www.led-professional.com

ISSN 1993-890X

LED professional Review

LpR

The leading worldwide authority for LED & OLED lighting technology information

Jan/Feb 2013 | Issue 35

Zhaga – A Successful Strategy

Copper Bonding Wires

TRIAC Dimming – EMI

Lacquer Systems for PCBs

LpS 2013
Call for Papers
Deadline: Feb 15, 2013

Content

Editorial	p 1	COMMENTARY	p 4
Imprint	p 60	News - PRODUCTS	p 6
		News - RESEARCH	p 24

EVENTS
LED Acceptance in the Global Lighting Market Continues to Grow p 26
by Alan Mills, LED professional

INTERVIEW
Zhaga – A Successful Strategy for Luminary Manufacturers p 30
by Siegfried Luger, LED professional

LED & OLED TECHNOLOGY
Copper Bonding Wires - A Feasible Solution for LED Packaging p 34
by Dominik Stephan & Alon Menache, RED Micro Wire

ELECTRONICS
EMI Problems in TRIAC Dimmable LED Drivers p 38
by Bianca Aichinger, RECOM Lighting

THERMAL MANAGEMENT
Reliable Thermal Management of High-Power LEDs p 42
by Stefan Hörth, Haeusermann

MANUFACTURING
Lacquer Systems for PCBs – p 46
Optical Requirements and Performance in Applications
by Dr. Manfred Suppa & Johannes Tekath, Lackwerke Peters

SPECIAL TOPIC
DC-Grids - Challenges and Chances for LED Lighting p 52
by Arno Grabher-Meyer, LED professional

ARTICLE INDEX 2012 p 58

Advertising Index

Philips-Lumileds	C2
Recom	p 3
Bicom	p 5
LEDLink	p 9
GSZM	p 11
Vossloh-Schwabe	p 15
EBV Elektronik	p 17
LED Light for You	p 19
Edison	p 21
Signcomplex	p 21
Instrument Systems	p 23
LpS 2013	p 25
Bicom	p 33
GSZM	p 33
LED China	p 37
LEDTech Asia	p 41
LED Lighting Taiwan	p 45
LEDTech Expo	C3
Optotune	C4

Copper Bonding Wires – A Feasible Solution for LED Packaging

Wire bonding is also a relevant process in LED production. It is a complex and relatively costly manufacturing step. One reason is raw material costs. Usually gold wires are used, but the price of gold is rising steadily. Dominik Stephan, Director of Application & Product Marketing, and Alon Menache, Director of R&D Engineers at RED Micro Wire propose a newly developed technology that could help to lower costs.

LEDs have been growing significantly in usage over the past years due to having a longer life, using less power and occupying smaller unit space than traditional light sources. We might say that the LED industry is in the beginning of a hype cycle. While LEDs can offer a better ROI than traditional lighting, they are still more costly. As a result, the transition from LED in display lighting to LED in general lighting is slower than it could be.

Manufacturing and packaging LEDs requires micro bonding wire. Like packaging for semiconductor chips, these wires have traditionally been gold. The move to a less costly wire material such as the copper being used in semiconductor manufacturing could reduce the cost of manufacturing and help bring LED technology to the point where it is generally recognized as the best solution for cost effective lighting. The LED industry has not done so because of drawbacks and challenges with copper bonding wire. Recently a new option, glass coated copper wire, was introduced. This article will look at the advantages of glass insulated copper wire for LEDs and discuss how lessons learned in the semiconductor industry may have a potential positive impact on the LED industry.

