Korea's PCB Industry
Raises the Standard

Korean PCB manufacturers are building everything from flip-chip packages to thick telecommunications boards. Will these fabricators keep their flags flying high, especially as they face stiff competition from Japan and China?

By Steve Gold and Bob Neves

In both war and commerce, Korea has often found itself caught between two important neighbors—China and Japan. Today, the country's printed circuit board industry finds itself dealing with these two countries as well. Sandwiched between high-tech Japan and low-cost China, the Korean industry tries to take the best of both nations, creating its own niche as a higher technology, higher volume circuit board-alternative.

The Korean Printed Circuit Association (KPCA) estimates approximately 80 percent of its members are clustered in the Ansan/Incheon area, about 40 miles west of Seoul (Incheon is the home of Korea's international airport). Dr. Hayao Nakahara of NT Information suggests the Ansan/Incheon area is akin to "Taoyuan in Taiwan, where 80 percent of PWB makers are centered around."

Some of the larger manufacturers, however, have factories outside the Ansan/Incheon area. These manufacturers include Samsung Electro-Mechanics, with plants in Daejeon and Busan, ISU-Petasys in Taegu (which will appear in the second part of our series), and LG Electronics, Cosmotech and Simmtech in Cheongju and Osan.

Late last April, *CircuiTree* visited some of the Korean peninsula's larger PCB manufacturers and suppliers. We got to see why Korea is emerging as a printed circuit board contender, and also better understood some of the problems it faces: low-cost Chinese competition, increasing supply costs, and a non-stop climb up the technology ladder. This first article in our two-part series will focus on Korea's rigid board market and three of its strongest players: Daeduck, Samsung Electro-Mechanics and LG Electronics (LGE).

The Korean PCB Market

Before one can understand the individual company strategies, one must understand the Korean manufacturing landscape as a whole. Thirty years ago, the PCB industry was a government-supported "key" industry. Only independents were allowed to build boards. Thus, companies like Daeduck—Korea's first dedicated PCB manufacturer established in 1972—and Korea Circuit Company (KCC) enjoyed a closed domestic market.

In the 1980s, the Korean government decided to open up the PCB market—and everything changed. "The government felt that this business was already an important part of the electronics business, however, because of the government restricted conglomerate companies from participating in the PCB industry, companies … were prevented until 1989," explained O.K. Son of CSS Technologies Co. Ltd.

Once the government relaxed its restriction, conglomerates like Samsung Electronics and LG Corp. were allowed to produce circuit boards for internal use. "When other competitors entered the PCB industry, it was 'inside-user' only," explained

Daeduck Deputy Sr. Manager B.R. Ahn. and Executive Managing Director Hee Joon Lee

Daeduck's Hee Joon Lee. "For example, [Samsung] could only sell to itself. But [eventually] they started to … sell outside the group." During the 1980s, the Korean government allowed large OEMs to manufacture PCBs for both internal use and merchant markets; Samsung and LGE quickly joined Daeduck and KCC as the largest Korean circuit board producers. By the mid-1990s, however, the larger conglomerate companies were allowed to compete with the smaller shops, and it's since been a free market.

Korean PCB manufacturing success is dependent on the country's global OEMs. Cellular phones, memory modules, flat panel and plasma displays, and automobiles are the Korean fabricator's domestic end markets, with familiar customer names like Hyundai, Kia, Daewoo, Samsung Electronics, LG Corp., and Hynix. Yet above all, Samsung and LG are the engine that drives the domestic circuit board industry, particularly with their dominance in cell phone and flat panel displays. Interview after interview, a common theme emerged: Korean fabricators are manufacturing the large majority of their circuit boards for one or more of these Korean OEMs. Though export numbers are growing at many of the companies we visited, Korean OEMs need cellular phone PCBs and memory module substrates. When Samsung and LG are competing for global superiority in cell phones, Korean fabricators are busy helping them. When Samsung and Hynix together produce nearly half of the entire global supply of DRAM, Korean fabricators are busy helping them.

In every interview we conducted, Samsung, LG and Hynix were mentioned as top customers. Lee suggested that "having big customers like Samsung and LG will be a big benefit for us against China, and even Japan."

