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TECH BRIEF

Tips for Increasing Yields when Wire Bonding Small MESA Chips

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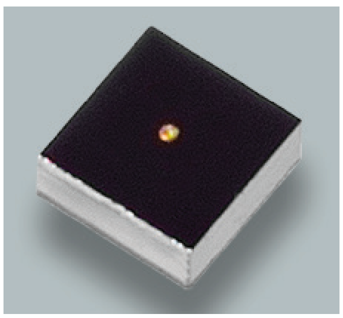
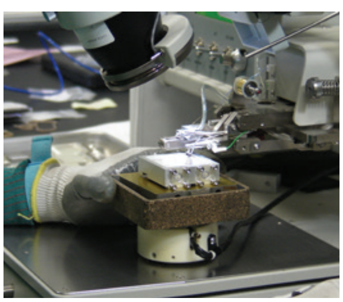
Smaller MESAs and faster processes force new bonding techniques.



Small MESA devices have posed a number of wire-bonding challenges, which have required advancements in wire-bonding technologies and skills. As MESA chip size has shrunk and market forces necessitate faster processes with higher yields, the difficulty around wire bonding MESA devices has only expanded. Overcoming these challenges requires not only the latest in wire-bonding equipment, but the process development know-how, and specially designed tools to bond with the utmost efficiency.

With extensive experience helping manufacturing centers prevent hundreds of thousands of dollars of loss, which can be attributed to ruined chips and reliability issues due to poor wire bonds, SemiGen experts are proficient with developing repeatable and value-added processes. This tech brief details some of the specific wire-bond concerns associated with small MESA chips, and how our experts have resolved them.

INTRODUCTION

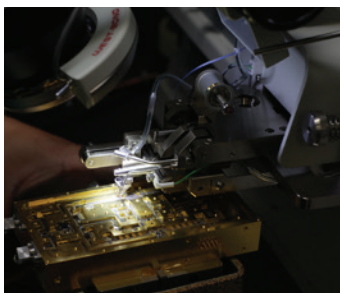


Sub-1 mil wire diameters and bonding areas smaller than 40 microns have led to a new breed of challenge with bonding small MESA chips. With market pressure and customer demands forcing greater speed and lower costs from manufacturing houses, destroyed chips and reliability issues have become less acceptable. The electrical performance demands on wire bonds have also increased for military, defense, aerospace, and satellite communications and high-speed digital devices, which only add to the challenge of successfully wire bonding the latest MESA chips.

Ideally, a manufacturer would benefit from a faster and more efficient wire-bond and testing process. This process would reduce the amount of rework and slowdowns introduced by wire-bond breaks and reliability failures. Additionally, this process would enable the use of semi-automated or automated wire-bond machines that require minimal setup and supervision, and adapt readily to new projects. To accomplish these tasks, a deep knowledge and expertise with a complex array of wire bonding small MESA chips for a variety of applications is necessary.

Following is a description of wire-bond technologies, challenges of wire bonding small MESA devices, and illumination into how to maintain consistent yields.

TYPES OF WIRE-BONDING TECHNOLOGIES



Wire bonding is the technique of electrically and mechanically connecting the minute beam leads from integrated circuit (IC) die to larger packages, or directly to another substrate such as a PCB, with fine wire. Wire bonding is performed on over 40 million ICs every year, and is the dominant form of electrical IC bonding from die to package. Traditionally, 1 mil to 3 mil wire diameters were used but, more recently, sub-1 mil wires are increasingly being used to reduce the capacitive and inductive parasitics on RF integrated circuits (RFICs), monolithic microwave integrated circuits (MMICs), and high-speed digital chips.

A significant number of semiconductor device issues are attributed to wire bond failures. There are several wire bond methods that are employed, depending on the materials, costs, die type, application-specific needs, and customer needs. Among the various types are high-temperature thermocompression, which is largely used on aluminum (Al) wire bonding to Al or gold (Au) pad material. Room-temperature, ultrasonic welding is also used to bond Au and Al wire to Al or Au pad materials. Last of the common wire-bond techniques is thermosonic, which uses a combination of ultrasonic welding and thermocompression, and comprises over 90% of wire bonding.