Background

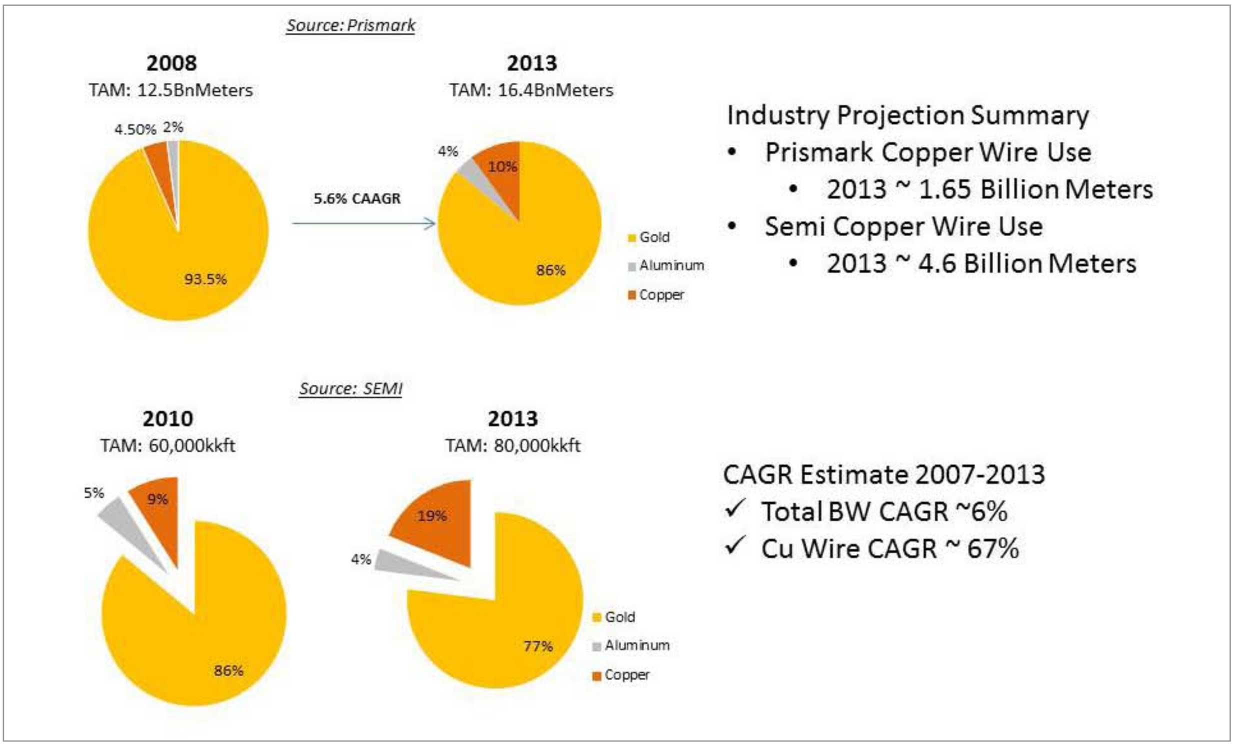
The most common bonding wire material used in LED applications is gold, which has been the traditional choice for semiconductor chips.

For the past 30 years, gold wire has predominated in the back-end semiconductor packaging industry. However, with the price increase for noble metals, gold in particular has increased by a factor of 6 over the last decade. There has been an ever increasing drive for cost reduction by implementing conversion programs from Au wire to Cu wire. In the past years, the semiconductor industry has been transitioning from gold to copper bonding wire, mainly due to the issue of cost (Figure 1).

The mechanical advantages of Au wire, in particular its softness, have been offset by the better electrical conductivity of Cu, and its fusing current (and the drastic price increases of Au), resulting in exponential growth of Cu in the wire bonding process over the last few years (Figure 2).

Figure 1: Gold (Au) price trend over the last decade

Figure 2:
Copper wire market share analysis (Prismark and SEMI)



A number of challenges, mainly in operation and materials management, have led the semiconductor industry to search for alternative solutions to copper bonding wire.

It appears that the issues of cost, material usability, and effectiveness are relevant to the LED industry. Innovations in bonding wire for semiconductors could potentially be implemented to benefit LED manufacturers as well, bringing growth and gain to both markets.

Challenges of Implementation

Due to the ever increasing cost of gold, combined with several performance advantages, copper has fast been gaining in popularity as an alternative to gold for wire bonding in semiconductor packaging. The high reliability of gold and relatively simple material management makes gold the industry's first choice. In contrast, LED applications which have a low pin count utilize much less wire than semiconductor packaging, which have a high pin count. As a result, the material cost seems to create less impact on the LED industry, resulting in lower urgency and demand for alternative solutions.

LED industry projections predict that, in the near future, high power lighting will be produced using LED clusters, for example, in street lighting. Such clusters will necessitate expanded use of bonding wire, larger amounts of wires and connections. As this trend is implemented, the cost of wire will be further highlighted and the demand to find a more cost-effective solution will grow. Already we are beginning to see discussions regarding possible alternatives to replace gold bonding wire in LED applications.