But Korean OEMs are more than just board buyers. Because these OEMs have not divested themselves of PCB assembly operations and PCB engineering skills, these conglomerates are much more familiar with circuit board manufacture then many of their counterparts in western nations. "In Korea, conglomerates don't use EMS companies. They operate their factories directly in-house. That's different from American companies," stated Lee.

Japanese printed circuit trends also heavily influence Korean OEMs. "Japan introduced 1.3 million pixel cameras into hand sets. Korea followed six months later. Now, Japan is introducing 1.8 million pixel cameras for handsets. Once again, within six months, Korea will follow this trend," said Dr. Nakahara. Taking the lead from their OEMs, Korean fabricators also follow Japanese circuit board technology closely. Many of the companies we visited had Japanese expatriate engineers involved in the day-to-day operations of their respective facilities. Taking their high-tech lead from Japan means Korean PCB companies are not afraid to spend on R&D. Quite a bit of income is spent on R&D looking at new ways of processing the boards, improving the yields, and bolstering quality. This willingness to spend on new technology is compounded by the Korean government's generous depreciation schedule. "The depreciation in Korea is very good," said KCC Chairman Mr. Song. "You're able to depreciate 50 percent of your investment in the first year, and in the second year, another fifty percent. So by 2.5 years, you've almost totally depreciated your investment." Song said that because of this depreciation schedule, his company can put 20 to 30 percent of its sales revenues into new equipment. "The only way we could do this is because of the depreciation law. Otherwise, it would be like the U.S. or Japan, making it difficult to invest in new equipment," Song said.

Another important influence on Korean circuit board production is China. Because their neighbor excels in low-cost production, Korean fabricators have migrated up from standard multilayer products to higher layer count boards. Build-up multilayer microvia production has boomed in particular. The chief end market for these high-density boards is cellular phones. Dr. Nakahara estimates that Korea produced about 130 million handsets in 2003. Samsung Electronics (55 million), Nokia Korea (35 million), and LG Electronics (28 million) led the way. "It is estimated that the top Korean build-up multilayer board makers produced about 110 to 115 million pieces for the production of [over] 130 million handsets," said Dr. Nakahara. "The total build-up multilayer board production in Korea in 2003 is estimated to be a little more than $650 million."

Daeduck

We met Managing Director Hee Joon Lee at Daeduck's Ansan industrial complex. Founded in 1972, Daeduck mainly serves the wireless and telecommunications sectors. Its PCBs are found in cell phones, microwave transmission equipment, and telecommunications infrastructure equipment. It also produces

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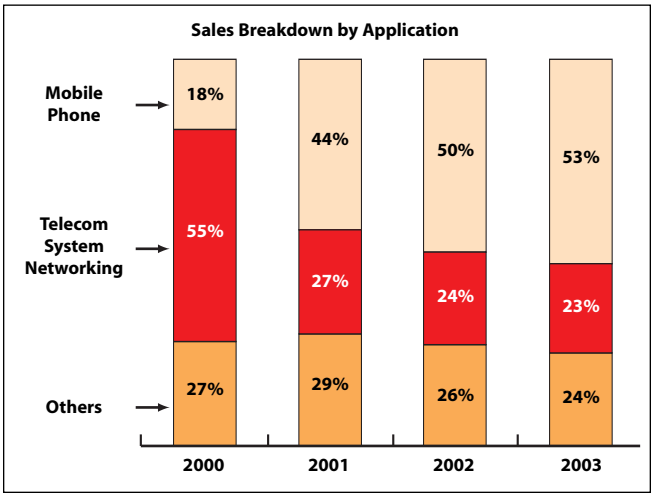

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boards for plasma display panels (PDPs) and liquid crystal displays (LCDs)—another surging Korean end market.

Daeduck produces a wide range of PCBs in three different plants with three separate product mixes. Plant 1, the site of our visit, produces fourteen- to 30-layer complex PCBs and backpanels. Plant 2, the Thin Laminate Board division, makes IC memory modules (impedance-controlled semiconductor substrates) and LCD modules. This plant is almost entirely dedicated to Samsung and Hynix. Plant 3 is the HDI division and produces build-up multilayer PCBs and some rigid-flex boards earmarked for cellular telephones. Daeduck uses 45 laser drill machines between the three plants.

