportunity of the solder to oxidize in an air atmosphere. With reduced defects comes reduced rework which is a reduction in costs.

AOI and In Circuit Testing
Automated Optical Inspection (AOI) and In Circuit Testing (ICT) are important tools that are used by the printed circuit board assembly houses to inspect for defects and to determine if the solder joints are functional during electrical test. If the boards have increased flux residue at the solder joint level, then the AOI system will have difficulty in recognizing the defects due to the poor contrast due to the residue. This will lead to misinterpretation by the AOI vision system and be classified as a defect. Nitrogen will reduce the flux residue and provide for a cleaner solder joint that will have better contrast for improved optical recognition that will be able to distinguish a good solder joint over a poor solder or defective one. ICT uses pin probes to make contact with the solder joint to run an electrical test to determine the continuity of the joint versus shorting or open. If the flux residue is concentrated at the joint, the probe may not be able to penetrate the flux to make good contact with the solder, therefore be designated as an open joint or shorted joint. The probes will build up with flux over time and will need to be cleaned or replace which will add cost to the board assembly.

Nitrogen will improve or reduce a majority of the common soldering defects that are observed, however it cannot reduce them 100%. Defects that are due to mechanical issues, such as deformed leads, cannot be improved by the use of nitrogen. However non-wetting, bridging (shorts), cold solder joints and poor wetting can be improved by the use of nitrogen. Inert atmospheres will reduce the amount of flux residue left on the board after reflow soldering and in turn reduce ions that can cause corrosion.

The use of nitrogen for wave soldering will reduce dross formation, tin oxide formation, and allow for lower solder material costs, reduced flux usage, increased productivity and reduced machine maintenance. Defect reduction can also be accomplished.

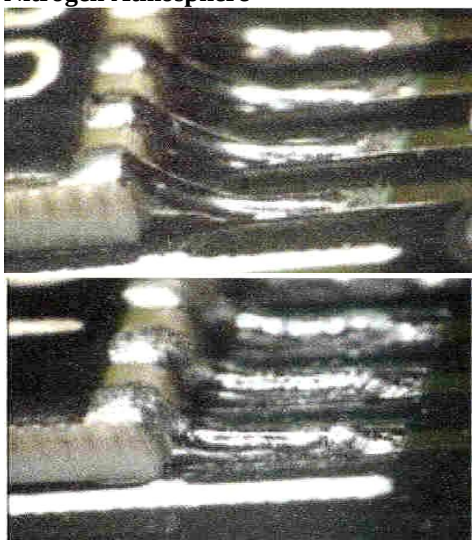
New packaging technologies are evolving toward smaller, thinner and more powerful devices. Despite the predicted elimination of the wave soldering process, this soldering technique continues to be widely used. The use of pin-through hole components and the overall cost effectiveness of the process maintain its viability. So as the pressure to reduce cost and improve quality increases in electronic manufacturing, assemblers using wave soldering must consider innovations to meet these challenges.

CONCLUSION:
In conclusion the use of nitrogen for reflow, wave or selective soldering is to improve the wetting of the solder to the board and components, reduce defects, improve reliability, and increase productivity and to reduce overall costs of manufacturing.

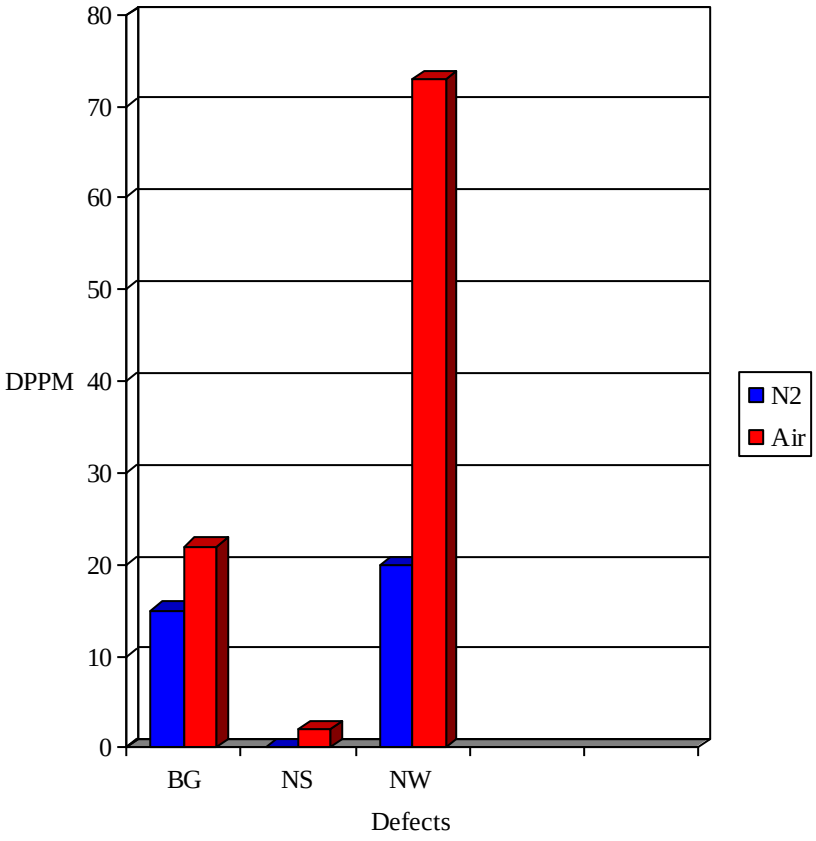
The following are two case studies, reflow and wave, that demonstrate the advantages of using nitrogen inerting atmospheres to reduce the oxygen levels in these assembly processes.

