Challenges of Wire Bonding In High Value and High Performance Medical Devices

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Abstract

Wire bonding is a fairly mature technology that has been used in medical implantable products for over twenty years. Today however, its relevance continues to grow as the size of die continues to get smaller. Size, weight and volume are paramount when developing and manufacturing an implantable medical device, which often needs to perform a specific function such as, monitoring or adjusting parameters of the device itself, monitoring patient data or communicating data from the device to the healthcare professional.

Wire bonding can be the answer to addressing many of the requirements mentioned above. This paper will review the current status of the use of gold ball wire bonding and its relevance to the medical device industry as well as discuss how advancements in wire bonding processes benefit today's implantable products.

Wire bond interconnections can be made using gold, aluminum and copper wires. They each have different bonding characteristics and therefore require different application methods and equipment. The advantages and characteristics of gold ball wire bonding will be reviewed as this process relates to High Value Medical Devices.

Achieving high yields can also be a challenge with any wire bonding processes. Today's smaller die and pads require smaller gage wires. Typical production requirements are .8 – 1.2 mil wire and 4X4 pads. The demand to still go smaller requires continual adaptations and ingenuity as wire thicknesses are being pushed to .5 mils and below. Bond pull testing at the beginning, mid and end of production runs becomes important to verify integrity of the wire bonds with such small wire gages.

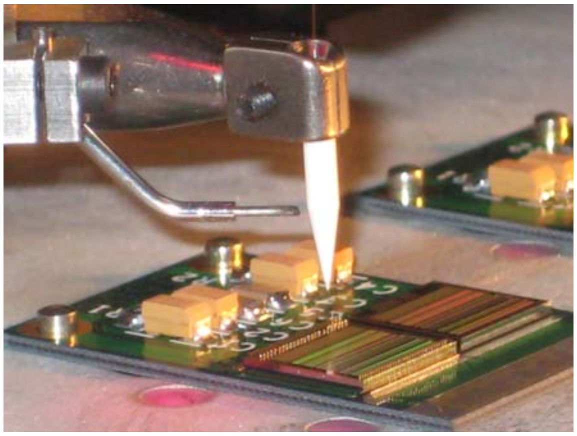
The complexities involved in wire bonding can lead to increased cost as well. To address this, a single process procedure is being adopted by many, which eliminates pattern plating and saves time and money. This new process will also be explained and reviewed.

Key Words: gold ball wire bonding, electronics in high value medical devices, bond pull testing, ENEPIG

Introduction

Wire bonding is a fairly mature technology, which has been in use in medical implantable products for the past twenty years. Over this time frame the techniques for wire bonding have proven themselves robust enough for the medical implantable industry and have enabled manufactures of these types of products to pursue a strategy of making their products smaller.

The types of products employing wire bonding, specifically, gold ball wire bonding include cochlear implants, pulse generators for pain mitigation, drug pumps, portable physiologic monitoring devices, and digital x-ray equipment, just to name a few. Picture 1 shows a high-density analog to digital converter for a digital x-ray undergoing the wire bonding process. This product has 224 wires with 100-micron pitch. The PCB utilizes 50-micron lines and spaces.



Picture 1
A Digital X-Ray board undergoing gold ball wire bonding.

Photo courtesy of Valtronic Technologies, Solon OH

These products, while diverse in their application, share common themes; such as a requirement for a high degree of reliability, small packages which must be comfortable for the patient or they must contain a significant amount of I/O, as in the case of digital x-ray.

Yet despite this proven track record of success with wire bonding, the medical industry at least on the surface appears to be moving away from this technology. Instead, it is employing surface mount technology with BGAs instead of bare die, even if it means the end product might be larger in size.

Wire Bonding Challenges

While cost is surely an issue driving this movement away from wire bonding (the price of gold has skyrocketed), there are other challenges that may be affecting this decision, such as inability to recover yield loss, waste of all material if a bad die lot is placed and then encapsulated, as you cannot replace an encapsulated bad die, and lastly the necessity to perform an in-process bond pull test to validate the implantable medical product. These, of course, lead to increased production time and ultimately increased cost.

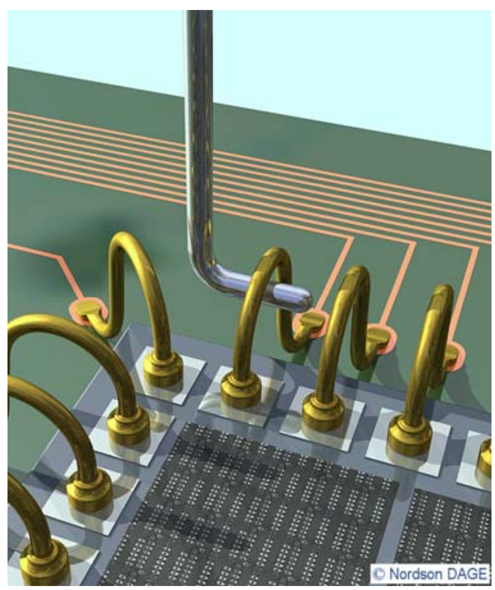
To further investigate the value of wire bonding as it applies to medical products lets review current state of the art in gold ball wire bonding applications.

