Present and Future of GaAs Technologies in Japan

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EXPLOSIVE GROWTH OF HIGH SPEED NETWORK SYSTEMS

The explosive growth of high-speed networks, like the Internet, is fueling the demand for large varieties and volumes of compound semiconductor devices. Figure.1 shows the various applications of compound semiconductor devices. The optical trunk line and lightwave access network markets, for example, use MQW DFB laser diodes, InGaAs Avalanche photodiodes, and PIN diodes. Wireless systems such as mobile telephony, Direct Broadcast Satellite television (DBS), Local Multipoint Distribution System (LMDS), and Wireless LAN consume large quantities of microwave and millimeter wave integrated circuits.

CLARKE NUMBERS AND GaAs TECHNOLOGIES

The "Clarke Numbers", according to the dictionary of Physics and Chemistry, indicate the relative abundance of elements in the earth's crust and are expressed as a percentage. Table 1 shows the elements, the Clarke number(%), the ratio and the order, respectively. Presumably, it would be easier and less costly to extract elements with high Clarke Numbers since they are most common. Is it just coincidence that the three elements with the highest Clarke Numbers - oxygen, silicon, and aluminum, respectively - are the primary elements used in today's Silicon MOS devices, which are the most common food for our ravenous electronics industry? On the other hand, the Clarke numbers for Gallium and Arsenide are one twenty five-thousandth and one fifty-thousandth that of Silicon. For this reason alone, it's not unreasonable to expect the cost of Gallium Arsenide to be higher than Silicon. Yet, why does the electronics industry still require these more exotic materials?

COMPETITION AND COEXISTENCE WITH SILICON BASED TECHNOLOGIES

Consider the optical trunk line market as an example of one of many markets that does require the capabilities of Gallium Arsenide devices. In this market, high speed Gallium Arsenide digital ICs must process a continuous stream of information very rapidly. The value of these systems is directly proportional to the speed and volume of information that they can process. Since these high speed systems can only operate as quickly as the devices that they are comprised of, there will always be a need for Gallium Arsenide devices as long as they maintain a significant performance advantage over Silicon.

The relative merits of Gallium Arsenide and Silicon devices become less clear when we consider low bit rate optical networks or low frequency microwave systems where Silicon devices can operate. As an example, 900 MHz Silicon transistors were developed nearly 30 years ago and are still commonly used in communication systems up to UHF band. In the early days of the mobile telephone market, Silicon power transistors were often used in the power amplifier sections of the handset. These devices meet the power, gain, and bandwidth requirements of the handset but it was found that Gallium Arsenide devices could also provide higher efficiency. As the market grew and customers began using their mobile phones for longer periods of time, consumers favored phones with longer talk time (time between battery charges) and this allowed GaAs devices to establish a stronghold in the mobile phone power amplifier market.

Today, both the Silicon and Gallium Arsenide camps continue to improve their process technologies to get, or maintain their piece of this high volume market. The Gallium Arsenide camp has graduated from GaAs MESFET devices to PHEMTs, AlGaAs HBTs and InGaP HBTs, while the Silicon camp has graduated from Silicon bipolar devices to LDMOS transistors and now Silicon Germanium HBTs. Undoubtedly, this race will continue for some time and the market will continue to accept the technology that offers the best combination of price, performance, and timing.

GaAs TECHNOLOGIES IN JAPAN

Japanese manufacturers have a long and successful history of developing Gallium Arsenide based materials and devices. Followings are the examples of the GaAs ICs recently developed in Japan.

Figure 2 and 3 show Ka-band high-power and low-noise MMIC's used in the LMDS application, respectively, developed by Fujitsu Quantum Devices. Fig 2 (a) shows the chip overview of the 3-stage amplifier and Fig 2 (b) shows the frequency characteristic of the MMIC. Fig.3 (a) shows the chip overview of the 2-stage low-noise amplifier and Fig. 3 (b) shows frequency characteristic of the MMIC.

Figure 4 shows the miniature 60 GHz transmitter/receiver modules for wireless LAN developed by NEC(1). The modules shown in Fig. 4 (a) are implemented by using AlN multi-layer ceramic and highly integrated in the extremely small size. The block diagrams of the transmitter / receiver modules are shown in Fig. 4 (b).

Figure 5 shows an 80-Gbit/s multiplexer IC developed by NTT(2). Fig. 5 (a) shows the cross-sectional view of the InP based-HEMT structure used as the active element of ICs. Fig. 5 (b) shows the circuit block diagram of the MUX IC.

As high-speed network systems such as the Internet continue to expand, it's more important than ever for Japanese GaAs device manufacturers to understand these markets and the many system requirements that influence device, technology, and vendor choices.

REFERENCE

[1] J. Mizoe, S. Amano, T. Kuwabara, T. Kaneko, K. Wada, A. Kato, K. Sato and M. Fujise, "Miniature 60 GHz transmitter/ receiver modules on AlN multi-layer high temperature co-fired ceramic", IEEE MTT-S, Dig., pp.475-478, 1999.

