

# China's Fast Growing Role in the Future of Compound Semiconductor Technology and Manufacturing

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## Abstract

In the past decade, China has emerged as a major player in the field of Compound Semiconductor (CS) technology and manufacturing. Growth in all aspects of the CS industry in China, from crystal growth to device (optoelectronic, photovoltaic and electronic) fabrication and packaging, has set the stage for a very solid foundation for a sustainable and healthy growth rate. This paper will outline the main areas of growth, ranging from fundamental research to high volume production and associated development in intellectual property.

## INTRODUCTION

Different aspects of the growth in the CS activities in China were reported in previous CS MANTECH conferences<sup>1,2</sup>.

Since 2006, China's CS industry with all its branches (microelectronic, optoelectronic and photovoltaic) as well as the associated building blocks (raw material, substrates, epitaxial services, device manufacturing and device packaging & testing) has undergone very rapid growth. Obvious indicators to that growth could be seen in the emergence of new Chinese entities as well as the increase in sales into China by foreign suppliers.

Other key indicators for growth include the volume of technical papers and patent applications, conferences (e.g. LED China), etc.

Whereas, to date, the majority of the growth has been in the raw material, substrates, optoelectronic devices and photovoltaic (solar cell) devices arenas, the emergence of some MMIC players in the microelectronic arena heralds a new chapter in China's CS growth.

In the following sections, the major activities and achievements within all sectors of the Chinese CS industry will be described in more details.

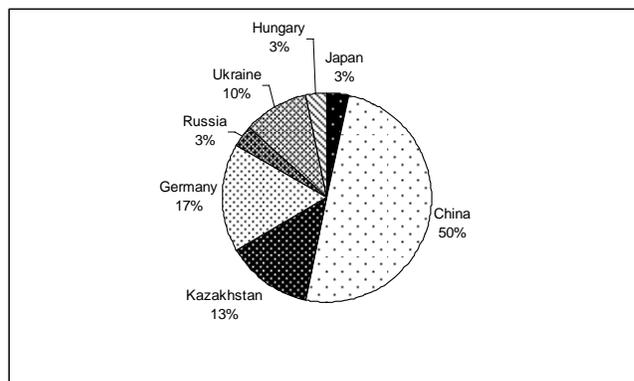
## SUBSTRATE SUPPLY

The major manufacturer of semi-insulating and semi-conducting GaAs and InP and semi-conducting Ge substrates is Beijing Tongmei Xtal Technology Co. Ltd. (a 100% owned subsidiary of AXT, Inc. (USA)). Semi-conducting GaAs substrates are also manufactured by China

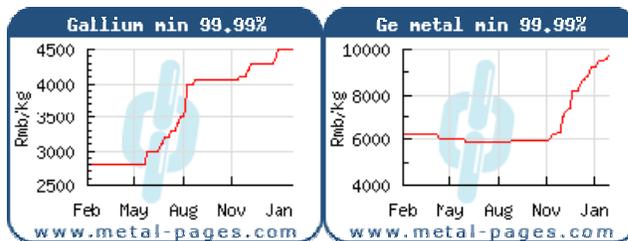
Crystal Technologies Co., Ltd. (CCTC) and China Electronics Technology Corp. (CETC) #46 Institute. Semi-conducting Ge substrates are also manufactured by Nanjing Germanium Company. Semi-insulating GaAs and InP substrates are used for electronic/wireless applications, semi-conducting GaAs and InP substrates are used for optoelectronic applications, and Ge is used predominantly for triple junction Ge/GaAs/InGaP solar cell applications.

## RAW MATERIALS

China is the world leading producer of virgin (i.e. not recycled) Ge and Ga (see Figure 1). In recent years, due to the rapid global growth in all CS sectors, the consumption of these minerals has increased substantially, and so did the prices<sup>3</sup>. The price increases were especially noticeable during the period Feb. 2010 to Jan. 2011 as reported in the "Metal-Pages"<sup>4</sup>, see Fig. 2.



