

G-1-2 (Invited)**Epitaxial Manufacturing Outlook for Microwave Industry**

Norio Hayafuji, Yong-Yin Chen, Jenq-Shinn Wu, Jiun-Tsuen Lai, and Chin-Kun Peng

Procomp Informatics Ltd.

No. 26, Li-Hsin Rd., Science-Based Industrial Park, Hsinchu, Taiwan 300, ROC.

Phone: +886-3-5773727 Fax: +886-3-5773706 Email: hayafuji@procomp.com.tw

1. Introduction

From the middle of the last decade, requests for personal communication system as well as data transportation become enormous than ever. To fulfill the demands of the communication requirement, microwave technology draws the focus of the popularity within the tech-universe. A lot of experts walked out of the laboratory and started to contribute themselves into the real-world application, which encourages the amazing progress on industrial products and generates great profits on the business aspects.

Due to the uniqueness of the material characteristics, compound semiconductor turns into one of the backbones that are able to satisfy the high frequency requirement for microwave industry. Just like the innovation stage of the silicon business, almost all the processes for final products were controlled and developed by IDMs (integrated device manufacturers) at the beginning. However, the pressure of cost reduction as well as capacity expansion forces them to consider re-arrangement of their resources, and it includes outsourcing several processes to vendors for risk distribution. Therefore, more and more companies setup to provide only process services instead of the whole package just because of this demands from IDMs, and epitaxial manufacturing industry is one of them.

2. Food chain of compound semiconductor industry

Since most of the IDMs gradually release their production capacity to their vendors, the whole microwave industry becomes a mix-up group with different requests and demands. From the top down, we have epi-house as the epiwafer provider, foundry fab provides device process through mesa stage, packaging factory cuts the dice and wraps up the goods, and testing factory performs the characterization (Fig. 1).

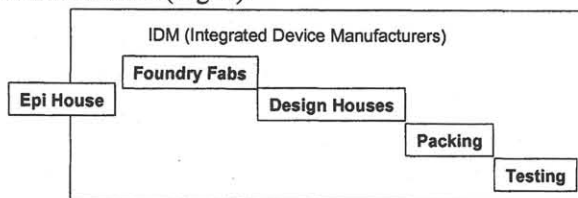


Fig. 1 The IDM function breakdown

Within these sub-industries, epiwafer manufacturing is the first to step up as a mature independent player since the material growth really needs a different professional aspect than device process. Foundry service is the next big shot. As the market fluctuates so volatile these years, most IDMs realize that spreading out investment risks and reducing costs are survival skills one must have. Foundry service

provides the opportunity for IDMs to expand the capacity immediately once the market demands roll back, but also protects IDMs to engage on potential high risks because of the heavy investment.

As for the packaging and testing businesses, the service providers are able to copy the existing process mode to compound semiconductors, since the silicon industry has already developed mature controls on both process flows. However, the future of demands for such services are still questioning because of the fast-changing standards on microwave products produced by compound semiconductors.

3. Epitaxy options*MBE or MOCVD*

In the epitaxy world of compound semiconductors, there are two major options: MBE and MOCVD. Both processes are able to produce excellent quality epiwafers, and both are proved as efficient processes with very high yield performance. The difficulty of material growth is no longer a major issue, instead the controllability of epitaxy process, device performance uniformity, and product lead-time become the battlefields for all the competitors.

Between MBE and MOCVD, there are still some differences. Since MBE process does not require carrier gas and other compounds for material reaction, therefore, it is easier for MBE scientists to focus on the necessary material/element for new technology study. Especially when the new device involves p-type doping layer, the hydrogen passivation effect makes MOCVD unpopular to apply for R&D purposes.

However, MOCVD has the advantage of high throughput. With well-trained technician and efficient schedule, MOCVD is able to operate all year long but only requires minimum maintenance period. It is very efficient when dealing with mass production request.

GaAs, InP, or Wide-band-gap

The GaAs system is the most general material system for microwave device manufacturing, which has been developed for over 40 years. But recent technology breakthrough and request for high-speed data transportation urge the industry to look for new material system, such as InGaAs/InP system, which is suitable for high-speed data transportation because of the higher electron mobility.

The wide-band-gap material system has pulled some attention since the first blue LED published [1]. After that, both SiC and GaN have been quickly developed into several product fields, including microwave application [2]. GaN-based microwave devices [3] [4] are appropriate to

apply into base station for wireless communication because of the high-power characteristics, and SiC MESFET [5] is suitable for wide bandwidth radio communication as well as cellular infrastructure application.