[2] T. Otsuji, K. Murata, T. Enoki and Y. Umeda, " An 80-Gbit/s multiplexer IC using InAlAs/InGaAs/ InP HEMT's", IEEE J. Solid-State Circuits, vol.33, no.9, pp.1321-1327. 1998.

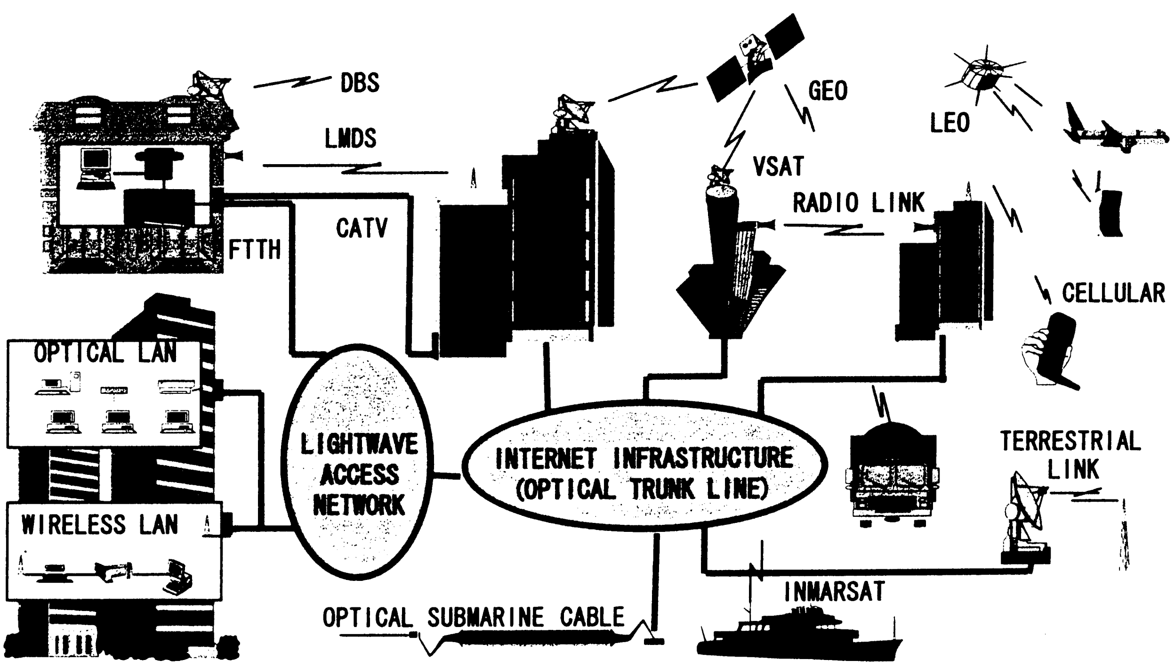
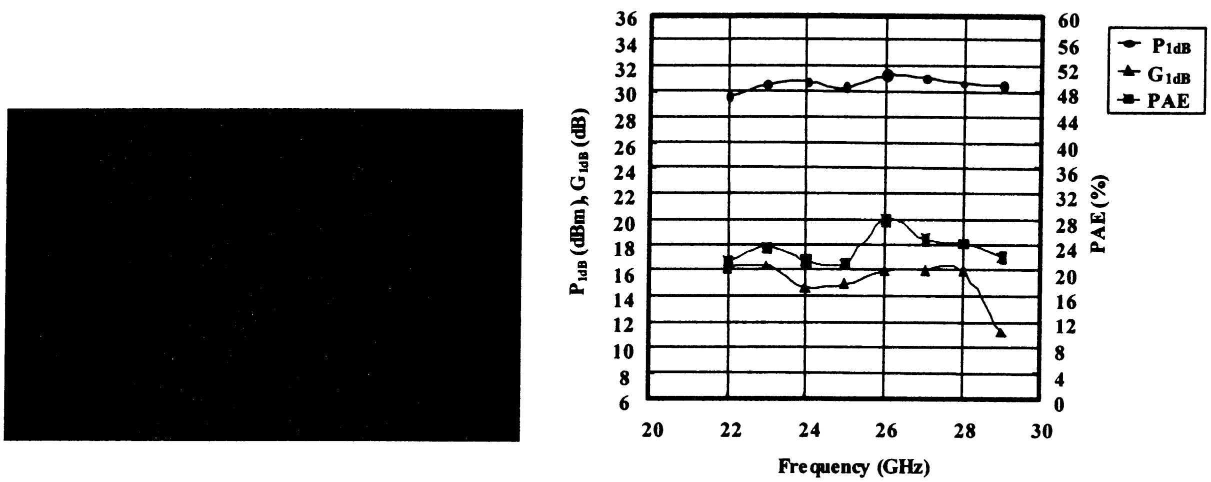


Fig. 1 The various applications of compound semiconductor devices.

