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Global Trends In Electronics Manufacturing

by Divo Mari

The electronics manufacturing industry is going through a series of evolutionary changes, including the push towards Lead-free electronics, "green" electronics and greater integration of electronic functions both on and within printed circuit boards. Dr. Jennie Hwang, a leader and long-standing contributor to SMT manufacturing since its inception, shares with us her vision on the trends that characterise electronics manufacturing today. Jennie Hwang has provided hands-on solutions to challenging production and reliability issues and has served as an advisor to many OEM/EMS companies as well as to the U.S. government. Her broad engagements encompass international business, corporate executive positions, CEO of startup companies and corporate and university governance. Her work is highlighted by numerous awards and honors. She is a worldwide speaker and the author of 250 publications including several internationally used textbooks.

Figure 1 - Dr. Jennie Hwang, partner of Asahi America and H-Technologies Group

What will drive the shift towards Lead-free and environment-friendly electronics along with the greater integration of electronic functions in the future? How will these trends develop in the three large geographic areas: Europe, Asia and North America?

This is a very broad-based, yet critical topic, thus I respond from several perspectives. While reflecting on the evolution of microelectronics/electronics industry, the essential milestones start with the discovery of electron in 1897, followed with the invention of transistor in 1947, the introduction of microprocessor in 1972, and the emergence of Internet hardware in 1990s. Going forward, indeed, the convergence and integration of functionality will be the main thrust of the industry. The market as well as emerging technologies will be driven by wireless, digital and consumer electronics.

Among manifold exciting technologies, the expanded Silicon technology (SiGe and Silicon photonics), 300mm wafer, finer than 65 nanometer circuitry, increased efficiency of subsequent interconnections at the packaging and PCB levels will fulfil the market's demand for electronic products with lower cost, higher speed, lower power consumption, and concurrent capability of digital processing and analog radio frequency broadcasting.

Overall, market push, global competitiveness and the ever-shortening life cycle of electronic gadgets have been driving and will continue to drive technological development. Additionally, environment-friendly manufacturing and the delivery of products that are safer at the end of their product life cycle have become essential to technology-business competitiveness. This is a continuing challenge to the industry.

In this era of globalisation, new economy or innovation economy will be fuelled by ever swifter flow of information, ever faster generation of knowledge, and by the way the information and knowledge are used. To produce more with less people and at a lower cost is becoming every operation's on-going goal. To swiftly move scientific discoveries from the laboratory to the manufacturing facilities to the marketplace, requires the practical knowledge and entrepreneurial spirit which are found in a niche of the workforce. Regarding the situation in the three continents, one thing is sure: all three will face fierce competition across the continental boundaries and there will be much competition within as well.

With the rapid pace of technological change and the powerful tools that are available, raising the intellectual bar, climbing up the food chain and moving up the technology curve constitute the backbone of the corporate strategy, and the strategy of countries and continents. In the long run, innovation and competitiveness are key to a constantly rejuvenating economy and to the well-being of each region.

Let's focus on Lead-free electronics, can you give us a general overview

of how the technology developed and where the industry stands today?

To cover this question, it would be facilitating to summarise the historical perspective. There were scattered Lead-free studies before the late 1980s, yet the concerted effort started around 1989 when the Lead reduction or elimination was included in the U.S. Mantech program as one of objectives to enable the advancement of military electronics in terms of cost and performance. I was privileged to be invited as the advisor to the solder-related areas.

In terms of technology, even before the research started, we knew that any working Lead-free alloy must be Tin-based for a very fundamental scientific reason: Tin is the only element that can wet (make metallurgical bonds) on the commonly used metal surfaces in electronics under "soldering process' conditions (say, lower than 400 °C). We also knew that none of the binary alloys can fill the role for reflow surface mount soldering. But what we did not know was whether a ternary system could do the job with the established manufacturing infrastructure (including established flux chemistry, operating modules on the production floor, etc.). As a result of systematic research in conjunction with verification in actual production environments, it was becoming clear that ternary alloys such as SnAgBi, SnAgCu, SnAgZn, Mg-containing and many others are unable to fulfil the mission if maintaining the existing manufacturing infrastructure is the goal. Consequently, we were unable to stop at the ternary system. In order to reach the goal, we had to extend our research to quaternary systems. Research and development thus continued to the quaternary systems and beyond.

In mid 1990s, one consortium made an effort to standardize Lead-free alloys. At the time, three alloys were selected—SnAg eutectic, SnBi eutectic, and Sn3.5Ag4.0Bi. As time went on, it became evident that none of these three alloys could offer the performance covering the requirements of versatile products of the industry.

It should be noted that, at the time, the systematic R&D was not driven by any legislation or regulations banning the use of lead.

More than 15 years of systematic research in materials by various OEMs who are at the frontier in Lead-free production serve as the basis for the selection of viable Lead-free alloys. Today, as a result, a short list of viable Lead-free alloys is available to the industry.

