Functional Testing of 0.3mm pitch Wafer Level Packages to Multi-GHz Speed made possible by Innovative Socket Technology

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Introduction

Today's electronic packages have high clock speeds (multi GHz range), fine pin densities (below 0.4 mm pitch) and high pin counts (over 1000). When these packages assembled onto a printed circuit board (PCB), they perform certain functions at certain speed. Socketing is one of the avenues to test the functionality of IC packages without damaging it. Socketing these high-speed and high-density IC packages requires an innovative solution to the challenges of designing a shorter signal path (less resistance), good electrical insulation (prevents signal loss), and proper thermal management. Design of the socket is dictated not only by the functions mentioned above, but also by the other parameters such as durability, power consumption, assembly methods and the environment in which the system will operate. Silver ball Matrix (SM) *GHz* socket (Figure 1) provides a solution that is fast, dense and durable.

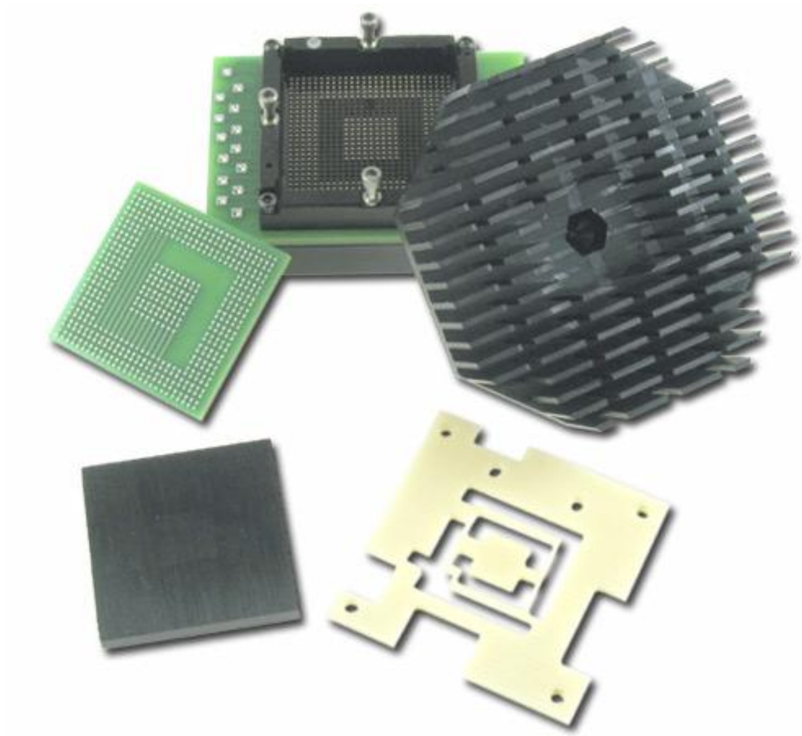


Figure 1

Socket Function

A socket can be defined as an electromechanical device, which provides removable interface between IC package and system circuit board with minimal effect on signal integrity. Removable interface is the major reason for using a socket and it is required for a variety of reasons, including ease of assembly, reworking, upgrading and cost saving. The cost advantage is saving the IC by not attaching permanently to PCB. The socket is semi-permanently (solder less) attached to the PCB, while the IC device can be inserted into or removed from the socket without disturbing the connections to the PCB. Socket helps to test, evaluate and inspect the complete system. Also, socket allows in the field for maintenance, testing, replacement or upgrades. This becomes a critical factor because of technology evolution.

Silver ball Matrix (SM) GHz Socket

Ironwood Electronics has developed a sequel to standard GHz socket, which can test IC packages with 0.3mm pitch. SM GHz Socket provides a range of high-speed, high-density socket solutions from very compact production sockets to robust test and prototype applications. A cross-section photograph revealing SM contact is shown in Figure 2. The sockets are designed such that force is evenly distributed on the top of the IC pushing the solder balls into a very high speed, Z-axis, silver ball columns. SM Contact is a unique contact that has precise silver balls held together by a proprietary conductive formulation. These conductive columns (diameter optimized for 50 ohm impedance) are suspended in a non-conductive flexible elastomer substrate with a patented solid core for enhanced durability and reliable performance over time, temperature and cycles. This flexible substrate is very compliant and resilient and enables the conductive columns to revert back to original shape when the force is removed. Elastomer is the only medium between IC package and the circuit board. A heat sink screw and the socket body provide heat dissipation for the IC in the socket. Precision guides for the IC body and solder balls position the device for perfect connection.