Though many industry analysts have written off cell phone board production in every country but China, Lee said this is not the case in Korea. "This year, business is better than last year. We have improved around 30 percent. The cell phone area is especially picking up." In fact, Lee said that cell phone board production has increased from 18% in 2000 to 50% of Daeduck's total business in 2004, dedicating Plant 2 entirely to this sector. Three customers account for about 80 percent of the orders here: Samsung, Nokia Korea and Curitel.

"In Korea, conglomerates don't use EMS companies. They operate their factories directly inhouse. That's different from American companies."

Daeduck Executive Managing Director Hee Joon Lee

Realizing the threat China poses to its business, Daeduck is working at strengthening its high layer count business. "Daeduck Electronics has suffered from revenue loss in [its] high layer-count multilayer board business, but fortunately, the strong demand from cellular phone industry in Korea and Daeduck's early entry in build-up … technologies has compensated the loss," commented Dr. Nakahara.

Lee explained that reduced high layer count revenues stemmed from its lack of customer diversity in that space. "Up to now, Nortel was mainly our [complex PCB] business," he said. "Now, we are chasing business from Cisco." Daeduck also keeps close tabs on its three plants by making each an independent business unit. According to Lee, "Each division—all three plants—are operating independently for profit and loss purposes. In theory, we are the same company, but realistically each plant is independent—each is a different profit center."

Dealing with China

Korean companies are split on how best to deal with China, mainly on the point of whether or not they need to manufacture boards there. Does a company risk losing its intellectual property by manufacturing in China? Or should it risk it to take advantage of the country's cheap and plentiful labor? Daeduck is one of those companies that has started a "sister company" in China. Located in Tianjin, Daeduck GDS is currently running single- and double-sided product there while Daeduck keeps its intellectual property in Korea. The boards produced in China stay in China "for the local market," said Lee. Even though Lee used the term "sister company" to describe the China facility, it is run very much like a joint venture. "We invest in that facility, so we have some say in how it will run," Lee explained. Daeduck also runs a small Philippine facility that does about $30 million in automotive PCBs, most of which are sent back to Korea for domestic consumption.

To date, Daeduck—like the majority of Korean companies we met during our ten days there—has no plans to move higher technology out of Korea. "Our multilayer and cell phone business will be maintained in this country, [along with] our semiconductor business," affirmed Lee. "China's operation is limited in a certain area; we will maintain our technology and automation in Korea. [Companies like Multek] didn't put all of their technology in China. They couldn't. CMK China is different from the one in Japan." Plus, logistically there is little difference for a Korean company whether it is operating in Korea or China. The real difference is cost of labor.

Lee explained that Korean manufacturers, like those in other industrialized nations, must pay close attention to government labor laws and industry labor unions. "We have to consult with our labor union. And it's controlled by the upper-level, nationwide labor union. So even though we make some compromise, the upper-level [union] may want more." While Lee said Daeduck has been "fortunate" in its labor union dealings, there is always a chance that organized labor could cause operation expenses to raise despite market conditions.

Automation also plays a part in the competitive equation. Since Korean labor rates are considerably more than most Asian nations, domestic PCB manufacturers like Daeduck continue to automate their mass production processes. Even though Daeduck is one of the more automated Korean PCB manufacturers, Lee admitted "we continue to increase our portion of automation because of labor costs." Still, in terms of mass production, Daeduck and other Korean factories are not far off from competing with the Japanese.

Automation also fits well with the end markets many Korean companies are pursuing: packaging and rigid-flex production. "Packaging will be rapidly improving," said Lee, "because without semiconductors, how can we make any electronics product? So, packaging has much potential. Also, rigid-flex will be an improving area. And also, we will prepare for embedded boards. All these processes require automation."

Thus, Korean OEM customers like Samsung, who are seeking higher end mass production, turn to Korean manufacturers. In Daeduck's case, they follow a customer like Samsung from mobile phone circuit boards into memory packaging. With Samsung and Hynix owning more than 50 percent of the global market, Daeduck is assured a dependable local customer base—as long as Korea's domestic market stays healthy.

