On-Shore Assembly Solutions for Long-Lifecycle Systems

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Abstract

With the growing instability of overseas semiconductor supply chains, domestic manufacturing solutions provide a secure and steady alternative through flexible and responsive production strategies customized to meet each customer's unique requirements to ensure stability and reliability. Mature technologies continue to drive volatility for long-lifecycle systems. This paper will explore the technical capabilities and infrastructure investments that allow customized onshore assembly and testing and reduce supply chain risks.

Advancing products and developing technologies, such as BGA (Ball Grid Array), QFN (Quad Flat No Leads), and Flip Chip, allow domestic facilities to prototype modern designs, scale pilot volumes, and ramp to high-mix, low-volume production while swiftly adapting to the ever-changing demand landscape. In collaboration with universities and vocational programs, local workforce training nurtures skilled labor pools that excel in handling intricate assembly tasks.

By leveraging domestic infrastructure for packaging, testing, reliability analysis, and failure diagnosis, manufacturers can expedite delivery times and just-in-time inventory management for long-life semiconductor products. Manufacturers can ensure that semiconductor components meet the stringent durability and lifespan requirements of long-lifecycle systems by conducting rigorous reliability testing and lifecycle analysis in domestic failure analysis laboratories.

Onshore facilities specializing in high-mix, low-volume production provide a reliable solution to combat disruptions in offshore supply chains. With their extensive expertise, well-established infrastructure, and adaptable manufacturing strategies, domestic partners assist companies in navigating through ever-changing market dynamics and uncertainties.

This paper will also outline strategies to mitigate risks, streamline production timelines, reduce expenses through consolidating manufacturing in one facility, and establish resilient supply chains for semiconductor systems with long lifecycles. It will shed light on areas that have been overlooked amidst the excitement surrounding the latest semiconductor fabrication technologies and the forefront of the now-defunct Moore's Law, all while focusing on the practical realities essential for today's long-term system companies.

Keywords
Domestic Assembly Solutions, Mitigating Obsolescence Risks, Offshore Risks, Supply Chain Challenges, Semiconductor Lifecycles, Semiconductor Packaging, and Manufacturing Services.

I. Introduction

The COVID-19 pandemic was an eye-opening experience for the semiconductor industry's supply chains. During this unprecedented time, the world was caught off guard, and it learned lessons about managing supply chains to keep critical customers supplied with necessary semiconductor components. There was panic and overordering from all sectors trying to ensure the delivery of critical components as supply constraints mounted at an enormous pace. From wafer fab to final test, the challenges and risks of all aspects of the semiconductor industry were pushed beyond their limits. To meet those challenges and risks head-on**,** some companies quickly pivoted and accelerated the expansion of domestic wafer fab, manufacturing capabilities, and tool and tooling of a full range of packaging and test solutions Stateside. This ensured the ability to manufacture new products and the continuance of obsoleted products for both manufacture and licensing options, as well as contract assembly, test, and warehousing of wafers for the future. The Russian invasion of Ukraine posed severe threats to supply chains for various industries, creating constraints on critical materials like aluminum, nickel, palladium, and titanium, as well as wire harnesses for the automotive industry. Due to the high-demand production world, the semiconductor industry is further challenged by more components becoming obsolete faster or requiring only low-volume assembly.

II. Offshore Challenges and Risks

In the high-volume, low-margin semiconductor world of offshore assembly and test (OSAT), suppliers are streamlining operations at a steady pace. Older package types are being obsoleted or made end-of-life (EOL) faster than ever. Newer package types, such as QFN, BGA, and Cu-Pillar Flip Chip technology, have become the breadwinners of the industry. Margins are key, and as the volumes on legacy packages, such as Plastic-Dual-in-Line-Package (PDIP), TSOP, SOIC, QFP (Quad Flat Package), and Plastic Leaded Chip Carrier (PLCC) have decreased, the largest OSATs have decided to discontinue offering them to their customers. The tooling cost for molding packages and trimming and forming leads can easily exceed $500,000 per body size for some package designs. With profit margins thinned and suppliers and volumes decreasing, offshore OSATs could no longer continue these assemblies. Tooling costs for high-volume assemblies are significantly less, while the assembly yields are also higher. QFN, Cu- Pillar Flip Chip Bumped die, and Ball Grid Array technology have proven to be the new frontier.

Wafer procurement quickly became one of the biggest challenges at the onset of the COVID-19 pandemic. It became more difficult to obtain wafer allocations from TSMC, the industry leader, and lead times increased by over four times due to COVID-19-related worker shortages in their factories. Semiconductor planners found that lead times on wafers went from approximately 12 weeks to over one year in many cases. Capacity allocation was prioritized for the largest customers and governments to prevent production line shutdowns for critical needs. The good news is that many have learned their lessons and begun building more wafer fab foundries in the United States, Europe, and Japan. Some of the biggest names in the industry have invested significantly in fab infrastructure since the pandemic. The automotive industry was particularly hard hit as allocations for wafer fabs worldwide became impossible to manage. After initially canceling orders, automotive clients tripled orders. They held those orders well beyond the pandemic due to the shock felt in real-time as situations progressed into nightmarish scenarios at the onset of the pandemic. Getting components needed for end-use customers' applications on time became and has continued to be a massive challenge. It should concern the industry that most Cu-Pillar bumping is still managed offshore, especially since flip-chip technology is at the forefront of the newest and most advanced products. Should there ever be another significant constraint period, customers will be jockeying for that capacity. Additionally, SnPb plating has been discontinued worldwide as industries move to more Pb-Free and Halogen-free options. A few possibilities stateside have become available in both the Pb-free and SnPb lead finish areas.