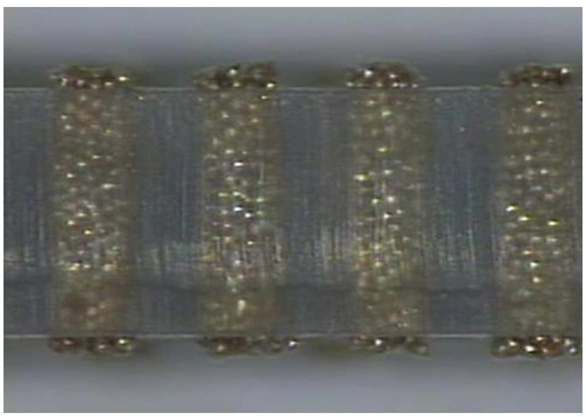


Figure 2

Mechanical Characterization

Removable interface requirements are generally stated in terms of the insertion/extraction force and number of insertion/extraction cycles a socket can support without degradation. Insertion/extraction forces become increasingly important as the number of pin count in the device increases as well as the ICs are direct silicon (wafer) that are very delicate as opposed to enclosed packages. The first test examines the relationship between deflection of the contact, force and the contact resistance. Displacement – Force (DF) test station was used to measure the contact deflection and its corresponding force. Force increases linearly as the displacement increases. Similarly contact resistance decreases as the force increases. Stable contact resistance has to be identified based on minimum force required. A desired displacement has to be identified based on the compliance requirement of each device/application. This information is very important for test engineer to set up failure criteria when performing device test using this contact technology.

The second test examines the relationship between contact resistance over contact life cycle count. An actual handler was used for this experiment. Contact set consists of 44 leads + 16 ground leads (QFN configuration) was mounted on the test board which was then connected to a tester. A gold plated shorted device simulator was mounted on the plunger head. The test set up was adjusted such that the head moves down 0.3mm which was the chosen travel for the SM contact. Initial contact resistance data was measured via tester and the ATE (Automatic Test Equipment) was turned on. This moves the plunger back and forth which in turn cycles the SM contact. A digital counter was inserted into the test setup to measure the cycle count. Test setup includes cycle speed ~2,500 actuations / hour, Dwell time:~0.7Sec, and ambient temperature. Test vehicle was designed for 7x7mm 44 lead, QFN shorted device simulator. No cleaning was performed to gold plated DUT (Device Under Test) or to the SM contact. Contact resistance data collected at different cycle intervals was shown in Figure 3.