Wire Bond Methods				
Wire Bonding	Operating Temperature	Wire Materials	Pad Materials	Note
Thermocompression	300-500°C	Au	Al, Au	High pressure, no ultrasonic energy
Ultrasonic	25°C	Au, Al	Al, Au	Low pressure in ultrasonic energy
Thermosonic	100-240°C	Au, Cu	Al, Au	Low pressure in ultrasonic energy

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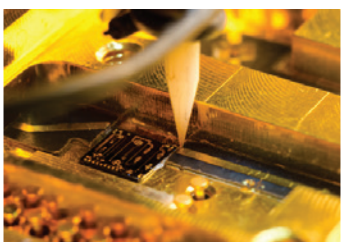
Wire bonds are typically formed using ball bonds or wedge bonds. However, as the performance demands increase, wire sizes decrease, bond pads become smaller, and bond-pad spacing is reduced, ball bonds are becoming increasingly dominant as the bond-forming method employed. Au wire bonding to Au pads was the original method used when wire bonding was developed, and it is still one of the most common materials used today. Aluminum wedge bonding is also used, as its lower cost appeals to certain applications. Nevertheless, Al wire can only be wedge-bonded and can only be used when there is adequate bond-pad spacing. Copper (Cu) and silver (Ag) bond wire is also used, though they are far less common.

CHALLENGES OF WORKING WITH SMALL MESA DEVICES



Quoting NASA,“Through the improvement of bonding technology the reliability of wire bonds is increasing, as is our understanding of the failure modes, though they continue to plague new manufacturing lines.” As any reduction in yield, or increase of cost and time associated with rework can have dramatic implications to the end cost of a product, improving yields on manufacturing lines largely comes down to the wire-bonding process success. There are only a few typical wire-bond failure modes that account for the large majority of wire-bond failures. The failures range from bond wires peeling off the bond pad to wire bonds breaking during normal assembly and use.

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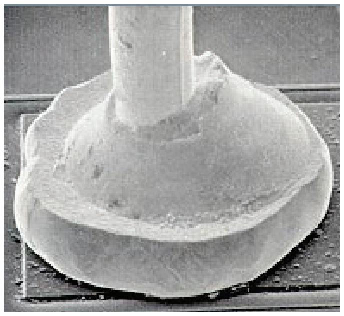
FIVE COMMON WIRE-BOND FAILURE MODES



1. Cratering and peeling

Due to the high pressures and heat involved with thermocompression, which also impacts thermosonic wire bonding to some degree, cratering and peeling of the wire bond pad is possible. This failure mode may lead to increased resistance from the die to the package, and lead to heat stress and performance issues with high-speed signals. Cratering and wire-bond peeling can also result in complete disconnection over time and stress.

2. Over-stretching and over-twisting

A bond wire that is stretched too far and experiences too much pressure at a connection point may break at the connection point or along the wire length. Moreover, if a bond wire is bent too tightly or twisted beyond specification, breakage can also occur. As bond wires are very fine and hardened to improve consistency, they are also brittle and any significant force may lead to a fractured or broken wire bond. Fractures can increase resistance and lead to failure due to further damage from localized heating.

3. Untamed tails

If a wire bond is not cleanly cut on each end, the wire-bond tail may extend to another bond pad, bond wire, or trace on the die itself. Beyond increasing the parasitic inductance and capacitance of the wire bond, inconsistent bond tails can cause electrical shorting and increased crossover/coupling effects in high-speed or high-power circuitry. Shorting, arcing, and cross coupling can reduce performance and damage, or even destroy, a die.

4. Poor adhesion

If the wire-bond and bond-pad weld do not cause adequate mechanical adhesion and electrical connection, a weak bond can ensue. A weak bond may have greater parasitic inductances, capacitances, and resistance than is specified by the packaging process. Also, localized heating from increased resistance can further weaken the bond and eventually lead to complete failure.

5. Missed Targets

Alternately, a wire bond may land partially on a bond pad, between bond pads, or even bridge bond pads. Any of these occurrences can lead to shorts, weak bonds, poor welds, and a wire-bond disconnection. Essentially, a wire-bond process must account for these failure modes and more, among the numerous wire-bond process variables. There are several methods of evaluating and testing wire bonds and wire-bond processes, especially for military, aerospace, and satellite applications, where standards can be extremely rigorous.

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BEST PRACTICES FOR WIRE BOND EVALUATION AND TESTING

Each application and die may have its own set of parameters and evaluation criteria. If the die is designed for use in military, government, aerospace, satellite, automotive, or other standardized applications, there may be a body of national or international standards to which the wire-bonding process must adhere. These requirements often come with specific evaluation methods and testing procedures.

Typically, these tests may involve internal visual testing, ball-bond shear tests, constant acceleration tests, random vibration, mechanical shock tests, and stabilization bake. Additionally, environmental tests for moisture resistance and temperature cycling may be used. Military standards, specifically MIL-STD-883, detail a wide array of tests and evaluations for U.S. military wire bonds. These include a test for bond strength, the destructive bond-pull test, method 2011.7, and a nondestructive bond-pull test, method 2023.5.

The time and cost of added testing, while producing adequate yields throughout testing and evaluation, must be considered when developing a wire-bond process. Mastering many military, aerospace, and satellite testing standards requires a high level of expertise.

