# Enhancing Semiconductor Fabrication Through Operational Optimization and Cost-Efficiency through N2 removal strategies

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## *ABSTRACT*

Nitrogen (N2) elimination is a critical consideration in the optimization of process lines, particularly in the context of semiconductor manufacturing. This study delves into the effect of removing nitrogen supply from all ovens and reflow machines within the midline and backend process line. The objective is to comprehensively evaluate the associated risks and potential impacts on product quality, process stability, and overall efficiency. Through rigorous analysis and experimentation, this research seeks to provide valuable insights into the feasibility and consequences of such a strategic shift. By examining factors such as oxidation, soldering quality, and thermal profiles, this study aims to inform decision-making processes regarding nitrogen utilization, facilitating informed strategies for enhancing operational effectiveness and cost-efficiency in semiconductor fabrication.


## 1. 0 INTRODUCTION

At present, the utilization of nitrogen (N2) in supplying all ovens and reflow machines within the midline area is a standard practice in our manufacturing processes. The primary purpose of employing N2 is to regulate oxidation during the processing of products, mitigating the potential for detrimental failures such as delamination. However, it is crucial to note that the products undergoing these heat processes are already safeguarded in several ways.

Firstly, they are encapsulated through molding or cap sealing, providing protection to the active components such as dice and wires. Additionally, the outer layers of the products benefit from plating, with ACP/ACC packages featuring protective plating. Similarly, for OMP and PQFN packages, the leadframe surfaces are meticulously cleaned and treated before undergoing tin plating.

Given these protective measures, the removal of N2 from these processes does not pose any discernible risk to the products being processed. Thus, the objective of the project is to eliminate the N2 supply entirely from all midline, backend ovens and reflow machines. This initiative aims to streamline our processes while ensuring that product quality and integrity remain uncompromised. Through this introduction, we set the stage for further exploration into the rationale, methodology, and potential implications of this strategic shift.

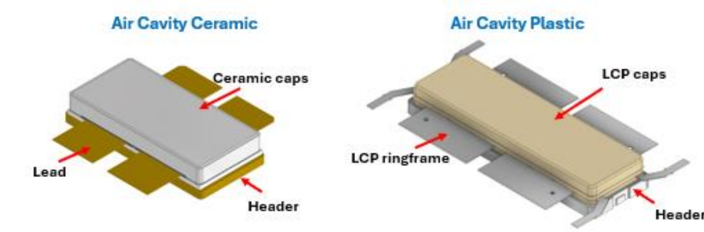


**Fig. 1. Air cavity packages.**

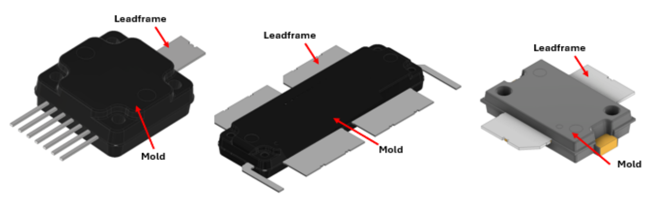


**Fig. 2. Overmold packages.**


**Fig. 3. Midline Machines with Nitrogen (N2) supply.**

## 2. 0 REVIEW OF RELATED WORK

The use of Nitrogen (N2) gas in semiconductor processing equipment serves various purposes including preventing oxidation, controlling atmospheric conditions, and improving process efficiency. Here are some of the common applications of N2 air gas in semiconductor processes.

**Oxidation Prevention**: N2 gas is often used in an inert atmosphere inside the semiconductor processing equipment. By displacing oxygen, nitrogen helps prevent oxidation of sensitive materials and semiconductor surfaces during fabrication processes such as annealing, deposition and etching.

**Atmospheric Control**: In semiconductor manufacturing precise control over the atmospheric condition within processing chambers is essential for ensuring consistent result and device performance. N2 gas is employed to maintain stable and controlled environments with low levels of contaminants. Controlling the humidity of oxygen content using nitrogen helps minimize unwanted reactions and contamination that could compromise device quality.