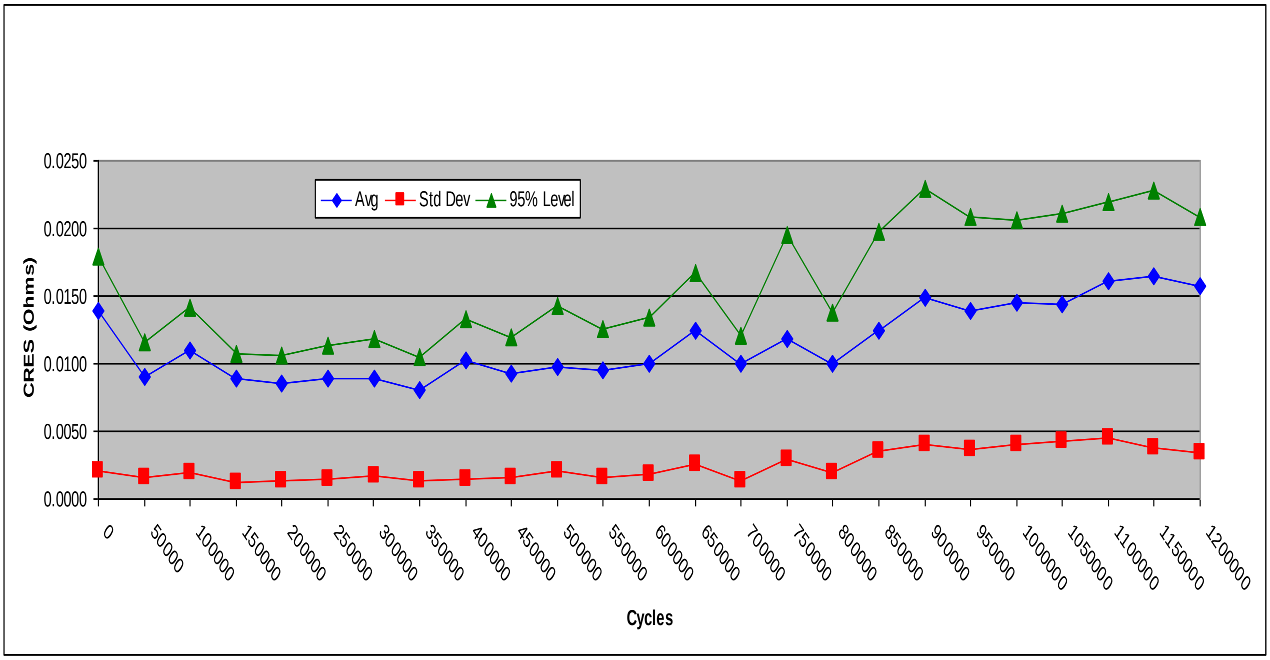


Figure 3.

It can be seen from the graph that the average contact resistance is less than 25mOhms over 1,000,000 cycles. Standard deviation was also shown to provide an understanding of the data spread. Based on the graph, it can be concluded that the contact operates over 1,000,000 cycles with 25mOhms average contact resistance. The experiment was repeated with different lot manufactured at different time. The data is consistent over different lot except the average is shifted down by 5mOhms. This shows that the process variations can cause shift in contact resistance within 5mOhms. Similarly, the contact was tested at various temperatures and acceptable range was defined as -50C to +150C.

Electrical Characterization

Electrical requirements are generally stated in terms of the bandwidth and current carrying capacity. Current capacity is determined by injecting drive current in steps of 10 mA to a maximum value of 5A. For temperature as a function of resistance dwell time is set to 3 minutes per data point to allow temperatures to stabilize. Result is shown in the below figure 4. From the graph, it can be seen that for 4A continuous current, the temperature rise is 14C. This is very critical for test engineer to know that there is no joule heating effect due to contact's base structure.