**Figure 1.** Percentage, by country, of annual output of Gallium (China's output is 75MT; world output is 150MT)



**Figure 2.** Price in RMB of Ga and Ge (source: Metal-Pages<sup>4</sup>)

Some of the notable suppliers of the key raw materials to the CS industry are as follows:

- Ga: Beijing JiYa Semiconductor Co. (4N Ga) and Nanjing Jin Mei Gallium Co. Ltd. (6N Ga)
- Ge: Xilingol Tongli Germanium Co. Ltd.
- As: Emeishan Jia Mei High Purity Materials Co Ltd.
- pBN: Beijing Bo Yu Semiconductor Vessel Craftwork Technology.
- B<sub>2</sub>O<sub>3</sub>: Nanjing Jin Mei Gallium Co. Ltd.

## LED MANUFACTURING

This is the fastest growing segment of the CS manufacturing arena. The estimated gross sales revenue from LED chip sales in 2009 was ~\$300M with the following companies representing the 5 top manufacturers:

- Xiamen Sanan Optoelectronics Co. Ltd.,
- Hangzhou Silan Azure Co. Ltd.,
- Shandong Inspur Huaguang Optoelectronics Co. Ltd.,
- Dalian Lumei Optoelectronics Corp., and
- Xiamen Changelight Co. Ltd.

At the time of writing this document, the number of Chinese companies in the 4-element and GaN based LED chip supply is estimated to be around 125 companies of which 25 are directly involved in fabricating, packaging and testing the LEDs. The estimated total number of MOCVD reactors that are presently in use in China exceeds 250. These reactors were supplied by Veeco and AIXTRON, and as a result of the growth in this segment, both companies have enjoyed a significant growth in their sales in the past 2 years. In the next 1 to 2 years, more than an additional 500 reactors will be installed in China for LED manufacturing propelled by the strong financial and tax policy support provided by several provincial governments in China for the expansion of the LED the industry.

## SOLAR CELLS

Since 2004, China, with generous government subsidies, has been moving fast towards adopting solar energy to eventually replace the traditional coal burning power plants. The high efficiency TJSC based on Ge substrates has received considerable attention for both space and terrestrial (CPV) applications. For example, in August, 2010 Emcore Corporation and San'an Optoelectronics Co. Ltd., entered into a joint venture agreement to manufacture CPV products for terrestrial and solar applications. Also, China's Hanlong Group, Mining conglomerate is presently building a large CPV manufacturing project in Chengdu city.

## MMICs

As mentioned in the Introduction section of this document, there are now several entities in China that are emerging as serious players in the MMIC arena. Three of these are:

- RDA Microelectronics, Inc. is a Fabless RF design house specialized in cellular, broadcast and connectivity products.
- United Monolithic Semiconductors (UMS) is a GaAs foundry with diverse processes for state-of-the-art HBTs and pHEMTs. UMS also offers a complete family of microwave products including: switches, attenuators, LNAs, power amplifiers, mixers amongst others.
- Institute of Microelectronics of Chinese Academy of Sciences (IMECAS) developed InP DHBT based oscillators and frequency dividers

## RESEARCH AND DEVELOPMENT

At the time of writing this document, the number of Chinese universities and research institutions that are involved in fundamental and advanced research in the CS field exceeded 30 in total. Most notable, amongst many, are:

- Tsinghua University,
- Shanghai Institute of Technical Physics,
- Shanghai Institute of Microsystem And Information Technology
- Hebei Semiconductor Institute
- China Electronics Technology Group Co., No. 55 Research Institute
- Haerbin Industrial University,
- Suzhou Institute of Nanotech and Nano-bionics,
- Chinese Academy of Sciences (CAS), and
- General Research Institute for Nonferrous Metals (GRINM)

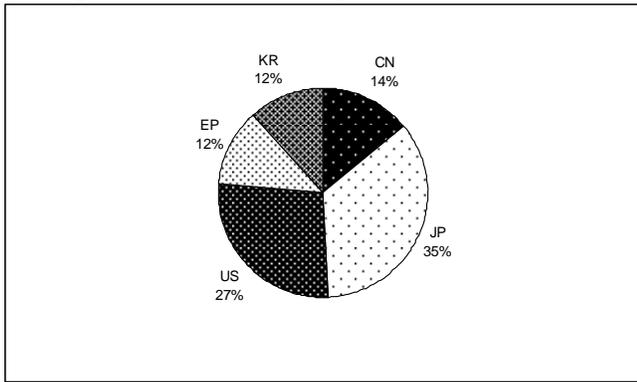
These institutions provide technical support for the manufacturing entities in China. They are also a growing source of manpower for the CS industries, many of which provide funding to these institutions.

