INTERVIEW

# Jennie S. Hwang

Jennie S. Hwang is an industry icon in the electronics manufacturing industry. Her distinguished career has encompassed academia, industry, government and she is a former President of the SMTA. Hwang is a prolific writer and author of many reference books, technical articles and columns. Trevor Galbraith interviewed Dr. Hwang about some of the highlights and her upcoming series of columns on Electronic Solder Joint Reliability in Global SMT & Packaging.

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**You have one of the most extensive biographies I have ever read with numerous academic, governance, business and industrial accreditations. Out of all of those achievements, what stands to you as the most memorable?**

My most fulfilling experience in general goes to the opportunities to work with full intellectual rigor and vigor. These include "having it all" – work and family, the ability to moving from the technology arena to university governance to business operation to the global industry.

In global industry, the environmental-friendly electronics has been one of the key challenges over the last three decades, which has concentrated my focus on issues related to the CFC Montreal Protocol that came into force in 1989 to eliminate ozone-depleting chemicals and the EU RoHS (Restriction of Hazardous Substances) that was adopted in 2003 to convert to lead-free electronics. Not being an environmentalist, my approach was purely for technology development and deployment. My sustained effort in these areas has become one of the memorable.

In late 1980s, under the U.S. Defense Mantech Program of the Army Materiel Command (today, U.S. Futures Command) with the goal of reducing the cost and enhancing the reliability of electronics used in weapons, the Program's tasks included improving the scientific basis of process controls used on production lines, focusing on soldering technology and advancing material properties, while addressing the environmental concerns (to make Lead-free). I was invited to participate as an advisor for the Program. This was the "official" start of my work on lead-free electronics.

Since then, the lead-free issue had gone through many ups and downs globally. Some denied the transition at the outset, and many stopped the transition at some point. Nonetheless, our team has never wavered, maintaining a steadfast and relentless effort on the materials research and developing the manufacturing know-how, which eventually harvested patents, licenses and commercial products.

Fifteen years after the EU RoHS Directive was adopted, achieving environment-friendly electronics has become a reality. I feel that our sustained effort is paying off.

My first half-day lecture entitled: "Lead-free Technology for Electronics" was delivered at NEPCON-West in Anaheim, CA in 1988. In addition to continuing lectures through the Professional Development Programs with professional organizations, a dedicated "roadshow" organized by IPC and another dedicated professional advancement course series organized by Blackfox Training and Certification were established to disseminate the lead-free technology to the industry. The 12-part lecture series covers all relevant areas of lead-free technology, manufacturing and reliability. The roadshow traveled to many locations across the U.S. and both European and Asia-Pacific continents over a period of twelve years.

In an effort to share and present the information and knowledge in an integrated form, after countless days and hours of hard work, two books were published on this subject. The first lead-free book, also my fifth book, "*Environment-Friendly Electronics—Lead-Free Technology*," focusing on technology was published by Electrochemical Publications, Ltd., Great Britain in 2000. The second lead-free book, also my sixth book, "*Implementing Lead-free Electronics—A Manufacturing Guide*", focusing on electronics manufacturing know-how was released in 2005 by McGraw-Hill. It is rewarding to receive numerous feedbacks on the "usefulness and value" of the books, columns, and lectures over the years. The upcoming series of columns on Electronic Solder Joint Reliability in *Global SMT & Packaging* will continue to address all relevant areas of lead-free electronics.

**You have endowed a YWCA award for STEM students for 18 years now. There has never been a greater demand for graduate engineers than there is now. What do you think can be done to attract students, and female candidates in particular to engineering and sciences disciplines? And what skill sets do you think the next generation of engineers need to have?**

The next generation engineers, men or women, need to be more adaptable, more flexible with faster response to changes. Abilities to learn and to acquire interdisciplinary knowledge and cross-cutting skills in a timely fashion will become more important to one's value, thus career.