Reflow Soldering

Nitrogen Atmosphere

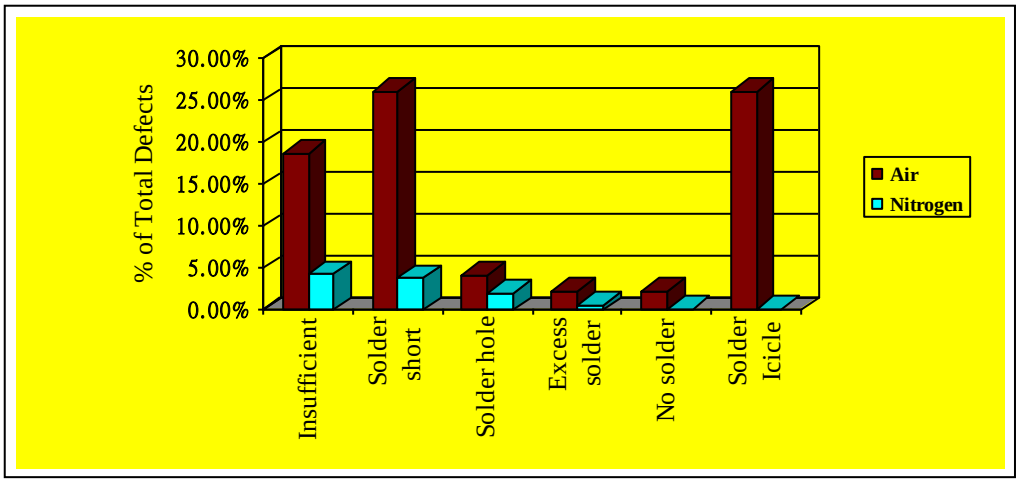


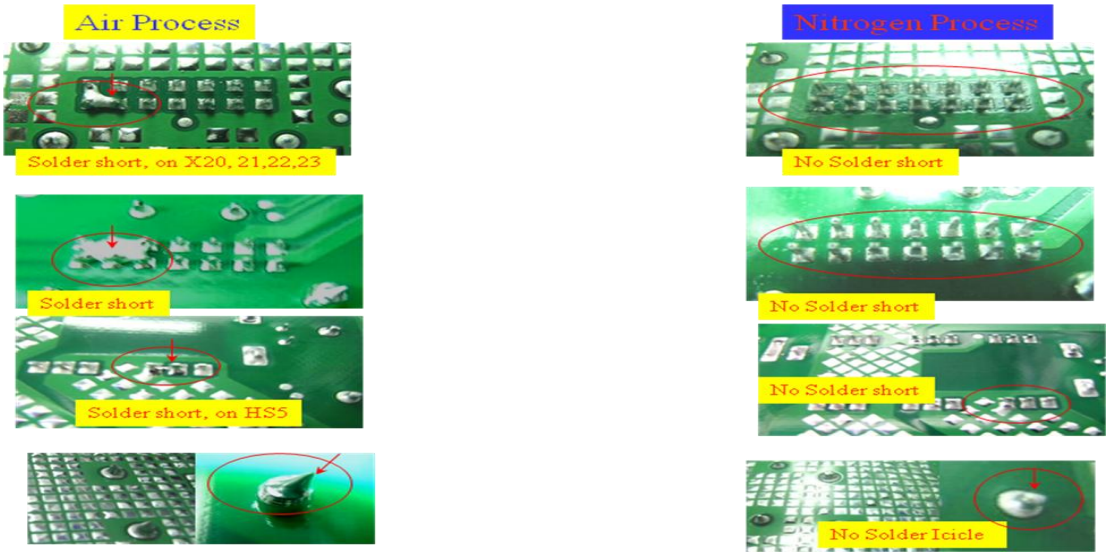
Air Atmosphere



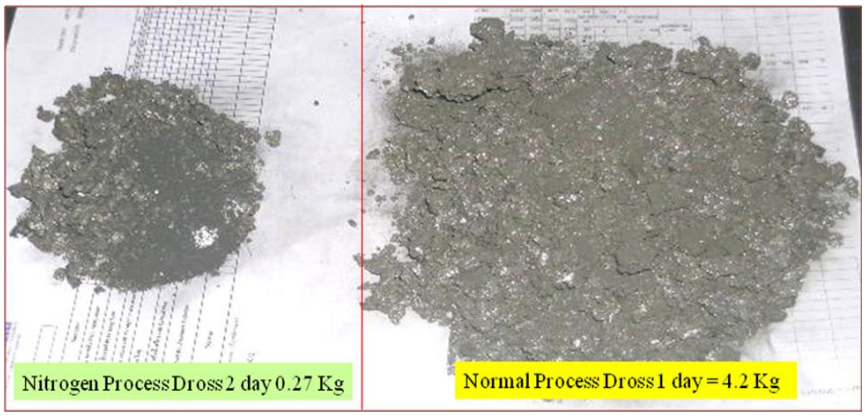
Defect	Air	N_2	% Defect Reduced
Bridging (BG)	21	15	28.6
No Solder (NS)	2	0	100
Non Wetting (NW)	69	20	71
Total Test Points	943,246	895,298	-
Total Defect Points	107	45	57.9
Total DPPM	113	50	55.7

Wave Soldering





Dross Reduction



Production Trials
Taiwan Based EMS Company

- *Summary of benefits*

Item	Reduction Rate	Savings/day (NTD)	Cost of Inerting System (NTD)	Savings/Month (NTD)
Dross	53%	2100 (A)		46,200 (B)
Cleaning hours	60%	375 (C)		8250
Flux	10%	50		1100
PTH Fill Improvement	0%	0%		0
Bridging	25%			
Sub Total				55,500
Monthly Costs			9750	
Total Savings/Month				45,800

Total saving per month is significant

Preliminary Results at EMS Customer in Wujiang

Basic Data:

- 10-11 Kg per day, 16 hrs operation per day;
- With their own N2 inerting system, ~15% oxygen content.

NitroFAS Trial:

- N2 flow rates at 5.4/5.4/5.4 m3/hr for each diffuser;
- N2 pressure around 4.0 bar;
- O2 content: 1500 ppm (top cover), and ~450 ppm under board (no top cover);
- 7.3 Kg dross collected after 6 days, 20 hrs/day (~ 0.37 Kg/ 6hrs)

Dross Reduction up to 90%.

427 ppm
Under Board

With more than 20 years of industry experience, Air Products can help you achieve more profits with fewer defects. We provide the total solution for electronics assembly and packaging, offering novel technologies, reliable gas supply atmospheres and the expertise that comes from being a leading supplier to the industry around the world.

For more information,
please contact us at:

Corporate Headquarters
Air Products and Chemicals, Inc.
7201 Hamilton Boulevard
Allentown, PA 18195-1501
T 610-481-4911
T 610-706-4730
F 800-272-4449
F 610-706-6890
gigmrktg@airproducts.com

Air Products PLC
Hersham Place Technology Park
Molesey Road
Walton-on-Thames
Surrey KT12 4RZ
UK
T +44-0-1270-614-314
apbulkuk@airproducts.com

Air Products and Chemicals (China)
Investment Co. Ltd.
Floor 5, Building 72
Lane 887
Zu Chongzhi Road
Zhangjiang Hi-Tech Park
Shanghai, China
T +86-21-3896-4391
F +86-21-5080-7525
Hotline 400-888-7662
infoasia@airproducts.com

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tell me more
airproducts.com/electronics_assembly