Today's small die used for gold ball bonding require smaller gage wire then the aluminum wedge bonding products of a decade ago. Typical production requirements are .8 to 1.2 mil wire and 4x4 mil pads. There is still demand to go smaller as wire thickness is pushed to .5 mils and below.

With such small pad sizes and small gage wire, the wire bonding process must be well qualified before it is implemented into an implantable medical device that will reside within the human body often times for years.

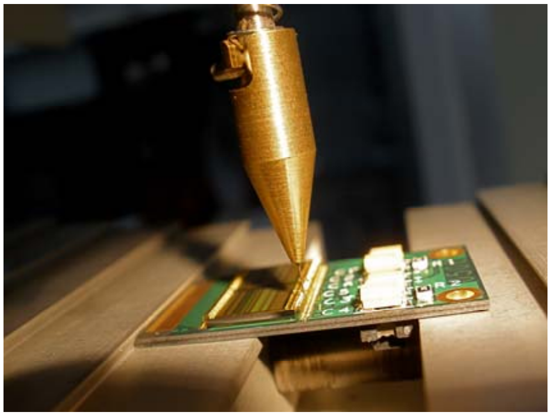
Qualification

The end resellers of these implantable medical devices all approach the qualification process differently. Some use die sheer testing and force measurements on the wire bonds for a representative sample of product prior to production start up. Others use an in-process inspection to ensure the wire bonder is running properly and consistently. These techniques may include performing bond pull testing on the PCB before a production run begins, bond pulls on a representative sample of wires and die, or in extreme cases bond pulls on every assembly followed by placement of a second wire after the first one is pulled. Picture 2 below depicts an artist rendition of a bond pull test. Picture 3 shows an actual photo of the same. Table 1 depicts typical summary analysis of a Bond Pull Test. In the example shown, destructive bond pull tests were performed. Further, some either burn in or thermally cycle their product and perform electrical testing after wire bonding and encapsulation to ensure integrity of the wire bonding process.



Picture 2
Bond pull testing conforming to MIL-STD-883.

Photo courtesy of Nordson DAGE Fremont, CA



Picture 3
Bond pull testing using Nordson DAGE Series 4000.

Photo courtesy of Valtronic Technologies Solon, OH

Table 1

Bond Pull Test

Test Group	(900789)	VW #	V7246
Operator	SBrown	Bonder #	8098A
Test speed	23.60mil/s	Rack #	AO
Test load	4.00g	Device #	U2
Machine	Series 4000 - 2096241		
Date saved	6/18/10 07:15:55		
Sample number	1300		
Total number of tests	16		

Destructive Tests Summary

Number of tests	16	Mean - 3*StdDev	16.538 g
Minimum load	17.734 g	Upper spec limit	25.000 g
Maximum load	20.488 g	Lower spec limit	4.000 g
Mean	18.821 g		
StdDev	0.761 g		

Test Detail

Test	Force	Type	Grade	Description
1	17.734 g	Pass	2	Heelbreak on ball, die-
2	18.147 g	Pass	2	Heelbreak on ball, die-
3	18.399 g	Pass	2	Heelbreak on ball, die-
4	18.854 g	Pass	2	Heelbreak on ball, die-
5	20.106 g	Pass	2	Heelbreak on ball, die-
6	20.488 g	Pass	2	Heelbreak on ball, die-
7	18.686 g	Pass	2	Heelbreak on ball, die-
8	19.224 g	Pass	2	Heelbreak on ball, die-
9	19.032 g	Pass	2	Heelbreak on ball, die-
10	19.602 g	Pass	2	Heelbreak on ball, die-
11	18.410 g	Pass	2	Heelbreak on ball, die-
12	19.216 g	Pass	2	Heelbreak on ball, die-
13	18.318 g	Pass	2	Heelbreak on ball, die-
14	18.342 g	Pass	2	Heelbreak on ball, die-
15	18.641 g	Pass	2	Heelbreak on ball, die-
16	17.945 g	Pass	2	Heelbreak on ball, die-

Testing is not the only issue that can create time and cost challenges on wire bonded product. Combined technology assemblies, those that have one or more wire bonded and encapsulated die on a substrate with surface mount components and through hole connectors present unique challenges to manufacture.