There continues to be additional challenges of being a woman in STEM fields, although significant progress has made in raising the percentage of woman earning STEM degrees and women in the workforce in general. However, the relatively low percentage of women pursuing STEM still persists.

Overall, the environment is much more "women friendly" today than when I started my career. Certainly, women's college education has been on a par. If you look at college graduation, female graduates are gaining higher percentage than male graduates. We have more women finishing higher education and advanced degrees. That is a major stride. But once you get into the workforce, we start to see that women are not predominating, particularly in the more challenging or higher positions. Change has occurred, but true equality has yet to come. At The National Academies / National Research Council, we studied the women in STEM back in 2006. Our findings indicated that "work and family" was a top challenge for women, and we also found that the number of women having a STEM degree entered into STEM field was not on par with the number of women who earned STEM degrees. Further, we found that women who entered into STEM-related professions were not able to sustain long-term work within the STEM field. On the one hand, we all support diversity, but on the other hand, there are disparities.

Having been the only woman in most of my schooling and working environments, from the boardroom to the factory floor to the classroom (I was the first Ph.D. from Case Western Reserve University Engineering School), I do have abundant thoughts and a lot to share. Among others, role models and mentorship can play a role to encourage female students to pursue STEM education and STEM-related careers. As one example, the Oral History archive has established a category for women in STEM to archive the experiences and views from the selected professional women, for the benefit of future women generations. The full transcript of my in-depth interview, which was a joint effort of IEEE and U.S. Airforce, is posted on the IEEE website.

**In materials science, these same drivers are pushing materials characteristics to their limits. What major materials advances will have a significant impact on future electronics hardware, from design to packaging and assembly?**

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I see the top three intriguing areas in materials advances are two-dimensional materials (2D materials); single-layer materials are expected to be capable of offering breakthrough performance in applications, particularly a new generation of electronic devices. In electric vehicle, materials technologies to make higher-performance and/or more economical batteries is much needed. Another area is to advance the basic understanding of quantum entanglement to develop leading materials and technologies, which will drastically impact on semiconductors, photovoltaics, imaging, bio-sensors, and electronic devices.

In electronic materials and devices, tuning 2D materials at the atomic scale opens enormous opportunities to design electronic properties for innovative applications through controlling surface conditions, defects, and the interfaces with other 2D materials. - a forefront research and technology development that could potentially yield breakthroughs, which will exert disruptive forces to the electronics industry.

**How do you think the current trade negotiations will impact electronics manufacturing in the medium- to long-term?**

Indeed the U.S. has "opened up" trade issues in multiple fronts including with China, EU and Americas. Consequently, many other countries are also or will be directly and indirectly affected, which is inevitable in this global economy.

Some believe this is a war - trade war initiated by the U.S.; others believe this is a necessary evil at this point in time. For instance, the North American Free Trade Agreement (NAFTA) was put in force in 1994. After nearly twenty-five (25) years, it is time to revisit this trilateral trade agreement to keep it in line with the current political, economic, social and technological landscape.

What are the main issues on the table to be negotiated, which vary with the country? Among others, some at the top of the list include:

- To reduce uneven tariffs of importing and exporting between countries, e.g., higher tariff when goods entering into Canada or China, but lower traffic entering into the U.S.
- To reduce uneven investment restrictions, e.g., restrictions on the entry of U.S. companies in Chinese market.
- To protect intellectual property.
- To relieve the "forced" technology transfer.
- To balance imports and exports in relation to countries, e.g., steel and aluminum imports to the U.S. from around the world.
- To correct overall trade imbalance.

As the trade "dispute" (that I would like to call it) intensifies, particularly between the two largest economies – the U.S. and China, one main debate is how would this trade fight affect an individual company's bottom line, the US. Economy and the global economy. The U.S. administration has put forth, with much resolve, a large-scale action against Chinese imports under Section 301 of the U.S. Trade Act; reportedly \$200 billion's worth of goods are on the line. Accordingly, many companies and trade groups representing different industry segments argue that tariffs increase the costs of doing business in the U.S., discourage investment, and invite damaging retaliatory actions by the U.S. trading partners.