SELECTING THE RIGHT WIRE BOND TOOL TO OVERCOME CHALLENGES WITH SMALL MESA CHIPS

Part of the challenge for small MESA chip wire bonding, is that every MESA chip may have significantly different requirements for the optimum wire bond. Balancing cost, performance, time, yield, and process development is becoming overwhelming for many manufacturers. To deliver the best quality bonds that meet stringent application-specific evaluation parameters and standards, the customization of wire-bond tools is often necessary.

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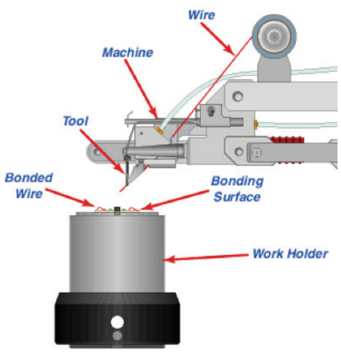
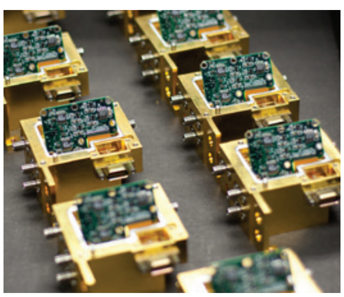


A key to wire bonding success is the original manufacturer, age, and condition of a wire-bonding tool. There are many features available with the latest semi-automatic and automatic wire-bonding machines that can dramatically increase yields, speed, and accuracy. For instance, only a few of the best wire-bonding machines enable ultra-precise dialing of the ultrasonic force, which is critical in ensuring a high-quality rapid bond.

Many wire bonding experts rely on the latest Westbond wire-bonding machines to maintain cutting-edge, wire-bond capability. The precision and accuracy of these machines allow technicians to provide performance-driven wire bonds efficiently.

ENHANCE WIRE-BONDING PERFORMANCE WITH SUPERIOR PROCESS DEVELOPMENT



There are several foundational variables to consider for any given wire-bond job. Each variable must be planned for in advance during the wire-bonding process development. Failure to account for these factors can lead to a reduction in yields and cause delays during manufacturing. Expertise and a significant time commitment are required to develop a sophisticated wire-bond process and, because of this, they are relatively rare.

Many manufacturers avoid developing quality wire-bond processes in order to cut costs and save on development time, or because their staff lacks adequate expertise and necessary resources. However, any corner cutting in the wire-bond process development will return reduced yields, ruined chips, and potentially substantial delays.

Alternatively, by using sample parts and mounting to a bonding coupon, the wire-bond process development can begin on a platform designed for continues improvement. Through repetitive refinement, this process development mode can proceed until the process is repeatable and passes MILSTD883 requirements.

Then the process can be further developed through a series of known practices, and the data and formulations are provided to the customer for an optimal process when using similar machines. However, some bonders cannot perform a consistently reliable attachment, and when customers are faced with these challenges, they will often subcontract the work to SemiGen engineers.

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Wire Bonding Process Variables					
Tool	Wire	Bonder	Bonding Surface	Work Holder	Bonded Wire
Position	Size	Calibration	Metal Purity	Temperature	Ball Formation
Clamping Force	Type	Optimized Bonding Schedule	Metal Uniformity	Heat Transfer	Wire Recrystallization
Characteristics	Breaking Load	Operator Skills	Metal Thickness	Rigidity	Wire / Tool Interface
Bondability	Elongation	Ergonomics	Surface Contamination	Environment	Geometry
Condition of Bonding Surface	Purity	Time	Surface Texture	Stability	Optimized Bonding Schedule
Geometry	Uniformity	Temperature	Metal Bondability, Initial	Positioning Accuracy	Location
Bonding Surface Area	Twist / Curl	Ultrasonic Energy	Metal Bondability After Time / Temperature	Synchronization	Wire Curl
	Surface Condition	Synchronization			Intermetallics
	Bondability	Bondability			Time / Temperature Environment
		Bond Pressure			Bond Interface Condition
					Ergonomic

Footnote: Developing an optimized wire bond process requires proper balancing of each aspect of the wire bond process. Hence, expertise in wire bond process development and precision customization of a wire bond tool to bring out reliable and accurate performance is of key importance.

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CONCLUSION

The challenge and scope of experience necessary to meet the latest manufacturer needs for the successful wire bonding of small MESA chips have greatly exceeded the expectations of even a few years ago. Rising with the times, SemiGen continues to build on more than 30 years of experience, solving a diverse array of wire-bonding challenges for virtually every application. When concerns over rising costs, reduced yields, and manufacturing delays associated with wire bonding small-geometry bond pads on small MESA chips exceeds a reasonable threshold, SemiGen experts are available to help develop a repeatable and value-added wire-bonding process.

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