**Purging and Cleaning:** N2 gas is used for purging and cleaning semiconductor processing equipment to remove moisture, airborne particles, and residual gases. It also facilitates removal of volatile organic compounds (VOCs) and other contaminants from equipment surfaces.

**Temperature Control:** In certain semiconductor processes, nitrogen gas is circulated or flowed over heated surfaces to control temperature uniformly and thermal stability.

In summary, the Nitrogen (N2) gas is not necessarily needed in the manufacturing processes if the product is already enclosed or molded in a way that protects it from any detrimental effects. In such cases, its absence wouldn't typically impact the product's performance. This can help streamline manufacturing processes and reduce costs associated with nitrogen gas usage.

## 3.0 METHODOLOGY

Two types of process flow were used in the study – the standard process flow with N2 supply and the adapted new process flow without N2 supply in all ovens and reflow machines at midline area. The study is divided into three parts – determining the soldering quality, external/internal visual inspection post UHAST for possible oxidation and delamination check on the sample that uses two process flow.

Table 1. Summary of Experimental Combinations

| No | Test Description | Reliability Result |
|---|---|---|
| 1 | MSL3 30°C/60% RH with 3x reflow 245°C based on J-STD-020E | Pass |
| 2 | Accelerated Moisture Resistance – Unbiased HAST 130°C/85% RH 196hrs based on JESD22-A102-B | Pass |
| 3 | Solderability testing based on JESD22 B-102D | Pass |

## 4.0 RESULTS AND DISCUSSION

The comprehensive evaluation conducted on the elimination of nitrogen (N2) at 100K area, spanning from midline to the packing process, yields promising outcomes, suggesting the feasibility of implementing this strategic change. Throughout the assembly process, evaluation lots underwent rigorous scrutiny, passing external visual inspections without displaying any significant deviations in physical attributes compared to production lots subjected to the standard process.

Table 2. Visual Inspection Results

| Device type | Quantity | Description | Glue Cure /PMC | Reflow | Drybake |
|---|---|---|---|---|---|
| OMP_Control | 24 | Normal flow (w/ N2) ACP Control lot | No anomaly | Not applicable | No anomaly |
| OMP_Eval'n | 93 | No N2 (PMC, Reflow, MBE Drybake) OMP Eval lot; | No anomaly | Not applicable | No anomaly |
| ACP_ Control | 16 | Normal flow (w/ N2) ACP Control lot | No anomaly | No anomaly | No anomaly |
| ACP_ Eval'n | 104 | No N2 (Glue cure, MBE Drybake) ACP Eval lot | No anomaly | No anomaly | No anomaly |
| | | | | | |
| TO270_ Control | 1 strip | Normal flow (w/ N2) _Dummy Strip | No anomaly | No anomaly | No anomaly |
| TO270_ Eval'n | 1 strip | No N2_Dummy Strip | No anomaly | No anomaly | No anomaly |
| PQFN_ Control | 1 strip | Normal flow (w/ N2) Dummy Strip | No anomaly | No anomaly | No anomaly |
| PQFN_ Eval'n | 1 strip | No N2 _Dummy Strip | No anomaly | No anomaly | No anomaly |

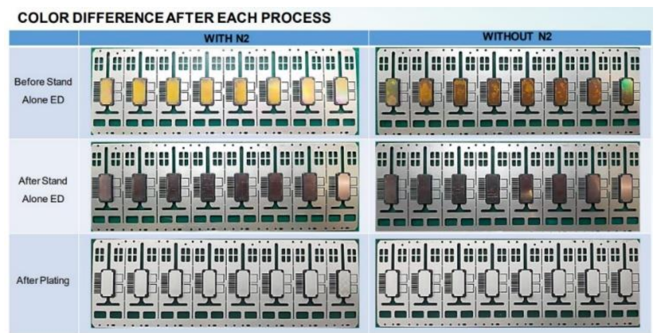


Fig. 4. Plating Results of OMP1 Control vs Eval'n lot.