From a production flow standpoint, a typical mixed technology product goes through die attach, where the bare die is attached to the PCB, wire bonding, encapsulation, then surface mounting of components, sometimes on both sides of the PCB. These types of assemblies usually spend part of their time in a dry room in between process steps to protect against moisture.

Following the processing there is usually a burn in cycle for the assemblies, sometimes hand mounting of connectors or mechanical parts and then an electrical test to prove functionality.

The point is, there are many steps to processing a board that uses mixed technologies and utilizes wire bonding to achieve its miniaturization. These steps all pose risk and add time.

Process Improvements

With all the challenges of wire bonding it is important to keep in mind that increased package and interconnection density drive the evolution of production methods such as wire bonding as much as the desire to keep the product small, light-weight and packed with functionality.[1] This has spurred continued development of techniques that help offset increased cost factors created by longer processing time and more processing steps.

One area that has undergone technological advancement and that is contributing to cost reductions of the PCB for wire bonding is the PCB plating process. Historically, PCB's for wire bonding has used electrolytic nickel gold and that process has provided excellent wire bonding performance. This process does have drawbacks, however, the three main ones are:

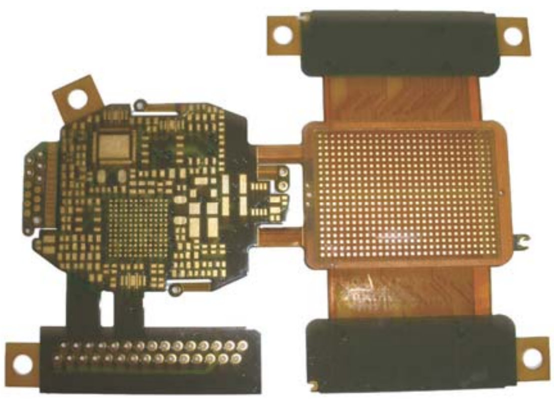
1) The high cost, driven by high gold thickness,
2) Solder joint reliability may be reduced
3) Plating process inherently limits the densities that can be achieved.

In the late nineties a process called electroless nickel electroless palladium immersion gold (ENEPIG) was developed. ENEPIG shows substantial advantages combining excellent shelf life, solder joint reliability, gold wire bondability and usage as a contact surface. The protection of the electroless nickel interface with the formation of a thin electroless palladium layer, prior to immersion gold, eliminates the potential for excessive gold attack on the electroless nickel surface. [1]

Further, it has the advantages of meeting lead-free/ROHS requirements and at current gold prices offers a substantial cost savings as well.

In their paper entitled, "Why Electroless Nickel Electroless Palladium Immersion Gold (ENEPIG)?" The authors Lam Leung, Rohm and Haas eloquently summarize the key advantages of ENEPIG for gold ball wire bonding as follows:
"The key advantages of ENEPIG, combining both excellent solder joint and gold wire bonding reliability, can be summarized in the following points:

- "Black Nickel" free--no possibility of grain boundary corrosion of nickel surface by immersion gold.
- Palladium acts as an additional barrier layer to further reduce copper diffusion to surface, thus ensuring good solderability.
- Palladium completely dissolves into solder, without leaving an excessively high P% rich interface, exposing an oxide-free nickel surface allowing reliable formation of Ni/Sn intermetallic.
- Withstands multiple lead-free reflow soldering cycles.
- Demonstrates excellent gold wire bondability.
- Process costs substantially lower than electrolytic nickel gold or electroless nickel electroless gold.



Picture 4
Illustrates the advantages of the ENEPIG process. The PCB shown is for an implantable medical device. The PCB itself is a six- layer flex board. Layers 3 and 4 contain 2 mil lines and spaces. The only way the PCB pattern could be made was with the ENEPIG process.

Photo Courtesy of Valtronic Technologies, Solon OH

Conclusion

Gold ball wire bonding is widely used throughout the medical electronic industry enabling companies to manufacture products packed with functionality in a small size and weight. Specifically, cochlear implants, pulse generators for pain mitigation, drug pumps, portable physiologic monitoring devices, and digital x-ray equipment which all benefit from gold ball wire bonding technology. While there appears to be a move to more commonplace surface mount BGA technology even at the sacrifice of size, many companies still rely on wire bonding to achieve denser interconnections and large I/O requirements in small lightweight packages.

Recent developments with PCB manufacturing processes such as ENEPIG are helping to address the cost factors, which have been pushing companies away from wire bonding and enabling even tighter interconnection densities to be made at a lower cost.

These developments and the proven reliability of gold ball wire bonding will continue to secure the application of wire bonding as a manufacturing process in the medical device industry.

References

[1] Lam Leung, Rohm and Haas, "Why Electroless Nickel Electroless Palladium Immersion Gold (ENEPIG)?", PCB007 Wednesday, September 17, 2008 |