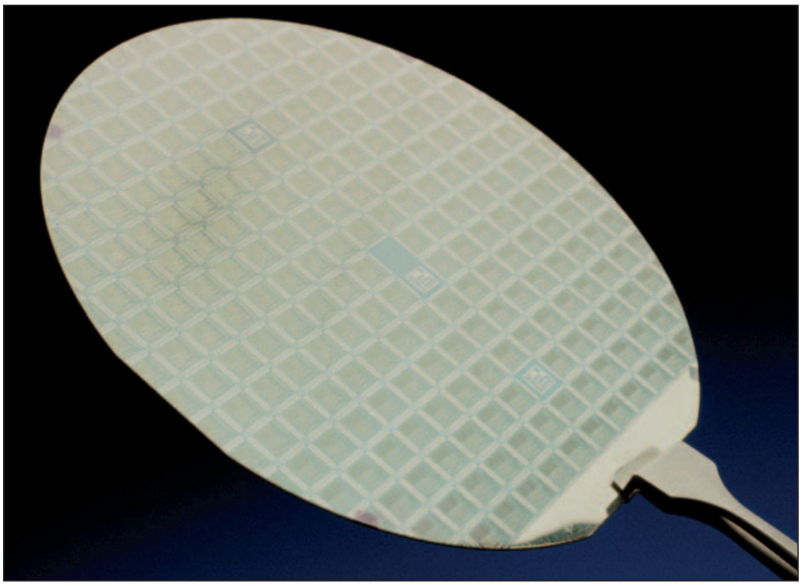
Considering a wide array of assemblies and applications and the inherent "fluctuations" of SMT manufacturing, the industry has a choice from among two production approaches. These approaches are essentially distinguished by the process temperature, which determines the choice of alloy. For SMT manufacturing, the alternate approaches are also distinguished by the process window, namely, the "same temperature" and process window as 63Sn37Pb or a "higher temperature" or a narrower process window.

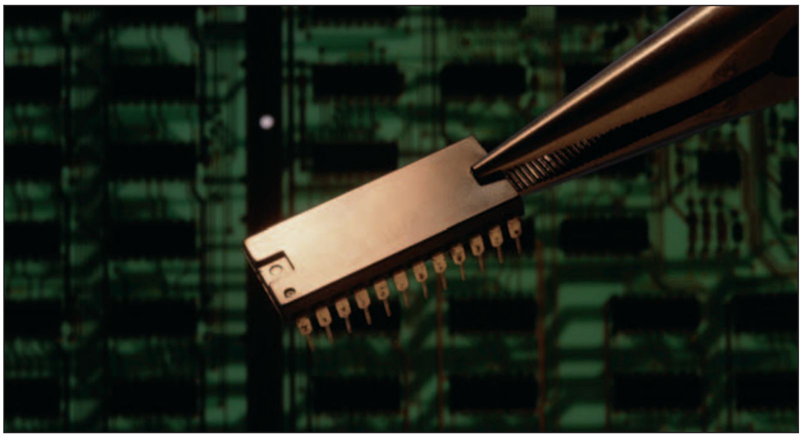
In short, a ternary alloy such as SnAgCu requires a higher process temperature than Tin-Lead. In order to run the existing temperature range, a quaternary alloy is needed (for specifics, refer to two textbooks: "Environment-Friendly Electronics: Lead-free Technology" and "Implementing Lead-free Electronics—A Manufacturing Guide"). On the global market, most Japanese OEMs are quite ahead in producing Lead-free products.

In implementing Lead-free electronics, what is the biggest challenge that the industry faces?

In the global marketplace, the biggest challenge that the industry faces is the confusion of disparate information and lack of integrated knowledge. There is so much fragmented information, notions, misunderstanding and hearsay. With the risk of not pleasing everyone, I am afraid I have to say that many statements were made without true knowledge or understanding of Lead-free technology and manufacturing know-how.

The success of making the shift to Lead-free relies on the ability to separate sound knowledge from the casual remarks, and to keep an open mind. An old saying that says: "The test of a first class mind is the ability to hold





opposing views at the same time, and still retain the ability to function," sums it up well.

In developing pastes and other Lead-free products, what were the greatest technological challenges?

The technological challenges were due to the fact that no ternary alloy is able to meet the characteristics and performance required by a wide array of products. Additionally, no ternary alloy is compatible with existing SMT process conditions.

The development work had to extend to quaternary systems, which bear a higher raw material cost. However, as for the system cost, what really counts is the total cost of ownership for a specific product, which embraces the full product cycle from procurement to production to reliability.

In developing Lead-free electronics, what has been the most pleasant experience?

Throughout the 15-year period of the sustained and systematic research and development effort on Lead-free alloy materials and the associated production processes, one unequivocal consolation is that the alloy material performance is perfectly congruent with the principles of Materials Science and Engineering. Furthermore, real-world production results coincide well with the experience and knowledge that have been learned during the 25 years of existence of SMT manufacturing. This is a great comfort.

What does it take to implement a sound Lead-free production process?

In implementing a new manufacturing system, success is ensured through a combination of solid technological fundamentals, real-world manufacturing know-how, knowledge of the options and the pros and cons associated with each one.