III. Overcoming Offshore Challenges and Risks

By investing in new wafer fabs and leveraging domestic infrastructure for packaging, electrical test, reliability testing, and failure analysis, manufacturers can hasten delivery times and just-in-time inventory management. In mitigating supply chain risk, the disruptions we experienced should diminish significantly as more manufacturing is brought back home. After decades of offshoring, the CHIPs Act, enacted by the federal government, should help bring some technology back to the United States. The new law will bring about $400 billion in investment through over 30 programs to strengthen domestic workforces for microelectronics research and development, with $2.8 billion for additional standalone educational projects.

Onshore facilities specializing in high-mix, low-volume production provide a reliable solution to combat disruptions in offshore supply chains from unexpected circumstances. By expanding domestic manufacturing capabilities and enabling assembly solutions for legacy products (long life cycle solutions >10 yrs.) such as automotive, industrial, medical, aerospace, and defense and growing key manufacturing services such as assembly, test, and quality, these address need for solutions to long-term system original equipment manufacturers (OEMs) around the globe. By offering fully authorized in-house long-term storage of assembled components and wafers/die and working with licensed manufacturers investing in their manufacturing, OEMs and original component manufacturers (OCMs) have places to go to fulfill all their needs while mitigating the risks of offshore assembly and supply chain constraints. Domestic quick-turn assembly with this new capability is being exercised today by several of the world's largest OCMs. Most of the OSAT supply chain is now available stateside , and long-term product risk is mitigated. If the only plans were to keep the OSAT supply chain going, this would not mitigate risk in all areas. By staying with a purely OSAT solution for long-term availability, the wafer fabrication process, package assembly, and test platform obsolescence have not been mitigated. Like any statistics, the odds of obsolescence multiply with each subcontractor. Simple OSAT supply chain management is hoping your silicon supplier, your assembly supplier, and your test provider can all keep doing what they are doing simultaneously. At the same time, volumes have gone down to where the long-term availability business case makes less sense for OSAT. With long-term wafer storage, assembly, and testing all stateside under one roof, the statistics of long-term availability significantly improve.

OEMs have invested heavily in signal integrity analysis of their long-life systems. Unfortunately, moving from an obsolete package that needs trim and form tooling, like PLCC, to one that does not, such as QFN, will result in signal integrity analysis changes. This analysis may not even be possible given the state of databases and toolsets at the (Original Equipment Manufacturer (OEM). Solutions available include custom QFN, DFN, and BGA assemblies that preserve original signal routing at the board level, resulting in few to no signal integrity concerns. Unlike most OCMs, OEMs try to keep legacy systems from changing assembly solutions. An example of this solution is an exact footprint of a 28 PLCC in the form of a 28 QFN available at one stateside manufacturer. The minor board change of adding a soldered pad under the package significantly improves thermal properties while maintaining all the signal integrity work previously implemented by the OEM back when the system was first deployed. This results in no signal integrity analysis needed, and the customer can confidently go forward with this drop-in solution while gaining better thermal dissipation and a thinner packaging solution.

Consolidating and standardizing material BOMs is another way to streamline operations when moving stateside. OSATs learned they offered too many combinations and options of die attach, mold compound, and wires. MOQs for materials with expiration dates are often unused. As companies bring more operations stateside, they are standardizing offered materials to eliminate the risks of throwing material away after being required to have large MOQs on hand. The advancement of lower stress and better thermally performing materials in the last decade has made this increasingly possible. Cu leadframes show that the consolidation of pad sizes amongst the smartest in the industry has been ongoing for several years. The outcome is less waste and the ability to cut costs, passing that on to the customers. Over the years, many stacks of Cu lead frames were thrown in Cu recycle bins as expirations passed and recertifications of the materials failed. The MOQs can be stretched further by consolidating pad sizes, avoiding significant waste.

IV. Conclusion

Since the pandemic's challenges, some companies have positioned themselves to overcome the challenges and risks of the semiconductor industry's supply chain constraints for their customers while enabling long-term system OEMs. By tooling up packages such as QFN and BGA as packages that OSATs are obsoleting stateside, such as SOIC, TSOP, PLCC, and PDIP, some are offering full-service assembly and test, as well as full licensing of OEM products that outlive their typical lifecycles. At least one company in the industry is managing a stock of wafers from OEMs totaling over 12 billion die and covering more than four decades of products. The company has positioned itself as a global leader in obsolete products that many customers will require for decades. They are based stateside, making it more attractive as a strategic partner for OEMs and OCMs looking to overcome supply chain issues and risks. Long-term system OEMs can benefit by taking advantage of the full-service offerings through forming strategic partnerships and licensing their products, whether old or new, or by taking advantage of the full range of assembly and test offerings. Having this capability stateside alone is a considerable mitigation to risk. However, having it with a partner that puts its long-term system customers and quality first makes it an unprecedented option in the industry.

V. Appendix:

Typical Product Lifecycle: