Activities of Indium Phosphide in Japan

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Abstract

An overview of the present InP activities in Japan is reported. This report covers all of present InP applications, i.e., optical devices, electron devices, epitaxial wafer suppliers and substrate.

Introduction

Device applications of indium phosphide can be divided into two groups, i.e., optical devices and electron devices. Both of them are related to optical communication, strongly.

Demand for Japanese communication does not seem to decrease due to recent popularization of internet access through ADSL (e.g., present number of ADSL users is over 5million as of November, 2002.) and exchange of photographs through cellular phones. However, because worldwide optical communication market has been very weak since 2001, InP industry in Japan is in severe economical situation.

Optical devices

Almost all of Japanese InP market are occupied by optical devices at present. Japanese optical devices have been supplied from sections or subsidiaries of big companies, such as *NEC, Hitachi, Fujitsu, Mitsubishi, Oki, Sumitomo, Furukawa, NEL* etc., and no change is observed in this style at present. Therefore, possibility of bankruptcy of the company is weak in comparison with a small venture company. However, present Japanese style prevent smooth shift from present technology sometime. For example, researches of vertical cavity surface emitting lasers (VCSELs) were started from Japan but no one has a plan to sell it because VCSELs has possibility to disrupt present technology for edge emitting lasers. Majority of optical devices are still edge emitting lasers. Because recent optical communication system uses wavelength division multiplexing (WDM), lasers with Bragg grating for selection of desired wavelength (or single-mode) become general.

Because the wavelength of single-mode laser for WDM has been still selected by sorting of chips and **Fig.2 Fig.**

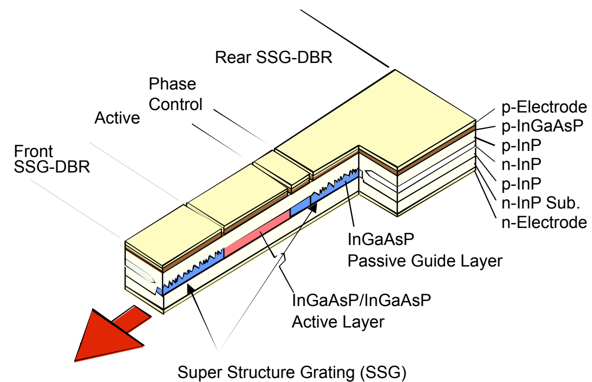

Fig.1 Shematic structure of super structure grating integrated with distributed Bragg reflector (SSG-DBR) laser for wavelength tunable laser by NTT [3].

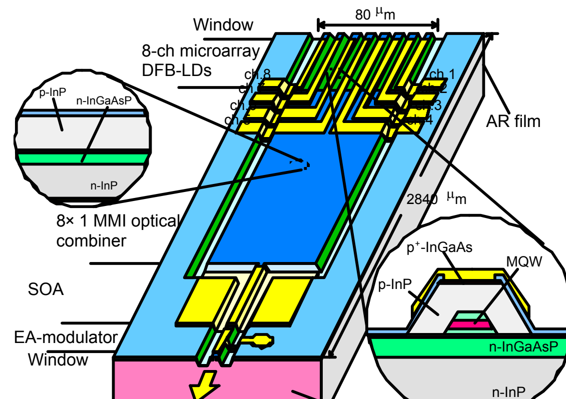

Fig. 2 Schematic structure of the wavelength-selectable eight-stripe microarray DFB-LDs with monolithically integrated MMI, SOA, and MOD by NEC [4].

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control of the operating temperature, R&D community for optical devices has an interest in development of semiconductor tunable lasers. To obtain several tens nanometer as tunable wavelength region, introduction of special Bragg grating into laser cavity by *NTT* [3] and combination of arrayed lasers with tunable wavelength range of several nanometers by *NEC* [4] were reported. Another interest is uncooled laser for short distance (or *Metro*) optical communication system. Lasers modulated at 10 Gb/s up to 85°C were developed by insertion of potential barrier around active region by *Hitachi* [5]. The barrier with aluminum composition prevents carrier overflow at high temperature.

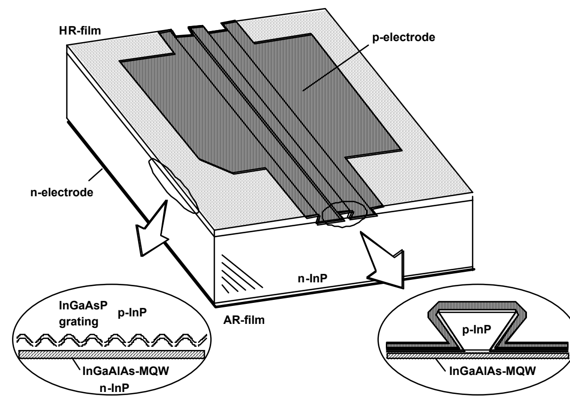

Fig.3 1.3-µm InGaAlAs-MQW DFB laser by Hitachi [5].

Epitaxial wafer suppliers

At present, edge emitting laser for optical communication requires crystal regrowth or selective growth for current confinement or Bragg grating. Thus process such as lithography or etching is required before the growth. As a result, the growth is a major part of fabrication process and suppliers continue to grow it themselves. Thus, InP epitaxial wafer suppliers such as *Sumitomo* and *NTT-AT* (subsidiary of *NTT*) must focus on small market such as wafers for detector or research.