HBT and HEMT

Major circuit designs for microwave application are coming from either HBT or HEMT. Because of the distinctive performance, usually HBT is applied on power amplifier, and HEMT is applied on switch.

Both device structures are key components in cellular phone handset, and these devices are not easy to be replaced due to their matured process and unique performances.

4. Key players in epitaxial manufacturing industry

The first few epiwafer suppliers that focus on microwave device epitaxy are located either in the United States or in Japan. Recently a lot of companies in Taiwan jump into the service ring and start to provide very competitive price with good quality wafers. With more and more companies join this industry, not only the epitaxial wafers become easier and easier to acquire, but also the epitaxial technology gets more and more advanced because of the competition. No companies can survive in the battlefield if they do not prepare to provide epitaxial wafers with satisfied quality.

Region	Company	Epitaxy Technology		Product	
		MOCVD	MBE	HBT	HEMT
US	Kopin	○		○	
	Emcore	○		○	○
Japan	Hitachi Cable	○		○	○
Taiwan	Procomp	○	○	○	○
	VPEC	○		○	○
	Giga	○		○	○
	kingmax	○		○	○
	Inforcom	○		○	○
	Epitech	○		○	○
	South Epitaxy	○		○	○
Europe	Picogiga		○	○	○
	IQE	○	○	○	○

Table I. Major epitaxial manufacturing vendors around the world

Table I. shows a list of major suppliers in the epitaxial manufacturing industry in microwave application. Most of these suppliers choose MOCVD as their major production tool, and a few of them choose MBE as the main gun for service. As far as we know, only Procomp [6] is producing both of MBE and MOCVD epiwafers in the same facility.

5. Market trend

The downturn of year 2000 to 2001 pushes a lot of microwave component manufacturers to re-consider their positions and the way of gross margin maintenance. As far as it goes, consolidation between component vendors becomes a way to keep profitable. This unstoppable trend increases the financial strength of survival companies, and creates opportunities for different technologies to combine.

Another trend is the rise of both foundry service providers and design houses. The driven force for such industry transferring is due to the need of costs reduction and capacity expansion. Because of the strong activities by these companies, the original IDMs have more opportunities to cooperate with other suppliers, but also encounter more challenges and competitions around the world.

For epitaxy manufacturers, market transformation stands for both opportunity and challenge as well. Although merger between component suppliers keep the company strong as before, it also means that the number in the customer circle reduced. Whoever keeps the strong relationship with the final survivors in the merger wins the competition.

On the other hand, increasing numbers of design houses and foundry services create foreseeing business opportunities. Strong linkage between these businesses may generate great profits since all the costs are controlled separately and the investment risks are dispersed.

6. Summary

From the epitaxy manufacturer point of view, the microwave industry is changing rapidly to satisfy the market requirement. Every company faces the problem of customer demands dropping due to market depression, and most of them switch their focus more to the new product development. The purpose is to keep ahead of other competitors once the demands come back.

As an epitaxy wafer provider, the biggest challenge is to fulfill the research request from customers. Continuously improving the technology level in-house is a must, and in the mean time keeping profit on R&D cases is another issue to conquer. But the outcome is that, once the market demands bounce back, the winner of the competition will be the company that continuously stands, and that is every player in this industry trying to reach.

For more detail information regarding to the technical data of epitaxy products, it will be discussed during the presentation.

References

- [1] S. Nakamura, T. Mukai and M. Senoh, *Appl. Phys. Lett.* **64**, 1687 (1994).
- [2] P. Parikh, Y. Wu, N. Zhang, P. Chavarkar, M. Moore, U. Mishra, W. Pribble, J. Palmour, L. Kehias and T. Jenkins, *2001 International Conference on Compound Semiconductor Manufacurrring Technology*, (2001) p. 151.
- [3] N. X. Nguyen, M. Misovic, W. S. Wong, P. Hashimoto, L. M. McCray, P. Janke and C. Nguyen, *Elect. Lett.* **36** (5), 468 (2000).
- [4] S. T. Sheppard, K. Doverspike, W. L. Pribble, S. T. Allen, J. W. Palmour, L. T. Kehias and T. J. Jenkins, *IEEE Electron Device Lett.* **20** (4), 161 (1999).
- [5] S. T. Sheppard, K. Doverspike, W. L. Pribble, S. T. Allen, J. W. Palmour, L.T. Kehias, and T. J. Jenkins, *56th Annual Device Research Conference*, Charlottesville, VA, June 1998.
- [6] <http://www.procomp.com.tw>