MICROWAVE DEVICES IN JAPAN

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ABSTRACT

The paper describes how the Japanese industries have shaped the microwave semiconductor devices and how they will participate in shaping the device business and technologies to meet the ever-advancing social needs.

Introduction

The recent progress of microwave semiconductor devices in Japan, especially of GaAs field-effect transistros, is so striking that they are establishing increasingly important positions, applications and requirements for advancing the-state-of-the-art.

Since the first commercially available low noise microwave bipolar transistor was anounced by Japanese semiconductor manufacturer, Nippon Electric Co., in 1968, they have been trying to have a good reputation in the world industry and been participating very actively to the noise figure race in the field.

Their efforts have been concentrated not only on realizing the highest performance of devices for both low noise and high power applications, but also on supplying highest quality to the market.

It is very interesting for us to know why they have been so active, how the Japanese industries have shaped the microwave device business, by whom necessary money for research and development of devices have been funded and where is the major market of microwave devices in Japan.

In this paper, first a review from the historical point of view is made how the Japanese industries have participated in shaping the microwave semiconductor device technology to meet the ever-advancing needs of society. Second it is investigated where is the market which needs microwave devices or technologies in Japan. An attempt will then be made to forecast the future trends of Japanese microwave society.

Historical Review

The history of microwave semiconductor devices in Japan begins about 29 years ago when the silicon point contact diode was first developed by Nippon Electric for the terrestrial radio relay link system for the Nippon Telephone and Telegram Public Corporation(NTT).

The actual research and development works on that diode were supported in part by NTT Laboratories. Looking back the-state-of-the-art devices at the time from 1950 to 1968, almost all new devices were developed for the NTT's communication systems and, of course, the development works were supported fully or in part by the NTT.

Tables 1 and 2 are demonstrating the representative devices in those days.

As there were no other particular government agencies or customers who were able to support strongly and continuouesly the advancement of device technology, it was very natural that the progress of microwave devices was closely related with the development of new communication systems.

Another fact that we should remember is that the semiconductor manufacturer had to supply high-rel devices to those applications. In such applications, replacement of deffective parts was often too difficult, or impossible, because of the inaccessibility of the equipment. Only devices that have an assured high reliability had to, therefore, be specified for use in these critical applications. It was essential for the manufacturers not only to realize the device performance but also to develop an effective quality assurance program of that device to meet the requirement of system's operation life.

Hence, the production line already installed from which the devices are being delivered to the market is basically capable of producing high-rel parts, even if those are for commercial applications.

Until the end of 1968, a large part of their business was from the communication systems for NTT.

Since 1969, however, it seems to me the situation has been somewhat gradually changed. The manufacturer began to find new sockets for their products in another market area. Chief reason for this was to obtain a resource to make it possible to invest the money for advancing a new device technology for future communication systems. By applying advanced device technology developed, they succeeded to deliver a large number of their products with highest performance to the TV, MATV and CATV markets at very low cost.

The year of 1968 was also the time when they started to sell their microwave devices to the overseas.

By doing so, they could expand their product varaieties for advanced systems even if the required quantity for each product was very small.

In conclusion, the microwave semiconductor business in Japan had been grown by strong support of communication systems companies who were selling a large part of their products to the NTT. This, on the other hand, was very good situation for the system's companies in developing their own unique advanced products using new devices, because the semiconductor manufacturers had no way to make their profit or to expand their business in another market at that time.

In recent years, they have had maney customers in the broad varaieties of market and they have been making profit to be invested a large part of their maney on the advanced technologies for the microwave systems. This fact tells us that the semiconductor manufacturers who are very strong in either of consumer or industrial market must be also strong in the microwave business. I would say it is true in Japan.

Market which Needs Microwave Devices In Japan

It is investigated where the sales of microwave semiconductor devices came from in the fiscal year of 1977 and the result is shown in the Chart 1 by percentage for each market segment.

Chart 2 shows the actual quantity sold to each market segment by percentage. We still owe approximately 43 % of our sales to the communications. If one takes a look at 10 years ago when the 90 % of microwave device business were from those market, however, the

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recent progress are very remarkable compared to that time. The quantity sold to the consumer market is also remarkable. This fact tells us that the device developed for a new communication system must be smoothly transferred to the production line, since the all production procedures and techniques were primarily developed for the microwave devices.

Here is a good example how the Japanese industies have shaped the microwave semiconductor business.

We have bipolar transistor which has 3 GHz of cut off frequency and was very expensive, 40 to 50 dollars ten years ago, but worked very well in the system. This transistor is now being used for the RF amplifier or mixer of TV-receivers at approximately 25 to 30 cents in a large quantity. We should be brave of using expensive device even for the consumer applications, if we are sure the quantity will grow and, of course, if we have great advantages to use it.