Element	Clarke number (%)	Ratio	Order
O	49.5	1.9	1
Si	25.8	1.0	2
Al	7.56	1 / 3	3
P	0.08	1 / 300	13
Ga	0.001	1 / 25,000	39
As	0.0005	1/ 50,000	49
Sb	0.00005	1/ 500,000	61
In	0.00001	1/ 2,500,000	68

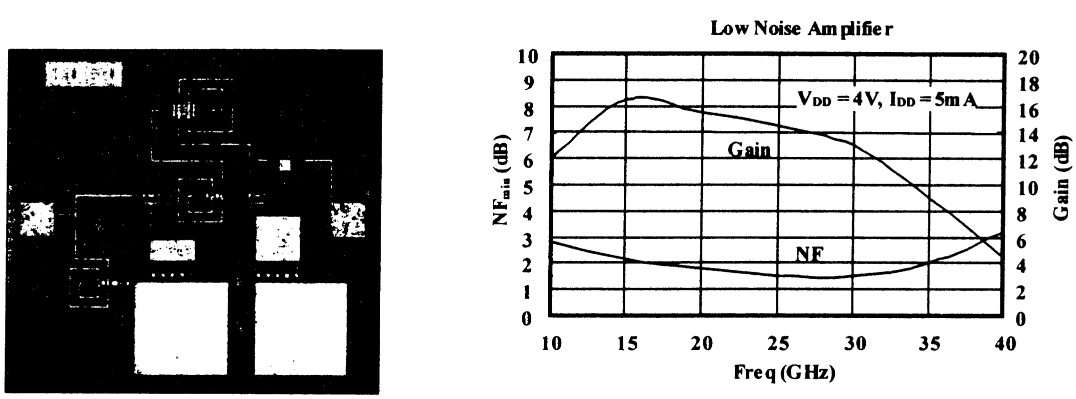
Table 1. Clarke number



(a)

(b)

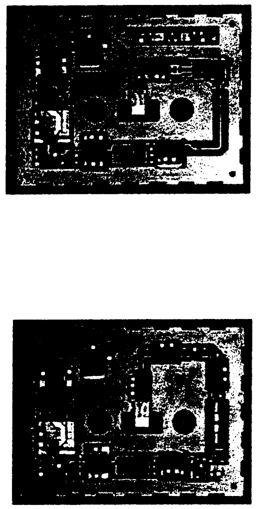
Fig. 2. Ka-band high-power MMIC



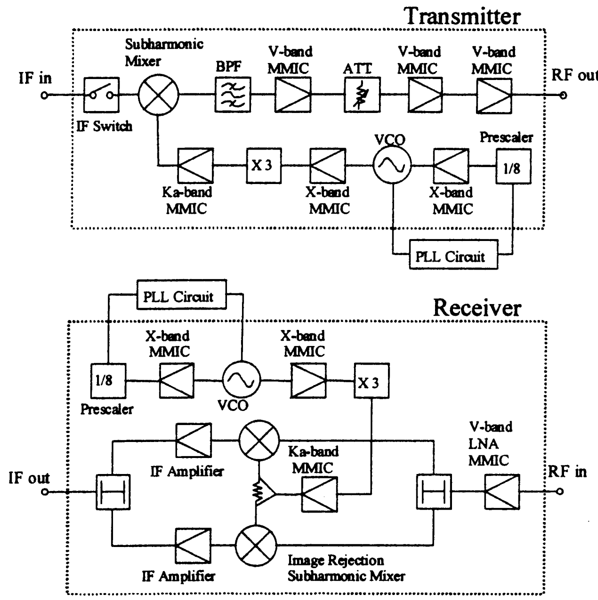
(a)

(b)

Fig. 3. Ka-band low-noise MMIC

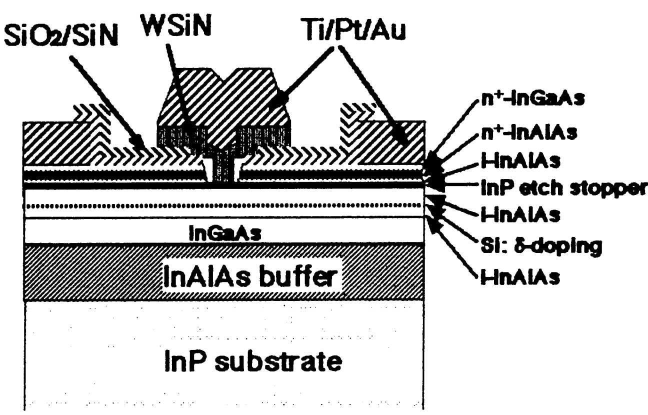


(a)

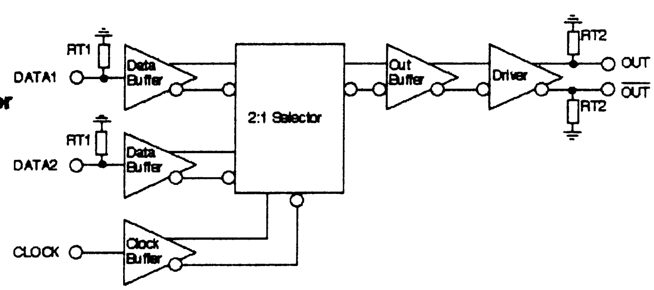


(b)

Fig. 4. Miniature 60 GHz transmitter/ receiver module (by courtesy of NEC)



(a)



(b)

Fig. 5. 80-Gbit/s multiplexer IC (by courtesy of NTT)