Samsung Electro-Mechanics

Samsung Electro-Mechanics Advanced Circuit Division opened in 1989, and it produced its first HDI boards in 1991. After establishing an R&D center in 1995, Samsung began both BGA

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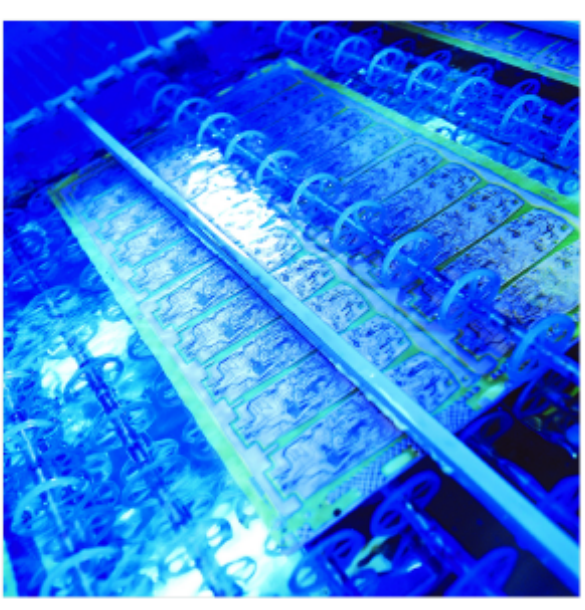
production and cell phone PCB manufacture in 1997. Today, the company is divided into three product divisions: BGA, HDI and flip-chip BGA made in two different plant locations: Daejon, and Busan, respectively. In HDI, SEM averages 900,000 square feet per month, in BGA production about 400,000 square feet per month, and in flip chip approximately 70,000 square feet a month (though packaging square foot measurements are misleading when compared to HDI).

In his notes on the company, Dr. Nakahara said Samsung "is beefing up build-up … technologies, both in the fields of IC substrate and motherboards…." Samsung ACI Division Vice President Dr. B.Y. Min said that multilayer capacity may be converted into substrate packaging applications. Samsung began flip-chip package mass production toward the end of 2002.

In fact, Korea's *Electronic Times* reported that Samsung is working hard to become the world leader in the printed circuit board substrate market with its flip-chip BGA substrates and other chip packages. Samsung reportedly is shooting for about $760 million in PCB substrate sales in 2004. "To achieve this goal, the company will invest 162.5 billion won this year … to raise production capacities of flip chip BGAs, chip scale packages and plastic ball grid arrays at its plants, including the third line in Busan, which is under construction," the *Electronic Times* report surmised. The line is scheduled for completion this September.

Samsung's strategy is entrenched in its research and development work. Dr. Min said his company does their own R&D and "leads customers" to Samsung's technology advancements. It also tries to perfect technology. In the case of flip-chip packaging, Dr. Min affirmed that his company's R&D drive targets many different package substrate technologies, including flip chip packaging.



An up-close look at Samsung's multilayer PCB etching process.

Samsung's substrate loading process.

"We are not the first maker of flip-chip substrates," he said, "but we are working hard to be the best quality flip-chip supplier in the world." Samsung has also taken this R&D drive into its build-up multilayer and stack-via PCB production processes, creating a "novel stack via process" called SAVia (Samsung Any Via) and a rigid-flex hybrid PCB called SEMBrid (Samsung Electro Mechanics & Hybrid). Dr. Min said the SEMBrid PCBs feature high-density for SMT components, along with good SMT quality and strong heat resistance properties.

Samsung is developing other "future technologies." Embedded function technology offers another interesting insight into the company's R&D-driven competitive strategy. Samsung management believes higher functional boards, like embedded PCBs, will play a large role in future PCB technology. Thus, development in these areas has occurred over years, rather than months. Samsung does not wait for the customer to order embedded circuit boards before developing the technology. "[Embedded technology] is on our roadmap. That's why we are working on it," Dr. Min asserted. As evidence of this embedded board drive, Samsung unveiled SEMOpto at last April's KPCA Show. SEMOpto is an optical fiber and waveguide embedded PCB designed to transmit high-speed optical signals without signal loss. It will provide high-speed, large capacity data transmission for board-to-board interconnections, with optical wavelengths ranging from 850–1,300 nanometers. Though not ready for mass production, Samsung is banking on it as a technology of the future.

Why work on developing technology that customers do not yet even know they need? Dr. Min believes, "The cycle time for investment in the PCB industry is very long. Whenever we need it, we need one to one-and-a-half years to start from the factory to supplying the actual product to the customer after qualification. So we have to look in advance."

