PROGRESS OF MICROWAVE SEMICONDUCTOR DEVICES IN JAPAN

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ABSTRACT

This paper reviews recent progress and development status of microwave semiconductor devices in Japan. Since in Japan, major development efforts have been concentrated to the GaAs MESFET devices developments, the paper provides particular emphasis to the introduction of GaAs MESFET device progress in Japan. Progress status in other semiconductor device area is also reviewed briefly.

Introduction

The most remarkable progress taken place in the microwave semiconductor device field in recent years would be the progress of GaAs MESFETs. It has given significant impact to the progress of microwave application systems in various fields. In the course of GaAs MESFET development, Japanese industries have played important roles, contributing much to the progress.

Today, technical efforts to improve the performance and reliability of both low noise and power GaAs MESFETs are being cotinued by the Japanese manufacturers and other organizations intensively. Therefore, major part of this paper will be devoted to review recent status of GaAs MESFET devices.

Although the activity for GaAs monolithic linear integrated circuit development is not so very active in Japan, but has been taking place steadily to prepare for the future microwave communication systems. This approach will be stimulated by the development activity on GaAs monolithic digital integrated circuits.

As for microwave integrated modules using GaAs MESFETs or Gunn diodes, microwave oscillators for Doppler sensors and for local oscillators for civil radar systems and marine radar systems, and further for local oscillators for comming SHF TV satellite broadcasting receivers, are also becoming active in Japan. Those modules are either in the form of waveguide configuration of of microwave integrated circuits.

As for silicon bipolar transistors, some high performance devices capable of operation at C-band are available, and may be used as local oscillators in microwave communication systems.

In the diode area, there is no important driving force to motivate exciting development. High power active diodes such as IMPATT diodes will be replaced gradually with power GaAs MESFETs, at least up to Ku-band. As for millimeterwave applications, except some local area communication network systems, no further large project exists.

Various new device technologies that support the production of new and high performance devices are intensively being developed in Japan, particularly on compound semiconductor device fields. In the future, such efforts will give fruitful results to expand the use of microwave semiconductor devices in the fields.

GaAs MESFETs

Technological challenges aiming to better performance and reliability are conducted intensively in Japan. On both low noise and power devices, the efforts have been very active. As for frequency range, the development is not limited to C- and K-band frequencies, but also to UHF frequencies, where consumer type applications relating to TV is taken place. For Japanese electronic industries, consumer equipment market is very important, and some manufacturers are going to introduce GaAs MESFETs to TV tuners and CATV circuits. Also, for SHF TV broadcasting to be planned in the near future, low cost receiver front end is needed, and for such applications, use of GaAs MESFETs are considered to be used.

To meet the above requirements, low cost and reproducible mass production is necessary, and some new technologies that enable to meet the condition, such as ion implantation, large area crystal growth and advanced wafer processing technology are under development. Such technology developments will give positive influence to obtain higher performance higher reliability GaAs MESFET devices.

Low Noise GaAs MESFETs

Intensive efforts are conducted to realize better noise figure performance. Today, GaAs MESFETs with noise figure at 12GHz of 1.5 - 2.0dB and associated gain of 8 - 10dB are produced commercially. Most of those high performance devices utilize state-of-the-art technologies such as electron-beam exposure technique, deep ultra-violet photolithography, and advanced wafer processing technologies.

In Japan, reliability qualification of low noise GaAs MESFETs has already been conducted [1], and actually the devices have been used in space satellites. NASDA, the National Space Development Agency, of Japan, has been aggressive for such qualification program.

As for the production of low noise GaAs MESFETs, Japanese manufacturers have occupied leading position in the world. They have got good reputation, and a number of GaAs MESFETs have been exported to overseas markets.

GaAs MESFET Low Noise Monolithic Integrated Circuit

As is well recognized, monolithic approach will be effective to obtain GaAs FET amplifiers at very high frequencies such as at 20GHz or higher. In Japan, the development efforts to realize the monolithic ICs is going on, and some preliminary experimental results are reported [2]. Such ICs will be used mainly in microwave communication systems in Japan. A 20GHz low noise monolithic GaAs FET amplifier using monolithic chip exhibited 6.2dB noise figue at 20GHz with gain of 7.5dB, and with band width of about 1GHz.

GaAs MESFETs for UHF Applications

As stated in the preceeding sections, development has been conducted to realize UHF band GaAs MESFETs.

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Those FETs are for TV and CATV applications. A dual gate MESFET has been announced, which is capable of 1.4 dB noise figure and 18dB gain at 800MHz [3]. To aim at reproducible manufacturing in large quantity, ion implantation is utilized to prepare GaAs active layer.

A GaAs MESFET with integrated feed-back elements is also reported 4. It provides noise figure of 2dB and gain of 9dB at 800MHz.

New Devices , New Materials

Use of heterojunction structure to utilize a high electron mobility has been proposed 5, and is called HEMT, or "high electron mobility transistor". This transistor exhibits superior performance at lower cooled temperatures such as at 77°K. No microwave performance has been reported at room temperatures. The device concept, however, has given an impact in the semiconductor device technology.

Research on InP material to realize MESFET has been taking place in some organizations, but the work still remains in a primitive stage.

Power GaAs MESFETs

In the power GaAs MESFET field, Japan has occupied leading position in the development and production, although some overseas manufacturers have worked out good performance.

Today, 5W C-band devices, and 2W X-band devices are commercially available in Japanese manufacturers. Development efforts are continued to realize 1W at 20GHz band devices.

Qualification for space application or high reliability application, has been going on. NASDA has made qualification on a series of power GaAs MESFETs for use in a maritime observation satellite.

Power GaAs MESFETs are not laboratory preproduction samples, but now are produced in quantity. Technology developments to enhance production reproducibility, to reduce cost, to expand production capability, are intensively being pursued, and in the near future, quality, production scale, performance and reliability, will be improved.

So far, a number of GaAs power MESFETs have been introduced in the fields. Approximately an order of 10,000 units are in the fields, and the field failure data suggest failure rate of approximately 100 FITs for "standard" non-high-reliability units. This number will be improved further as the time elapsed.

Other Devices

Microwave GaAs MESFET oscillators

In addition to the Gunn oscillators that are used for civil radar applications such as door opener sensor, speed detector and alarm radars, oscillators using GaAs MESFETs are developed. Those oscillators use MIC configuration, combined with a waveguide structure.circuit. Such oscillators will also be used for SHF TV receiver sets in the future.

Silicon Bipolar Transistors

Recently some high performance transistors have been developed that are capable of operation as an oscillator at 8GHz or up to 10GHz [5]. Those devices may be used as local oscillator in some microwave communication systems, mainly because of its lower cost than GaAs MESFETs.

Conclusion

Recent status of microwave semiconductor devices in Japan has been reviewed briefly. Major efforts of technical developments are now in the GaAs MESFET device area, and intensive research and development activities, as well as efforts of establishing the production technologies, are conducted.

This paper may overlook some other important progress, and the auther would like to apologize if that is the case.

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