Although Cu costs approximately one tenth the price of gold, copper bonding wire has some drawbacks that have made the LED industry reluctant to replace the standard gold wire. Drawbacks include higher wire hardness, which reduces the wire process robustness, more complex application requirements due to the need for bonding under a protective gas environment, and more rigorous material management, mainly due to oxidization.

Higher hardness of copper means that the bonding process must use more energy to create the bonds, i.e. higher ultrasonic power, which can lead to pad damage problems and potentially reduced reliability. The fact that copper is less ductile and work-hardens easily leads to a major potential pitfall when using it for sensitive wire bonding applications. It is better to bond the copper wire under a protective environment since it oxidizes much more easily than gold and the presence of oxide layers predicates even higher bonding forces and potential reliability failures.

There is clear correlation between material hardness of a wire material (Au and Cu) and the size of a bonding window, where a ball can be welded to the bond pad. Both materials have different bond mechanics - Au forms the major bond strength based on inter-diffusion and intermetallic phase formation at the interface and copper, which does not show major IMC phase after bonding is believed to have its bond strength from mechanical interlocking (it does form IMC between Cu and Al at a later stage in heat treatment/reliability testing). Hence copper requires a larger amount of force to establish the bond to the Al layer. This higher force is also attributed to larger work-hardening of copper as compared to Au. In both materials, the bonded ball is harder than the FAB (Free Air Ball) but work-hardening is larger for copper. As a result, copper wire is more prone to pad cracking; subsequently we can say that softer copper wire is less prone to pad cracking.

Unfortunately, the use of higher bonding force can lead to two potential negative consequences that can impact the quality, function and longevity of the bond and hence the packaged chip: cratering and aluminum splash (or splash-out). Cratering refers to damage that penetrates through the pad and into the underlying dielectric layers. Aluminum splash occurs when the higher force used for copper causes the top aluminum layer of the pad to splash out beyond the ball footprint and potentially even beyond the edges of the pad.

Copper oxidization is a major issue that affects the entire bonding process – materials management to production of the final product (chip or LED) needs to be adapted accordingly. It is usually recommended to implement strict control over the storage of copper wires in order to assure wire usability. There is typically a limited shelf life, usually about 6 months after manufacturing, within which the wire needs to be consumed. This applies to storage with original packaging. Once the package is opened (and the wire is exposed to an oxygen-containing environment) wire lifetime for bare copper is reduced to about one week. After this there is a clear deterioration in bond performance due to oxidation of the copper.

Engineers and R&D teams dealing with LED packages have more limited resources than those available to researchers in high pin count assembly houses. As a result, overcoming technical challenges and discovering innovations are difficult and more time is required to implement new technologies.

There are some inherent problems with LED applications that are particularly related to use of Au wire and can be overcome when using copper. Intermetallic phase formation is very rapid, especially when using a soft, high purity Al pad metallization. Copper forms intermetallic phases at a much slower rate, which improves long-term reliability. Another problem is overcurrent, which damages the wire. Copper offers better electrical properties and can carry larger amounts of current. So the risk of fusing is reduced.

The LED industry can learn from the semiconductor industry, which has long been searching for an alternative to gold wire and attempting to overcome the challenges of copper wire, without inflating the cost of material. A different solution is needed, one that has the reliability of gold, at a cost like that of copper. Such a solution will ultimately benefit both the semiconductor and LED markets.

