China's Compound Semiconductor Industry: The Impact on Global Manufacturing

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Abstract

The economic rise of the People's Republic of China is having a significant impact on the global economy far beyond its shores. The potential impact this may have on the manufacturing of compound semiconductor devices is reviewed. Particular emphasis is placed on parallel development in the broader Asia region and the infrastructure China already has in place. The successes, as well as failures, to date are also presented.

INTRODUCTION: ASIA AND COMPOUND SEMICONDUCTORS

The Compound Semiconductor "Industry" actually consists of a number of different market segments. For the purposes of this paper six distinct market segments are considered part of the broader Compound Semiconductor Industry; specifically:

1) High Brightness LEDs (spec: GaN-based and InGaAlP-based materials)
2) Telecommunication laser diodes (primarily InGaAsP-based)
3) Optical storage lasers (AlGaAs-based for CDs and InGaAlP-based for DVDs)
4) Electronic Devices (e.g. GaAs, InP and GaN-based FETs, pHEMTs, HBTs, etc.)
5) Solar Cells (non-silicon, primarily for satellites, although terrestrial applications are emerging)
6) Conventional LEDs (spec: GaP-based and GaAsP-based)

Since this last market segment (conventional LEDs) is of declining importance it will not be considered here.

Japan, the USA and Europe led the world in research and development of these compound semiconductor-based devices in the 1980s and early 1990s. Since the mid-90s other Asian regions, such as South Korea, Taiwan and South East Asia have developed (or tried to develop) a significant industrial infrastructure to produce these devices. Some examples include:

1) The development of a massive infrastructure in Taiwan for production of HB LEDs, including everything from epitaxial wafer production to packaged lamps and systems. Significant infrastructure also exists in South Korea, and Malaysia is home to off-shore packaging facilities for some of the major LED producers (specifically Lumileds, OSRAM and Avago [formerly Agilent]) as well as local companies.
2) Significant investment during 1999-2000 in both Taiwan and South Korea for the manufacturing of electronic devices, both epitaxial wafer foundries and device processing. Most of this investment did not bear fruit, with much of the epitaxial wafer capacity converted to production of HB LEDs. Some device processing companies, such as WIN Semiconductor in Taiwan, have done well and continue to operate.
3) Some investment in the late 1990s for production of laser diodes, both for telecommunication as well as optical storage. The industry for telecommunication lasers in Asia suffered with the global telecom meltdown in the early 2000s. Japan still leads the world in the product of optical storage lasers, given its large vertically-integrated companies producing CD and DVD players, although some production now exists in South Korea, at companies such as Samsung and LG.

THE RISE OF CHINA IN THE GLOBAL ECONOMY

Much has been written of China's rise in the global economy, beginning soon after the Cultural Revolution ended in 1976 and China opened up its economy in the 1980s and 1990s. China's GDP has been growing at ~10%/year for nearly two decades, and it is has the largest population of any country. It dominates the world in production of toys, shoes, bicycles, and is becoming increasing important as a production base for a variety of different products, ranging from textiles to home appliances to semiconductor chips. It has a large infrastructure of advanced IT devices, ranging from mobile phones to computers and internet users. Its impact on the global economy is substantial, both as a manufacturing base and a consumer of raw materials. And, unlike Taiwan but similar to Japan, it is starting to product companies with regional and global brand names that will compete in a variety of different technologies and markets, from home appliances to computers and electronic devices.

CHINA'S HISTORY IN COMPOUND SEMICONDUCTORS

China boasts a large infrastructure of research institutions, including leading universities and government research laboratories. These universities produce a large number of well educated engineers and scientists, from bachelor degree to Ph.D. level. The government research laboratories, which were primarily focused on defense-related applications before the 1980s, have become increasingly interested in consumer-oriented applications,, with an eye to generating income by spinning out new companies to pursue commercial markets.

These universities and laboratories have been researching compound semiconductors since the 1980s. Initially this work was done on small, relatively crude, homemade MBE, LPE and MOCVD systems. However, since the ending of CoCOM restrictions on the export of advanced technologies at the end of the Cold War, this research has become increasingly advanced. Many universities and research laboratories now have state-of-the-art compound semiconductor research facilities, and have been active in the creation of new compound semiconductor-based companies.