Looking to the Future

As was mentioned previousely, the major activities of developmental works on microwave device has highly forcused on communications so far. Only very little defense activities in microwaves has been seen in the last decade. It is too difficult to predict a realistic picture of microwave devices in defense system in Japan, since this is entirely depends upon the government policy.

By excluding the defense system from our consideration, it is confident that the microwave market in Japan would be divided into two major segments in the future. Those are : (1) communication systems and (2) Cansumer applications.

Communication Systems. According to the recent market analyses by many literatures publisized, it is no doudt that the communication industry will grow continuousely with higher rate to meet ever-advancing needs of society. It is particularly true in the satellite communication systems.

So far up to the present time, Japanese industries have not been as active as the United States in having domestic satellite communication systems. However, this would be gradually changed in the future, if they think it is worthwhile to have them.

I would rather think, this is strictly personal thoughts, that the Japanese industry would go with somewhat different ways from that the United States is doing to meet the needs of soceity, such as optical communication system.

For this reason the microwave semiconductor manufacturer will also have capability to produce optelectronic devices to be able to supply whole varaieries of components for the system.

Both power and low noise GaAs MESFET's which are attracting most of the attention in the field will continue to find new sockets at any frequency ranges in any communication systems replacing with vacuum tubes, bipolar devices and diodes. However, one should remember that it is first priority to develop a proper quality assurance program of power GaAs MESFET to offer a sufficient reliability to meet the required system's operation life. Also its cost will be the next goal.

As for low noise GaAs MESFET's, the device performance seems to be rapidly approaching a theoretical limit by recent advanced technology. A refinement on the device technology will be continually pushed operating frequency up, however, device designer should find another solution to realize a more better performance with another semiconductor material especially beyond the X-band frequency range.

The works on GaAs monolithic integrated circuit will also be emphasized.

Although somewhat tamed by now, new advances are still continually made in the bipolar transistors, pushing useful frequency of operation to as high as X-band.

Attractive market for these devices will be in the mobile telecommunication and in the solid-state repeater station for the TV broadcasting system.

Regretfully the Gunn diodes could only be survive in the special applications, such as low noise oscillators and pumping source for parametric amplifiers.

Because of higher power capability at higher freqency range, both GaAs and silicon IMPATT diodes will be continually grown in the market where the GaAs MESFET will not be able to catch up,

Conventional bipolar transistors and diodes are being steadily improved but are causing no great excitement. Major effort is concentrated on improving reliability and manufacturing yields, and pushing operating frequency limits higher and higher.

The works on MIC's in the communication systems in Japan is somewhat a little behind the United States. System users have not confident to use the chips without 100% stringent production screening and life tests before they use them for MIC assembly.

However, this is changing and they are approaching their final goal. The MIC works, however, will be very active in near future in communications industry.

Consumer Applications. This market is very attractive for microwave devices in Japan. There are a lot of rooms in that market where we could penetrate.

A direct satellite-to-home TV set is one of them.

It needs tremendous amount of microwave devices to receive X-band signal from the satellite. We can dream the production quantity of several hundred thousands of half-micron gate GaAs FET's per month, if the system will be reality. The cost reduction would be the final goal.

Although this kind of system will not be reality. We are still able to consider possibility of low cost X-band repeater station for the home TV in the shaded area against the toll buildings. Power GaAs FET or IMPATT could be sold to this.market.

It is commonly understook, the new low cost applications, such as intruder alarm and door openers, have been made possible by drastic reduction in the prices of Gunn and detector diodes. Those applicaitons will grow with high rate in conjunction with the development of car collision avoidance system.

Another attractive market can be seen in the sophisticated home TV-receivers in the future. A low cost GaAs tuning varactor diode or monolithic synthersizer designed with GaAs or silicon crystal, or monolithic broad band amplifier could penetrate into that market.

Static-Induction-Transistor(SIT) could catch up the vacuum tube in microwave oven, if the cost will meet the requirement.

Conclusion

The microwave semiconductor devices have been substantially advanced by strong support of Japanese communications industry and are being grown in the consumer market by extensive efforts of device manufacturers.

In the future, advancement will be steadily made by strong support of either communications industry or consumer markets pushing the device performance to as high as possible.