Similarly, Samsung is attempting to use process technology to minimize cost increases associated with rising supply costs. "The increasing prices of copper and epoxy have affected us, as well as … the shortages of materials. However, we are trying to

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Samsung ACI Division Vice President Dr. B.Y. Min.

overcome those things by technical means," explained Dr. Min. When asked to describe these technical means, Dr. Min said Samsung is interacting more frequently and more closely with materials suppliers to ensure supply of various products to customers.

And what about competing with both China for low-cost PCBs and Japan for its high-tech business? Dr. Min believes the Korean PCB industry can compete with both Japan and China on their terms. He acknowledges Japan has developed technology advantages, and he also recognizes China's large labor force as an advantage that makes it an attractive place for mass production. So the company depends on innovation to keep its customer base happy. "Samsung as a company is developing new processes and new applications, such as rigid-flex PCBs." Called SEMBrid, these boards were developed in Japan but "we revived it for cellular phone applications," said Dr. Min.

It seems competition from Chinese manufacturers does not concern Korean fabricators as much as all the new Chinese manufacturing capacity being built. Still, Dr. Min cautioned that an oversupply situation is being created by companies moving into China at breathtaking pace. "The global economy's health is moving up and down very rapidly," he commented, "and yet the PCB industry has [built] so many more facilities." To protect itself, Samsung will avoid getting caught in the price wars that often accompany excess capacity situations.

LG Electronics

Korean conglomerates might struggle in the shadow of Japanese technology, but their take on the vertical integration business model is enlightening. LG Electronics epitomizes the Korean philosophy of "vertical but independent" integration—a sort of virtual vertical integration that facilitates the sharing of ideas, roadmaps and industry information, but holds no promise of supply being bought by a "sister" company,

The company was established in 1958 as one of Korea's first consumer electronics companies. Today it has grown to 55,000 employees worldwide in 73 subsidiaries around the world. The parent company wants to become a "Top Three" global electronics company by focusing on three core competencies: digital appliance, digital display and media, and telecommunications equipment. This was evident by company slogans pasted in almost every room we visited.

The company's Digital Microcircuit division began in 1971 as an internal single-sided board shop. After reaching a technical agreement with AT&T in 1983, LGE began producing multilayer boards. LGE commenced BGA substrate manufacture in 1997, and it started making HDI cell phone boards shortly thereafter.

LGE began mass production of backplanes last year. "We are the only supplier in the Asian area to make these big, thick boards

LGE MLB Production Engineering Group Manager Hoon Jang and LGE General Manager of Overseas Sales & Marketing B.G. Kim.

in mass production.... We have achieved a yield target of approximately 85 percent," said B.G. Kim, general manager of overseas sales and marketing. "For backplanes, we build up to 38 layers in mass production, with eight millimeter thickness. Our maximum panel size is 24 by 30 inches," added MLB Production Engineering Group Manager Hoon Jang. Both gentlemen were proud of the fact that LGE is currently fabricating boards using Sanmina's buried capacitance technology; the company is in the process of renewing its contract with Sanmina to continue the license.

In 2002, LGE enjoyed sales revenues of $265 million; it earned $305 million in 2003 producing PCBs for customers with names like IBM, HP, Sun and Lucent. Still, LGE's best customer is, well, itself. "We have the captive market in LG. That's why we increased our total capacity for cell phones. Now it's about 5 million pieces per month, but our target is 6 million pieces per month," said Kim. Sixty percent of the boards made by LG are for domestic use. Of that number, about 70 percent are consumed by LG for its end-use products. LGE gets no guarantee of any specific

portion of its parent company's business; it must remain competitive in terms of price and quality to keep its parent company's business. "Nobody guarantees a certain level of volume, but our captive [position] is one of the strong points of our business. They guarantee us some minimum volume, so it's easy to make a production plan based on monthly or quarterly [projections]."

Recognizing that all its eggs are in its parent's basket, LGE would like to diversify its customer base. "In Korea, telecomm is now booming," said Kim. "But our future target focuses on global markets. Even though we have LG [as a] captive market, it is a small amount compared to the [potential] global market."

LG follows a much more vertical model then many Korean OEMs. Where Samsung is treated largely as a sister company, LGE gets some capacity promises from its parent company. Downstream, Samsung has no sister companies involved in materials, while LG owns materials subsidiaries that supply LGE. "We have LG Cable [making] copper foil. We have LG Chemical [making] CCL. So from copper foil to CCL, CCL to PCB, it's a real integrated system," explained Kim.