CHINA'S FUTURE IMPACT

China has conducted research and development in all six areas of compound semiconductor manufacturing identified above. In the mid 1990s various government research labs and companies acquired manufacturing systems targeting all six compound semiconductor markets. These universities and research laboratories have developed expertise and technology in all these areas. There is a large amount of capital available in China today, spanning from venture capital to private companies (e.g. construction or other low-tech enterprises) to regional governments in search of high technology start-ups in which to invest. The combination of advanced technology and abundant investment capital has created numerous public-private partnerships to create a variety of new high technology enterprises. New start-up companies have been spun-out or created to pursue all aspects of compound semiconductor manufacturing.

However, these enterprises have had very limited success to date. Many of these companies have faced a variety of challenges, including a lack of transparency, difficulties in going from R&D results to stable production, quality control, and a basic lack of commercial success and profitability.

The one market segment which may serve as an exception to this experience is that of HB LEDs. China already is home to a very large LED packaging industry, with estimates ranging from 600 to 1500+ different LED packaging companies (albeit most of them small family companies, but with some notable exceptions). Most of these packaging companies have a relatively low technology base; mainly focused on production of low end 5 mm lamps and other commodity products. However, some of these companies are increasing pursuing more advanced packaging types, such as high power LEDs (>0.5 watt input power).

China has also created a significant number of MOCVD-based LED epitaxial wafer and chip companies. Some of the larger ones include:

1. Lumei Optoelectronics
2. Shanghai Rainbow Optoelectronics
3. Shanghai Blue Light Technology
4. Xiamen Sanan
5. Fangda
6. Podium

These companies have all raised significant capital (ranging from US$10-50M each), and have built large state-of-the-art manufacturing facilities. All produce significant numbers of either GaN-based and/or InGaAlP-based HB LED chips. However, it is debatable that their production devices have yet to reach "world class" levels, and it is believed that none have reached true commercial success to date (e.g. profitability).

However, it is believed by some (particularly the author) that China will be on the "bleeding edge" of the Solid State Lighting Revolution in the next 5-10 years. Deployment of LED-based lighting systems is already significant, mainly for architectural lighting, and is readily visible upon a visit to any major city in China today. With a number of factors driving adoption of LED-based lighting in China, including a need to temper the fast-growing consumption of electricity, new green-field applications in the many new buildings under construction, the Beijing 2008 Olympics, and national and regional pride, it is believed that China will have a large domestic consumption of LED-based lighting systems. How this domestic demand will impact the commercial success of these China-based LED companies is yet to be seen.

CONCLUSIONS

A model of success in the compound semiconductor manufacturing of HB LEDs could have an impact across the other compound semiconductor segments as well. China is creating leading companies in the production of CD and DVD systems, cellular phones and infrastructure, telecommunication systems, and satellite technology. The confluence of a growing economy, a large supply of well-educated engineers and scientists, advanced research labs, plentiful investment capital, and entrepreneurial spirit and a growing domestic demand for advanced compound semiconductor devices could have a huge impacts on China's industry – and with that, the world's.

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ACRONYMS

LED: Light Emitting Diode
GaN: Gallium Nitride
InGaAlP: Indium Gallium Aluminum Phosphide
InGaAsP: Indium Gallium Arsenic Phosphide
AlGaAs: Aluminum Gallium Arsenide
CD: Compact Disc
DVD: Digital Versatile Disc
GaAs: Gallium Arsenide
InP: Indium Phosphide
FET: Field Effect Transistor
pHEMT: pseudomorphic High Electron Mobility Transistor
HBT: Heterojunction Bipolar Transistor
GaP: Gallium Phosphide
GaAsP: Gallium Arsenide Phosphide
HB LED: High Brightness LED
GDP: Gross Domestic Product
Ph.D.: Philosophiae Doctor (Doctor of Philosophy)
MBE: Molecular Beam Epitaxy
LPE: Liquid Phase Epitaxy
MOCVD: Metal Organic Chemical Vapor Phase Epitaxy
CoCOM: Coordinating Committee for Multilateral Export Controls
R&D: Research and Development