Against this backdrop, inevitably tit-for-tat trade tariffs are occurring. During this period, some products or industry sectors will experience a down side loss. For example, China as a supplier of many electronic components, parts and products. Despite intense lobbying by the U.S. semiconductor industry, the next round of tariffs on Chinese imports will include billions of dollars' worth of semiconductors and related chemicals/materials. This will trickle down through the electronics hierarchy to the electronics manufacturing.

Presently, the U.S. is enjoying solid economic growth while China's economy shows sign of slowing with downward fixed asset investment and upward unemployment rate, which delivers sobriety to both of the large economies and gives the U.S. a slight edge in negotiations.

Trade negotiations will not reach the end-game in a short time horizon; it will be somewhat a marathon through many rounds of negotiations in the near- and mid-term. In the long run, it is hoped that a higher degree of trade balance would materialize and the related issues would be ironed out, eventually to the best interest and the benefit of all countries in question and thus the global economy.

All in all, the continued talk between countries is helpful. Talking is always better than not-talking at all. And the anticipated upcoming meeting between President Trump and President Xi of China in November put us on a brighter trajectory.

**Autonomous vehicles, medical electronics and other applications are driving further miniaturization of assemblies. Do you see a convergence between SMT manufacturing and Advanced Packaging becoming mainstream in the future and the electronics manufacturing industry is going through a smart-factory revolution at the moment. As the automation of processes and equipment reaches standardization, do you think that mapping the behavior of materials will be the next big challenge?**

As eluded in my answer above, advances and breakthroughs of the new materials design including materials-mapping and modeling will be a grand challenge to the science and technology community in the U.S and across national borders.

In electronics manufacturing, rigidity is out, flexibility is in; stiffness is out, agility is in; sluggishness is out, and swiftness is in. Responding to the evolving new industrial era (we may call it Industry 4.0), delivering customized products with flexible, modular production flow at an optimal economics becomes necessary. Manufacturing companies need to develop a deep understanding of the technologies, translating business objectives into technology roadmaps targeting at operational efficiency. This will be accomplished by leveraging the machine-to-machine communication, machine-to-human interaction, cloud computing and advanced analytics. For instance, intelligent machines can trigger maintenance processes autonomously and are capable of predicting failures; data analytics aids to detect process inefficiencies, thus reducing production cost.

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I cannot emphasize enough that inventory management is imperative to the success of manufacturing operations, and its optimization is paramount to a healthy balance sheet and cash flow, especially for a raw-material-intensive businesses. Companies must keep track and control of both the days of inventory as well as the actual dollar value of inventory. Doing well in this area mitigates the mishap of production outpacing demand as well as eschews the cash flow trap.

Using cyber-physical systems, supply chains will be fully integrated and automated. Cyber physical systems deployed throughout the value chain enable the linkage between data and material flows, creating the complete visibility of the supply chain, in a stationary or in-transit state. This also facilitates the formulation of reliable inventory forecasts, the avoidance of unscheduled downtime, and the timely reaction to unexpected changes in production.

Visibility, traceability, predictability and sophisticated simulations, coupled with speed, agility and flexibility are the underlying characteristics of intelligent manufacturing. The fourth industrial revolution epitomizes "gravitational pull" that is set by multiple and complex drivers as well as crosscurrents—expanded globalization, technological explosion, digital tools, Internet-centric data flow and global competitiveness, among others.

As striding toward the fourth industrial revolution, regardless of a particular business strategy, be it a service provider or an agile niche product producer or a low-cost mass merchandise supplier, success in the era of Industry 4.0 hinges on a comprehensive vision coupled with a compelling business model embodied with a decisive strategy and defined core value drivers. To that end, focus areas for future investments can then be identified. Key efforts are to be made on the collectivity and connectivity of technologies, seamless integration of data, effective use of digital tools, and the vision and continued deployment of new technologies to achieve operational optimization and business excellence.