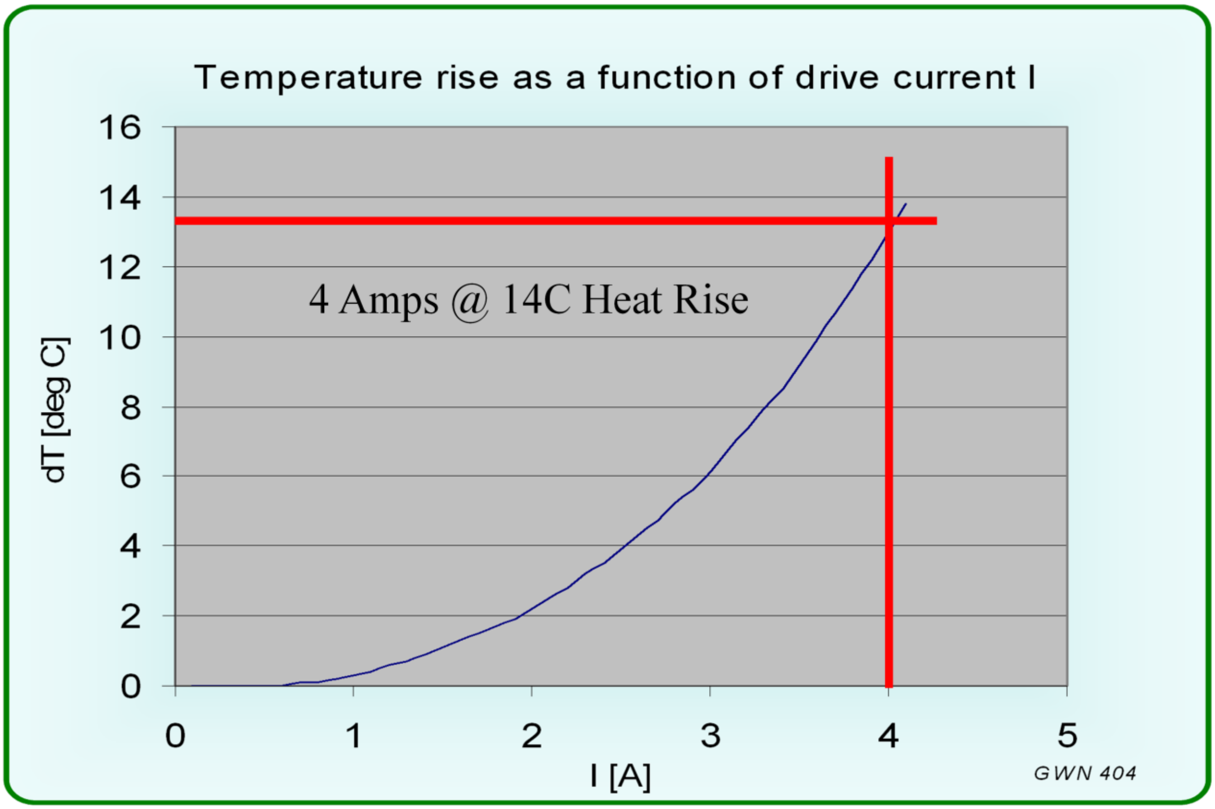
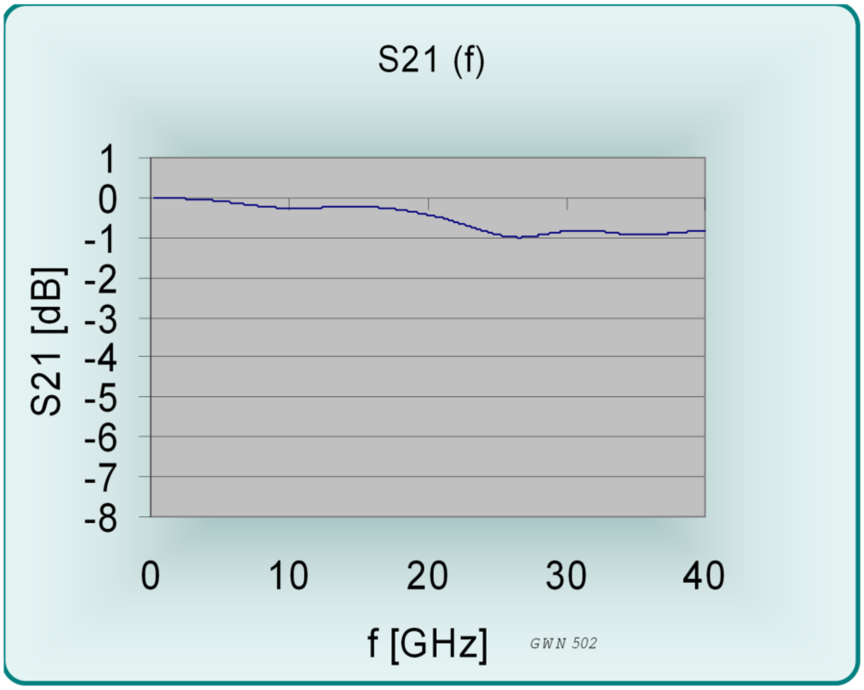


Figure 4.

Final test of measuring bandwidth determines if this contact technology is right for particular test application. Bandwidth is typically specified in terms of insertion & return loss. A vector network analyzer is used for this experiment. A signal is sent from port 1(top of the contact) and received at port 2 (bottom of the contact). Signal reflections are measured and reported as S21 curves shown in Figure 5.



Insertion Loss -1dB @ 40GHz

Insertion loss of -1dB @ 40GHz is interpreted as 90% of signal pass through the interconnect medium and only 10% of signal is lost through the interconnect transition at 40GHz frequency. This is very critical for the test engineer as the IC functionality is being verified at specific frequency.

Conclusion

A primary concern to anyone utilizing the high density WLPs is that the socket must provide a high performance, low and stable value of resistance while meeting mating requirements, in particular mating force and the number of mating cycles it must withstand without degradation. SM GHz Sockets solve such concerns and provide unmatched solution for high-speed, high-density, high pin count application needs. The test results share the electrical and mechanical characteristics of the contact interface. The simple design of the socket makes it cost efficient and allows assembly to the target board using existing hardware. A unique feature of this socket is its separable components that can be easily replaced and reused.

Author

Mr. Ila Pal is VP of Marketing at Ironwood Electronics. He has MSME degree from Iowa State University as well as an MBA from St. Thomas University. He has six patents, published many articles and presented many papers. He can be reached at ila@ironwoodelectronics.com