Specifically, evaluation lots utilizing OMP and ACP3 as device carriers were assembled and processed at midline using ovens without N2 supply, including box ovens and reflow ovens. These lots successfully passed stringent tests, enduring 192 hours of UHAST at 130°C/85%RH with pre-conditioning at MSL3+3x reflow at 245°C.

Reliability Result Summary:

- uHAST Results PASSED with no shift observed in FT

| Device Type | Test | Conditions | Duration | Sample Size | Test Results (fails/SS) | Comments |
|---|---|---|---|---|---|---|
| OMP | uHAST (with MSL3 precon + 3x reflow @ 245C) | Ta= 130°C/85%RH | Precon 96H 192H | 77 | 0/77 0/77 0/77 | ▪ Pass FT ▪ Bvdss, Dvm, Idsx, Rdson and Yfs were <10% shift after 192H. No major shift observed on other test parameters. |
| ACP | uHAST (with MSL3 precon + 3x reflow @ 245C) | Ta= 130°C/85%RH | Precon 96H 192H | 77 | 0/77 0/77 0/77 | ▪ Pass FT ▪ Bvdss, Idsx, Rdson, Rth and Yfs were <10% shift after 192H. No major shift observed on other test parameters. |

Fig. 5. Reliability Result Summary

Remarkably, internal visual inspections post-UHAST test on ACP products revealed no corrosion, underscoring the resilience of the products assembled and processed using ovens without N2 supply. Furthermore, crucial electrical parameters such as Dvm, Idsx, Rdson, Yfs, and Bvdss exhibited negligible shifts (<10%), with no major deviations observed in other parameters. Importantly, the performance of the products remained unaffected by the absence of N2 during assembly and processing.

Furthermore, they demonstrated satisfactory performance in solderability testing conducted at various intervals, meeting the stipulated customer requirements specification.

Table 3. Solderability Test Results Summary

| Device type | Test conditions | Duration | Test results | Remarks |
|---|---|---|---|---|
| OMP | Sold @ 0H | 0H | 0/5 | 100% solder coverage on all leads and backside metallization |
| | Sold w/ 8H steam aging | 8H | 0/5 | |
| | Sold w/ 16H dry baking @ 150C | 16H | 0/5 | |
| ACP | Sold @ 0H | 0H | 0/5 | |
| | Sold w/ 8H steam aging | 8H | 0/5 | |
| | Sold w/ 16H dry baking @ 150C | 16H | 0/5 | |
| TO270 | Sold @ 0H | 0H | 0/5 | |
| | Sold w/ 8H steam aging | 8H | 0/5 | |
| | Sold w/ 16H dry baking @ 150C | 16H | 0/5 | |
| PQFN | Sold @ 0H | 0H | 0/5 | 100% solder coverage on all pins and backside metallization |
| | Sold w/ 8H steam aging | 8H | 0/5 | |
| | Sold w/ 16H dry baking @ 150C | 16H | 0/5 | |