Achieving a holistic "standardization" that embraces all elements of a true smart-factory still has a distance to go.

**If someone were to give you a blank check to develop a critical product, material or service that would help the future development of electronics manufacturing, how would you invest it?**

I like a blank check, who doesn't!

I will strategically invest it in a niche area in the Artificial Intelligence (AI) arena by making a concerted effort to speedily develop its technology, transition the technology to a useful product/service, to introduce the product/service to the global market.

AI is an enormous field – an engine behind autonomous vehicles, 5G and many other applications! To face the challenges of the AI era, new semiconductor technology will call for innovations to develop a wide array of new processor ICs and memory chips. This is a demanding area in technology and a growing space in business. Recently, the Defense Advanced Research Projects Agency (DARPA) has created $1.5 billion fund to work on advances in chip technology, dubbed the Electronics Resurgence Initiative. The funding is an exorbitant increase in hardware budget, focusing on chip design, architecture, materials and integration. Also, leveraging on machine learning to substantially speed up new chip design. New chip designs will drive the down-stream manufacturing including packaging and SMT assembling.

Today artificial intelligence (AI) and machine learning (ML) and its subset deep-learning have become common "every-day" words, however the present reality and future potential are yet to evolve. As a result, on one hand, there has been the sheer excitement about evolving intellectual and dexterous capabilities to improve our lives, businesses and security; on the other hand,

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there have been mere trepidation about unknown and/or unintended consequences.

The ability to incessantly chew through any amount of data and unlimited combinations of variables, parse data, capture knowledge, and make a deterministic or predictive model makes machine learning surpass human capacity. Being unconstrained by the preset assumptions of statistics can also surpass human analysts ability to make predictions with higher degrees of accuracy. Its incessant processing power has enabled AI and will continue to make inroads. A variety of applications have employed AI, to different extents, ranging from financial services to business operations to military prowess.

In business, AI/machine learning can apply to every function of doing business. It is going to play an impactful role in business intelligence and analytic solutions and creating the knowhow to rapidly transform learned data into action to create competitive advantage. AI will also help Internet of Things (IoT) data analysis in data preparation, data discovery, predictive analytics, geo-spacial and location. One example is to develop management processes that build the most effective teams of judgment-focused humans and prediction-focused AI agents.

The increased workload and almost unlimited processing power propelled by AI/ML will require the most advanced semiconductors, packaging approaches and manufacturing prowess ever developed in order to reach the interconnect density needed.

Going forward, to enable AI and its building blocks—machine learning, deep learning, neural networks, new chips (processor and memory), new architectures as well as the system design that deliver low power-consumption, high performance, low latency, high bandwidth and fast speed will be the ever-demanding targets. Only by fulfilling these performance, inference processing in lieu of traditional program processing can be achieved. Equally demanding is to assess and optimize for different types of AI workloads - a business case to justify building custom-designed chips (e.g., ASIC).

In the AI era, AI talent is key, yet in short supply with demands exceeding availability. As global competition develops and new technologies continue to become available, who will have the upper hand remains to be seen. Up to now, the U.S. semiconductor industry is still in a leading position in AI hardware. This is an on-going, global competition among scientists/engineers, companies and countries. There is a long distance to go before reaching the full potential of AI to truly mimic human cognitive capabilities and functions, e.g. asking "right" questions at the "right" time, solving "right" problems in real-time.

AI is creating a new paradigm. Ultimately, to best pair human-machine intelligence, we should expect synergistic performance and capability by integrating judgment-focused humans and prediction-focused AI agents; and AI should be destined to augment human cognition, capabilities and capacities without causing ethical and social issues. That is the real value and virtue of human-machine intelligence-teaming!

Back to that blank check, in identifying new opportunities to use that blank check, I will incessantly asking myself the questions: What will be the impact? How to make an impact? What is next?