Electron Devices

Because CMOS can supply very high-scale integration circuits with low cost, applications of another high-speed electron devices are limited to high-speed optical transmission system, RF/microwave transceivers and high-frequency ADCs and DACs [6]. In such fields, present interest of Japanese community for InP electron devices is limited to circuits for high-speed optical transmission system over 10 Gb/s. Present target of the speed is 40 Gb/s. The circuits for 40Gb/s was reported in 1997 already [7]. However, actual commercial use is delayed due to recent shrinkage of optical communication market. Actually, InP electron device is not commercialized except devices for measurement system or small sample at present. SiGe bipolar transistor, present competitor of InP electron devices, gets the possibility to reach 40 Gb/s as the system in this delay. However, InP electron devices has inherent high-speed of electron, thus the devices must work as major electron electron devices when the speed is over 40 Gb/s. Recently, 100-Gbit/s multiplexing and demultiplexing error-free logic operations was reported [8].

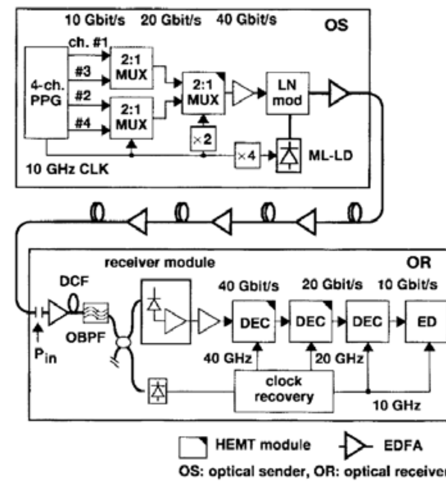

Fig.4 40 Gb/s optical repeater in 1997 by NTT [7].

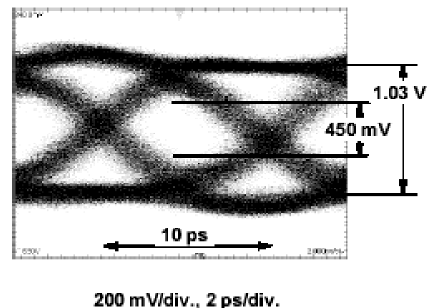

Fig.5 100 Gb/s output waveforms of the selector IC by NTT [8].

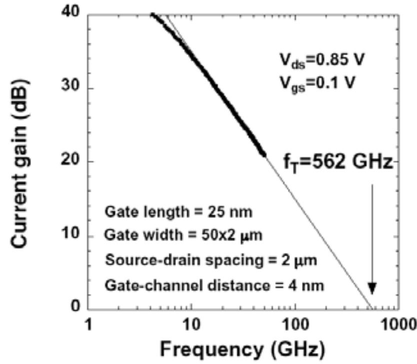

Fig.6 Microwave performance of fastest InP HEMT by Fujitsu and CRL [10].

The performance of Japanese InP electron device itself is in the state of the art. Especially, InP high electron mobility transistors (HEMTs) continue to have highest cutoff frequency (f_T) records in the world from 1998. This record was started from f_T of 350 GHz by *NTT* [9]. Present world record is 562 GHz reported from joint research team of *Fujitsu* and *Communication Research Laboratories* [10]. Delay time of 4.6 ps for logic circuit was also reported by using ring oscillator [11].

In other InP electron devices, *NTT* reported highest f_T of 341 GHz in heterojunction bipolar transistors (HBTs) [12]. Highest current density as InP HBTs was also reported at the same time. Toward low power dissipation and higher performance in the future, narrowest emitter width [13], smallest total base-collector capacitance [14] were also reported. Undoped emitter for high-speed operation by relatively low current density [15] and simple fabrication process with sufficient speed and good uniformity [16] were also reported as another interesting directions.

Substrates

Finally, we would like to comment InP substrates in Japan. Two major companies in Japan, *Sumitomo* and *Nikko Materals* (former *Japan Energy*) are major suppliers of InP substrates in the world. Recently, *Showa Denko* announces that they can supply 6-inch wafer as a sample [17]. However, integration of optical devices is not progressed except combination of laser and modulator and demand for larger size of substrate is not so high. A 2-inch wafer is majority in case of optical devices at present. Thus it will take time to use the larger-size wafer for commercialized production because we must wait commercialization of

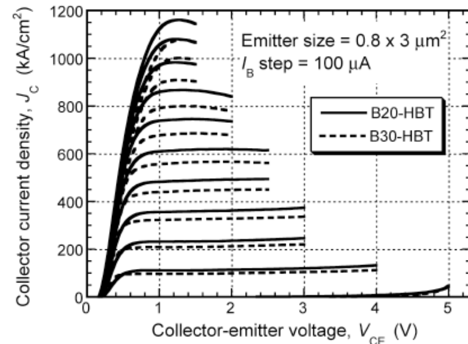

Fig.7 Common-emitter *I-V* characteristics of InP DHBT with highest current density as InP HBT [13]

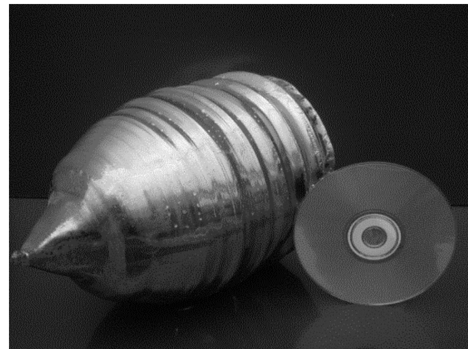

Fig.8 6" Diameter Fe-doped InP Single Crystal by Showa Denko [17]. Right hand side disc is standard compact disc.

InP electron devices and replacement of apparatus for size-up of wafer.

Conclusions

Strong capability of InP industry in Japan are demonstrated through research and development of new devices and materials. However, recent recession of worldwide optical communication market made a strong damage in the InP industry in Japan, because present InP applications in Japan is limited to optical communication area.

Acknowledgements

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