Development of Optically Interconnected LSI

~Integration of Ring Resonator Switches using Electro-Optic Materials~

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● Introduction

With the progress of miniaturization and switching speed of transistors, the performance of LSI is now governed by the signal transfer speed of the interconnection. Therefore, recently the RF wireless interconnection and optical interconnection are attracting much attention as the next generation interconnects in LSI instead of metal interconnection. In this twenty-first century COE program, the wireless interconnection and optical interconnection are studied. The author is in charge of the development of optical interconnection in LSI.

● Previous Research Achievements

The author has studied (1) plasma CVD of Si nitride, (2) thin film deposition and etching using photochemical reaction, (3) hetero-epitaxy of GaAs on Si substrate, and (4) MBE of high-temperature superconducting film. Present research subjects are as follows.

1) Optical interconnection in LSI
2) Process technologies for ultrasmall transistors
3) Creation of ultra-clean wafer environment and its device level evaluation

1) is the subject of this COE program. 2) is one of the main subjects of Research Center for Nanodevices and Systems. We have developed "Atomic Layer Deposition of Si Nitride" with self-limiting growth mechanism. 3) is the cooperative study with the private companies for past 8 years. We have developed 300 mm wafer boxes with self-cleaning function by using UV/photoelectron and photocatalyst methods. We have proved the cleaning effect using MOS capacitors. For these results, we have received three awards from Japan Association of Aerosol Science and Technology, and Japan Air Cleaning Association in 2000 and 2001 fiscal years.

Concerning the optical interconnection, we have developed (1) compact optical waveguide, (2) stack-type branched waveguides with good controllability of branching factor, (3) grating coupler which guides the light from the light-emitting devices into the waveguides, and (4) high-speed lift-off technique of light-emitting devices from GaAs substrate and the method to bond the lifted-off light-emitting devices onto Si LSI. Figure 1 shows examples of the developed technologies and optically interconnected pattern recognition chip which was fabricated by integrating the developed technologies.

● Outline of COE Research Subject and its Impact

The outline of the optically interconnected LSI, which is now under development, is shown in Fig. 2. Since the high density integration of light-emitting devices consisting of compound semiconductors seems not easy, we propose a monolithic integration of optical switches on Si substrate. As a candidate of the optical switch, we are studying micro ring resonator, which is recently noticed as wavelength division multiplexing (WDM) device, utilizing electro-optic material. Compact size (a few tens of micron) optical switches can be realized using electro-optic materials such as $LiNbO_3$ and $(Ba,Sr)TiO_3$ for the ring resonator. Since $(Ba,Sr)TiO_3$ is studied as high-k material for DRAM capacitor, the integration of this material is promising.

When the proposed technology is completed, high performance LSI with ultra-high speed over metal interconnection will be realized. In addition, this technology contributes to further miniaturization and higher

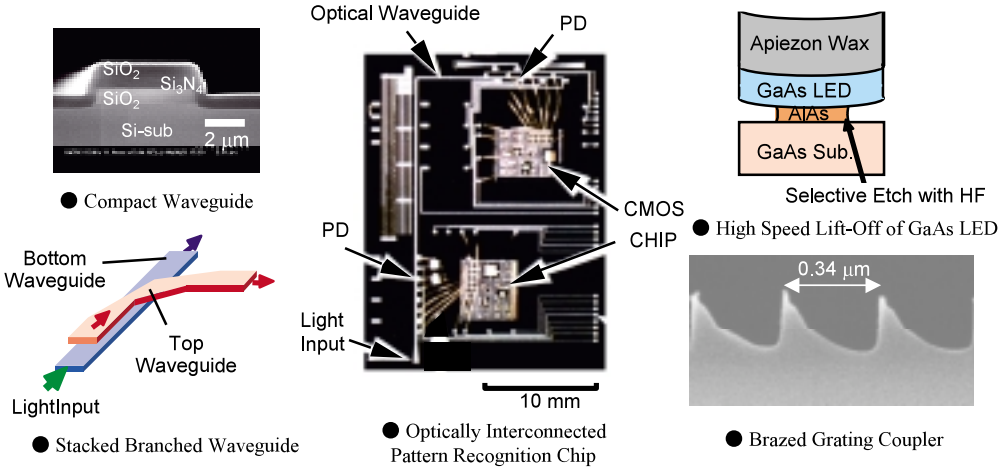

Fig. 1 Various technologies for optical interconnection developed at Research Center for Nanovevices and Systems.

performance of WDM devices which are widely used in the optical fiber network and greatly contributes to the development of information society.

● Research Plan

The detailed research plan is as follows.

Ⅰ. Development of design and fabrication method of micro ring resonators

As a preliminary research, the micro ring resonators using plasma CVD Si nitride is designed and fabricated. We have succeeded in observing resonating characteristics.

Ⅱ. Study of tunable micro ring resonator using electro-optic materials

・Fabrication technology of electro-optic films such as $LiNbO_3$ and $(Ba,Sr)TiO_3$ with large electro-optic coefficient

・Development of barrier layer for metallic elements such as Li, Ba, and Sr

It is necessary to suppress the diffusion of these metallic elements in order to integrate on Si LSI. We utilize already developed "Atomic Layer Deposition of Si Nitride".

・Low voltage operation of micro ring resonator switch

(1) Large electro-optic coefficient is a key issue.

(2) Steep resonance characteristics are realized by using cascaded ring resonators and devising the resonator structure.

(3) Transparent metal is effective for the low-voltage operation.

Ⅲ. Development of SiGe high-speed photodetectors

High speed SiGe pin photodetector operating at wavelength from 1.3μm to 1.5μm will be developed cooperating with Prof. Miura (modeling) group.

Ⅳ. Implementation of optically interconnected LSI shown in Fig. 2 by integrating the developed technologies.

Finally, we would like to demonstrate the excellent function of the optically interconnected LSI.

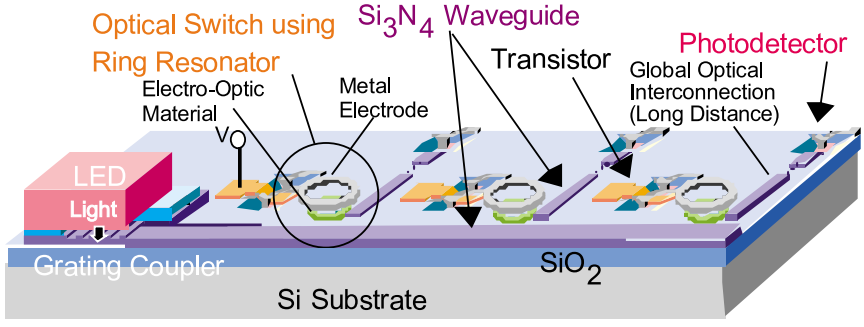

Fig. 2 Schematic of optically interconected LSI proposed in this research program.