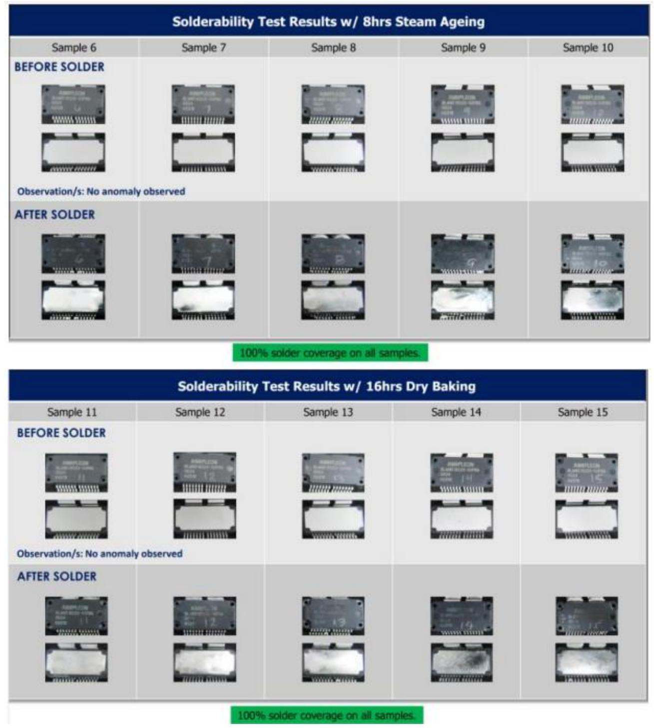


Fig.6. Sample photo of OMP1 undergone solderability test

It can be seen on table 3 and on Figure 6 that the evaluation lot passed solderability testing in all test condition.

Based on these compelling findings, we confidently recommend the implementation of this evaluation in production. The successful qualification of evaluation lots underscores the robustness and reliability of our processes, affirming the viability of transitioning to N2 elimination across the midline to packing process line. This strategic initiative not only streamlines operations but also upholds product quality and performance, aligning with our commitment to delivering excellence to our customers.

## 5.0 CONCLUSION

In conclusion, our study aimed to evaluate the impact of processing samples using ovens and reflow machines without nitrogen (N2) supply compared to the standard production process. Through rigorous experimentation and analysis, several key findings emerged:
Samples processed using ovens and reflow machines without N2 supply did not exhibit any major changes in physical attributes when compared to production lots subjected to the standard process. This suggests that the absence of N2 supply

did not significantly affect the overall physical characteristics of the samples.
Importantly, the performance of the products processed without N2 supply was found to be comparable to the control samples subjected to the standard process. This indicates that any potential differences in processing conditions did not adversely impact the functionality or reliability of the products.
These findings have significant implications for production processes, particularly in scenarios where the availability or use of N2 may be limited or impractical. By demonstrating that N2-free processing methods yield comparable results in terms of physical attributes and product performance, our study provides valuable insights for optimizing manufacturing processes while potentially reducing costs and resource requirements.
In summary, our study contributes to the body of knowledge surrounding manufacturing processes by highlighting the feasibility and effectiveness of N2-free processing methods in maintaining product quality and performance. These findings offer practical guidance for industries seeking to optimize their production processes while ensuring consistent and reliable product outcomes.

## 6.0 RECOMMENDATIONS

It is important to note that while our study focused on specific processing conditions and product performance metrics, further research may be warranted to explore additional factors and variables that could influence the outcomes. Additionally, ongoing monitoring and validation of N2-free processing methods in real-world production settings are essential to confirm the reproducibility and scalability of the findings.

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## 9.0 ABOUT THE AUTHORS

Marjorie Tinao has accumulated extensive experience in the semiconductor industry, starting her career in 1985 at Philips Semiconductors Philippines. Overtime, she transitioned into the role of a Reliability Technician, where she developed expertise in product reliability testing and quality assurance processes. Currently, she is a Quality Engineer at Ampleon Philippines.

Jelvic Fundan has a solid educational background in Electronic and Communication Engineering from Mapua Institute of Technology. His career journey began in 2008 at Amkor Technology Philippines, where he served as a Product and Package Engineer. Currently, he holds the position of Senior Engineer, Assembly Process at Ampleon Philippines.

Michael Latorena's career journey highlights his expertise in mechanical engineering and facilities management. Beginning as an equipment maintenance engineer in the pharmaceutical industry, he honed his skills in ensuring the efficient operation of critical machinery. Currently, he is employed as a Facilities Engineer at Ampleon Philippines, Inc