In addition to technical papers and presentations at international conferences by these institutions, they are also making significant contributions in the intellectual property arena as noted in the volume of patent applications handled by the China patent office known as State Intellectual Property Office (SIPO).

## INTELLECTUAL PROPERTY

The Chinese government continues to encourage innovation as evidenced by increase in annual R&D budget as well as the extension of tax-breaks and other monetary incentives. As a result, the annual growth in the total patent volume of

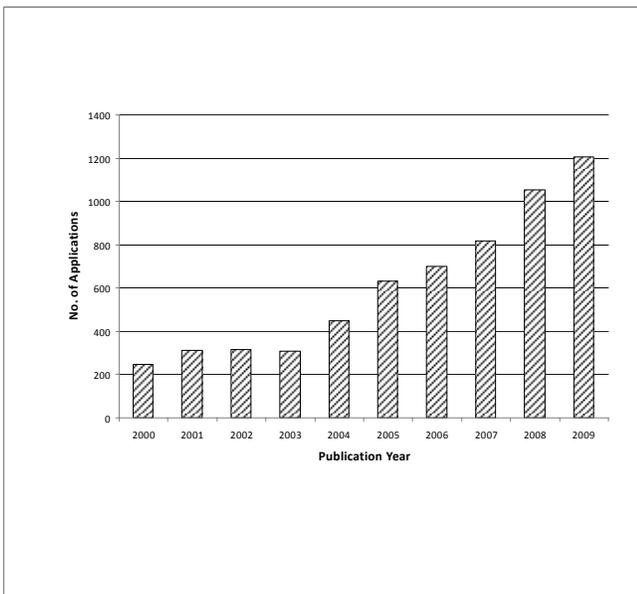
China originated patents has, since 2006 positioned it third after Japan and the USA, see Figure 3.



**Figure 3.** Total Patent Volume in Aggregate (2003 to 2009)<sup>5</sup>

Furthermore, in 2008, when global economic activity started to decline, the growth in worldwide patent applications declined due to zero growth in patent applications in the US and a drop in the number of applications filed in Japan and the Republic of Korea. Despite the slowdown, the overall growth rate of patent applications continued to be positive, reflecting strong growth in China<sup>6</sup>.

Our search for SIPO patent applications that are related to III-V materials in the period 2000 to 2009 yielded the data that is shown in Figure 4.



**Figure 4.** China originated III-V semiconductor related patent applications by publication year.

The data shows a very substantial growth in patent applications by a factor of nearly five times in that time-frame.

## SUMMARY AND CONCLUSIONS

With the diverse resources, the rapid integration of the supply chain components, growth in the intellectual property contributions, and Chinese government support, China is poised for a considerable growth in the CS arena. China is also offering new opportunities for international investments as well as international suppliers of key services and equipment.

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## REFERENCES

- [1] Qi Huang and Junming Zhou, *Advance in Compound Semiconductor of China*. CS MANTECH Technical Digest (2003).
- [2] Robert C. Walker, *China's Compound Semiconductor Industry: The Impact on Global Manufacturing*. CS MANTECH Technical Digest (2006).
- [3] Robert G. Ochrym and John J. Cerilli, *Substrates Challenged by raw material process*. Semiconductor Today, Vol. 2 (7), 2007
- [4] Metal-Pages, <http://www.metal-pages.com/metalprices/>
- [5] Eve Y. Zhou, *Patented in China: The Present and Future of Innovation in China*. Thomson Reuter Report 2010.
- [6] World Intellectual Property Organization (WIPO), *World Intellectual Property Indicators*, 2010 Edition.

## ACRONYMS

- VGF: Vertical Gradient Freeze
- LED: Light Emitting Diode
- CPV: Concentrated Photovoltaic
- RF: Radio Frequency
- LNA: Low Noise Amplifier
- HBT: Heterostructure Bipolar Transistor
- DHBT: Double HBT (see above)
- pHEMT: Pseudomorphic High Electron Mobility Transis