Within the practical constraints established, such as the generally accepted flux chemistry and the SMT infrastructure, the "same-temperature" process needs to be paired with a quaternary alloy. The viable ones include the SnAgCuIn, SnAgBiIn and SnAgCuBi systems. The "higher-temperature" process goes with SnAgCu and SnAgBi systems (SnCu for low-cost wave soldering). These conclusions are not drawn from spotty tests; rather, they are the results of systematic development, evaluation and manufacturing verification and reliability assessments.

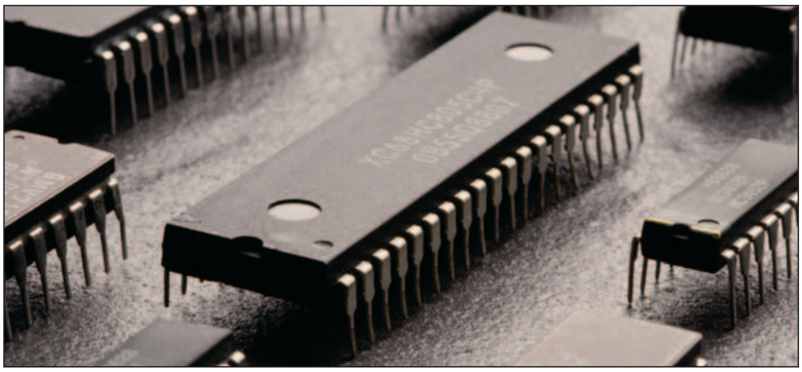
With the understanding of the viable options, the choice should be based on production and reliability requirements.

Considering the numerous offers coming from the many manufacturers of Lead-free products, what specific characteristics do Asahi solders and products have that represent unique benefits for the customer?

Asahi provides technology, manufacturing and business solutions to the electronics industry, focusing on the implementation of Lead-free systems. For the last ten years, the company has made a consistent and persistent effort to develop Lead-free solder materials and processes.

As far as Asahi's products, one of the company's primary missions is to service OEMs and EMSs in converting from Lead-containing electronics to Lead-free electronics by providing a full range of high-performance and high-quality materials without requiring changes in process and equipment.

In order to mitigate manufacturing disruptions and disadvantages, Asahi focuses on "drop-in" solutions for Lead-free reflow production (SnAgCuIn compositions), high fatigue-resistant solder material (SnAgCuIn compositions) and low cost wave soldering material (enhanced SnCu).



Among many production successes, one cited below is an example reported in the Nikkei Shinbum News on October 9, 2004, entitled "Reasons Why Hitachi is Adopting Same-Temperature Type of Lead-free Alloy". [Exerpts: Hitachi has implemented Lead free process in both domestic and overseas manufacturing plants since the end of 2003. The reason the company has been able to do so is because it has managed to manufacture high density PCBs using low melting point lead free solder… Hitachi has selected SnAgCuIn type of solder with a melting temperature of 204°C with 7% In. The company has also decided to use SnAgCuIn Lead free solder in communication and medical equipment as well as for larger PCBs. Hitachi has made the decision to use SnAgCuIn low melting point alloy as its tensile strength, thermal cycling, high temperature aging and other properties have been tested and its long-term reliability has been proven. The company has been prepared to use low melting temperature alloy in products such as communication and medical equipment, where the solder joints must meet the long-term reliability requirements. Apart from SnAgCuIn type of alloy, Hitachi has also tested SnZn low temperature alloy but due to its reliability issue, the idea was finally dropped…Although the industry has pointed out that Indium is a rare high-priced metal, the actual cost increase will only be between 20 to 30 percent. Furthermore, regardless of whether Indium is used, the cost of Lead free will always be higher…. It is not possible to use just one type of Lead free like SnAgCu with a melting temperature of 217 – 220°C. Apart from its temperature, the alloy must possess the original nature of conventional SnPb alloy and its characteristics. Using SnAgCu alloy at high temperature, the increase of the board's surface temperature will result in high temperature distribution across the board, especially for large boards. …Hence with a component temperature increase of +21°C, the ability to withstand such high temperatures is a major concern… Due to these reasons, there are some products that cannot be produced. With respect to such products, the consumer electronics industry which currently uses low melting temperature alloy include NEC, Sharp and Fujitsu, etc, while Panasonic uses SnAgBiIn type low temperature alloy. Thus, the industry is not in the position to standardise. Hitachi adopted such a measure to eliminate the issue related to components and reliability…EU ROHS directive has set July 2006 as the deadline and there is not much time left. Consequently, the industry will have no choice but to prepare to utilise low melting temperature alloy technology].

The increasing integration of electronic functions is creating new types of boards and assemblies - for example PWBs with embedded active and passive components as well as optoelectronic boards – and the market is requiring new types of materials and processes from the materials suppliers. What technological advancements will meet these market demands?

Again, an intriguing question. Several key advancements are of particular interest in order to meet emerging market demands. For example, expanded Silicon technology, needed to produce lower cost and higher performance products; "well-rounded" printed circuit materials possessing controlled CTE, moisture resistance, reduced impedance, increased dimensional stability, increased thermal stability and lower cost; and the materials and processes that can minimise heat exposure, eschew potential heat-related damages during manufacturing, minimise the impact on the environment and lower energy consumption. Certainly, nano-technology will come into play.