Acknowledgement

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TYPE OF DIODE	DEVELOPED & MANUFACTURED FOR WHAT APPLICATIONS	WHEN	END USERS
Si Point Contact Mixer	4 GHz Terrestrial Radio Relay Link	1950	NTT
Ge Point Contact Mixer	4-6 GHz Terrestrial Radio Relay Link as an Up-Converter	1955	NTT
Si Varactor	Frequency Multiplication & Parametric Amplifier	1961-63	NTT & Others
Ge Tunnel	High-Speed Switching for 24-CH PCM	1961	NTT
Si Snap-Off	Local Oscillator for Low Noise Receiver	1963	NTT
Si Hyper Abrupt Junction	11GHz 2700CH Radio Relay Link	1965	NTT
Si and GaAs Schottky	4-11 GHz Radio Relay Link	1967-68	NTT
GaAs Varactor	4 GHz Cooled and Uncooled Parametric Amplifier	1968-70	NTT & Others
Gunn	4-11 GHz Radio Relay Link Low Noise Local Oscillator & Pumping Source for Para-Amp.	1968	NTT & Ohters
PIN's	Attenuator, AGC, Switching for 4-11 GHz Radio Relay Link	1968	NTT & Ohters
Si & GaAs IMPATT (SDR)	Solid-State 6-20 GHz Radio Relay Link	1968	NTT & Others
Si & GaAs IMPATT (DDR & Read)	Solid-State 6-20 GHz Radio Relay Link	1973	NTT & Others
Pulsed IMPATT	Defense Systems	1975	NEC

TABLE 1. Progress in Microwave Diodes

TYPE OF TRANSISTOR	DEVELOPED & MANUFACTURED FOR WHAT APPLICATIONS	WHEN	END USERS
Ge Mesa Diifused Base	High-Speed Switching for 24-CH PCM	1962	NTT
Si Double Diffused	Linear Amplifier for 4 MHz Coaxial Carrier Transmission, $f_T \simeq 900$ MHz	1963	NTT
Si Double Diffused	Linear Amplifier for 12 MHz Coaxial and Low Noise IF for Radio Relay, $f_T \simeq 1500$ MHz	1965	NTT
Si Double Diffused	100 Mbit PCM. f_T = 3-4 GHz with Platinum-Gold Metallized	1965-68	NTT
Si Double Diffused	60 MHz Coaxial Cable Transmission f_T = 6-7 GHz	1966-68	NTT
Si Double Diffused	2 GHz Low Noise Amplifier NF = 4.5dB	1967	NTT & Others
Si Double Diffused	4 GHz Low Noise Amplifier NF = 4.0dB-3.5dB 400 Mbit PCM	1967-73	U.S. Market & NTT
Si Double Diffused	1W 4 GHz Medium Power Amplifier	1973-75	NTT & NEC
GaAs MESFET	C to Ku Band Low Noise Amplifier	1976	World Market
Si Bipolar & GaAs MESFET	L to Ku-Band Power Amplifier	1977	World Market

TABLE 2. Progress in Microwave Transistors

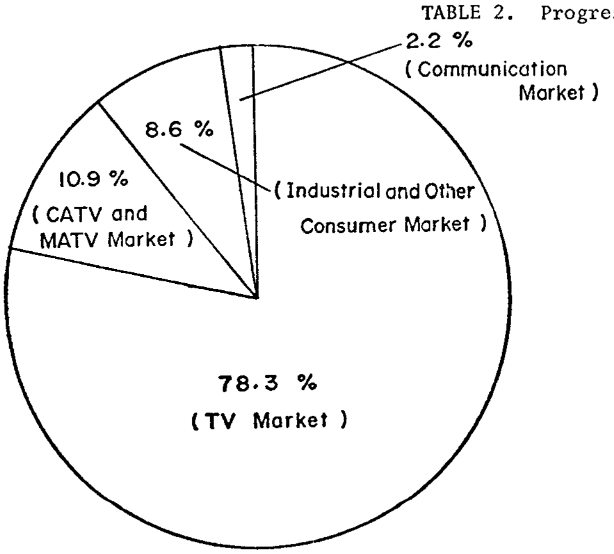

Chart 1. Total Sales by Volum.

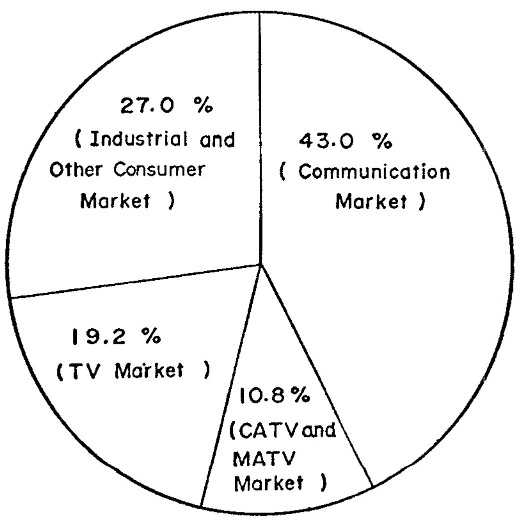

Chart 2. Total Sales by Dallar Amount.