Such integration also helps during periods where PCB materials are in short supply. "We have a very stable supply system for raw material," continued Kim. "For example, at the end of last year, most PCB shops had trouble to get raw material from their suppliers. We didn't have any problem during that time." According to Kim, 70 percent of LGE's laminate material comes from LG Chemical.

Raising the High-Tech Flag

LGE will spend $10 million this year on increasing cell phone board capacity at its Osan plant. This capacity investment is aimed at increasing production that utilizes NMBI technology. Jang said he expects some 435,000 NMBI cell phone boards to run through his Cheongju plant this year—next-generation cell phone boards for LG. "We are also applying the NMBI process for camera modules, RF modules, and memory modules. We have several versions of the NMBI process," explained Jang.

Such a foray into a difficult Japanese build-up technology surprised Dr. Nakahara. He said, "A surprise at LG Electronics when [I] visited its Cheongju HDI plant is the usage of NMBI technology, which LG licensed from Japan's North Corporation.... LGE is using this technology to produce between 1,000 and 2,000 m^2 of ... boards.... [LGE] will use internally developed NMBI technology, which forms bumps by plating, for mass produced handset boards and intends to use North version of NMBI for flex and chip substrate production."

Another technology LGE is developing is its rigid-flex multilayer board for navigation systems. These boards are twelve layers, with four-layer flexible circuit pieces. Though not built in large volumes today, these could be lucrative products in the next couple of years.

Much though LGE is climbing the technology ladder, how will China affect its strategy? "I would say this is an unstable situation for every PCB shop in Korea," commented Kim. "We are in the middle. Technology-wise we are better than China, but our prices are higher than China and less than Japan. So some major customers [overseas] think about LGE like we're part of the Taiwanese and Chinese market, because we are located in Asia. But finally they find we are technologically more capable—not less than the Japanese, especially in backplane technology. And only Ibiden makes higher layer counts than LGE." Jang concurred, saying, "I believe our technology is very close with big Japanese companies, but our labor price is less. Yet we have higher technology than China or Taiwan."

LGE has a Chinese strategy in place, and yet it plans on maintaining higher ground in technology. "Under ten layers, we don't have any customers," remarked Jang. "That's why we're focusing on the high end market in China.... We are very focused on the handset and network systems. These [are] two very high-tech [markets]." Where LGE differs from some other Korean companies is in its Chinese manufacturing plans. "About three years ago, we decided not to [manufacture] in China," Kim said. "At the time, we decided ... only the labor cost is low. But power supply, water, major raw materials—there are many difficult points. That's why we [increase capacity] here in Cheongju."

Kim explained that since his company focuses on no products below fourteen layers, it is only necessary to have Chinese partners. "One customer may have many part numbers, from low to high layer count.... We can still purchase low layer count [for less than] our manufacturing costs." Thus, LGE outsources its four- and six-layer boards to Chinese partners, a fairly common Korean practice according to Kim. "There are so many PCB shops that can make the low layer count boards—four to six—with a very low price, and then we can control the quality before shipping to our customer," he said.

"We are in the middle. Technology-wise we are better than China, but our prices are higher than China and less than Japan."

LGE Overseas Sales & Marketing GM B.G. Kim

Only the Largest Thrive

Though our visit to Korea affirmed that the market is growing, it is still dominated by the largest companies. Dr. Nakahara observed, "There are approximately 100 PWB makers in Korea, but only about 30 of them belong to KPCA.... The annual sales revenues of small size makers are probably less than $5 million. Therefore, the dominance by the Top 10 over Korean PWB shipments will continue at least in the foreseeable future."

Next month we'll return with the second part of this series. We'll examine Korea's blossoming flexible circuit industry, including a look at the Korea Circuit Company, a rare operation that mixes rigid production with a flexible circuit business that's one of the fastest growing in the world. We'll visit Young Poon, a flexible manufacturer that's one of Korea's leading flexible circuit manufacturers. We'll also take a look at a Korean fabricator that could become more familiar to western competitors in the future—ISU Petasys. Finally, we'll look at the growing Korean supplier base—and whether or not it can support the fast-growing domestic industry. **CT**

We cannot express enough gratitude to One Son of CSS International for his help in setting up these interviews and planning our 10-day investigation of the Korean industry. Thank you very much, One, for your help, your camaraderie, and your keen understanding of Korea's PCB industry.