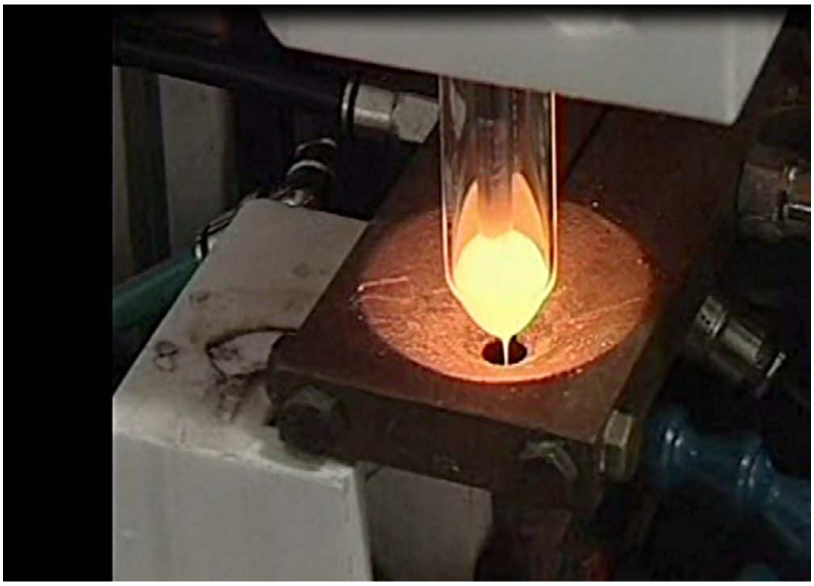
A Possible Solution

In order to find a promising solution it is necessary to think out of the box. One method of opening up new possibilities is to get away from the traditional wire drawing process. The Taylor-Ulitovsky process achieved this in an academic environment years ago. However, the process has never been duplicated for high-volume mass production until now.

The modified Adar-Bolotinsky process has made it possible to produce micro bonding wire directly from the melt - by casting instead of the traditional drawing - and taking this capability to mass production. This special manufacturing process also makes it possible for RED Micro Wire (RMW) to develop RED Copper wire which is a unique composite wire with a thin glass coating and a soft copper core. These unique composite wires can be created with other metal cores, opening a myriad of new opportunities for the wire bonding industry, some yet to even be imagined.

Glass can greatly increase wire strength and stiffness, yet still provide a smaller effective wire diameter on smaller bonds. Based on the manufacturing method, a full coverage of glass can be ensured, which in return ensures insulation. In addition, fusion current, floor and shelf life are no longer limiting factors since there is no exposure of copper and risk of oxidation.

Another special feature of the cast wire manufacturing process pertains to the mechanical properties of the wire. Hardness tests shows that the copper core is even softer than a



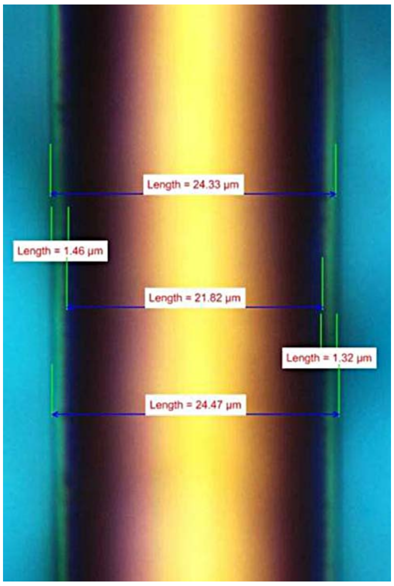


Figure 3: **Inductor unit of the RED Micro Wire (RMW) process (left)**

Figure 4: **RMW copper wire with glass coating (right)**

Table 1: **Wire and FAB (Fee Air Ball) hardness values of selected technologically available materials; *refers to the copper core**

	Wire hardness	FAB hardness
Gold wire	70-80	60-70
Normal copper wire	90-100	90-110
Soft copper wire	85-95	85-95
RMW glass composite	75-85*	65-75

typically highly annealed copper wire, as seen in table 1. This is true for the core of the wire, which indicates good bondability but also, more critically, for the FAB. The FAB hardness is in strong correlation to the bond pad deformation and cratering, which is a huge problem for standard copper bonding wire. In other words, the unique casting process creates attractive Cu mechanical properties and it is likely that the glass coated wire will greatly improve issues related to ball hardness and pad cracking.

The special wire characteristics of glass insulation create additional benefits. A major benefit is the elimination of risk of copper oxidization, which is one of the main challenges in operation and material management of Cu wire. In addition, the insulation prevents short circuits due to wire touching, a characteristic that is an important consideration in semiconductor packaging. This enables relaxation in design rules, which is highly beneficial in high pin count applications. The impact of these benefits on LED applications is yet unknown and necessitates further testing.

Conclusion

Wire bonding has been around for many years and has remained more or less the same throughout its use – the same materials, same processes, etc. New innovations, for example LEDs, necessitate new advances.

Glass-coated wire and the wire properties it creates appear to be an interesting development for the semiconductor industry and the LED market. Achieving softness in the range of gold wire is very promising. It is necessary to test the ramifications of the glass coating in LED applications to better judge the feasibility of this solution for the LED market. Certainly a viable, cost saving solution will help place LED technology into a total cost range that is attractive to the mass market. Further research and testing will help the industry to better understand the ramifications of this innovation and the possible gains in adapting such a solution.