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New RAM-bus Memory System with Interchip Optical Interconnection

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A new optical RAM-bus (ORAM-bus) memory system has been proposed. The ORAM-bus memory has a number of optical interconnections to connect many memory chips. The data transfer using the guided optical interconnection is performed through the optical coupling flip-flop (OC-FF) in the optical coupling sense amplifiers. Furthermore, the ORAM-bus memory test chips were fabricated using 2um CMOS technology. The LEDs were successfully bonded onto the silicon LSI chips by using the newly developed micro-bonding technology. It was confirmed in the test chips that the optical writing operation for ORAM-bus memory can be successfully performed.

1. INTRODUCTION

It is very improtant for improving the computer system performance to increase the data transfer speed between the processors and the memories. The clock frequency of processor chip has rapidly increased for these years owing to the dramatic progress in the LSI technology. On the other hand, the access time of dynamic random access memory (DRAM) which has been employed as the main memory has not been reduced so much. As a result, the difference of the operation speed between microprocessor and DRAM has rather extended. Recently, however, new DRAMs with rapid data transfer function have been proposed. The very high speed data transfer between the processors and the memories can be achieved by using such new DRAMs. The RAM-bus DRAM is one of these new DRAMs[1]. The cache memory function is included in the RAM-bus DRAM. Furthermore, the data are transferred in parallel between the built-in cache memories and the DRAM memory cells in the RAM-bus DRAM. However, even in the RAM-bus DRAM, the data transfer speed and data band width of the data bus become the problem when much higher data transfer speed is required. Then, we propose the new memory system with the interchip optical interconnection to significantly increase the data transfer speed of the data bus. We call this new memory system an optical RAM-bus (ORAM-bus) memory system[2].

2. CONCEPT OF ORAM-BUS MEMORY

The ORAM-bus memory is the RAM-bus memory with optical interconnection. In the ORAM-bus memory, the data are directly transferred from the built-in cache memories of RAM chip to those of other RAM chips through the optical interconnections. The configuration of ORAM-bus memory is shown in Fig.1. Many memory chips are connected by a number of optical interconnections in the ORAM-bus memory in order to extend the data band width and to increase the data transfer speed. The equivalently very high data transefer speed of 100～200Gbit/s can be achieved in this ORAM-bus memory if one thousand of guided optical interconnections are formed and the clock signals of 100～200 MHz are used. The data transfer using the guided optical interconnection is performed through the optical coupling flip-flop (OC-FF) in the optical coupling sense amplifiers as shown in Fig.2[3]. The electrical sense amplifier in the optical coupling sense amplifiers also acts as the cache memories. The optical coupling flip-flop (OC-FF) circuit consists of the data store portion and the data transfer portion[4]. The flip-flop with two high resistive loads is used in the data store portion. The resistive load in the flip-flop also acts as the photoconductor. Therefore, the data store portion is responsible for optically writing the data into the built-in cache memory. Two LEDs are included in the data transfer portion. The data are optically transferred by these LEDs to other chips. The cross-sectional structure of ORAM-bus memory with the optical interconnection is shown in Fig.3 where (a) shows the cross-section in the vertical direction to the optical wave guides and (b) shows the cross-section along the optical wave guides. The

memory chip with LEDs and photoconductors is bonded into the glass substrate with the optical wave guides using the large metal bumps. The LEDs are also bonded into the memory chip using the small metal bumps.

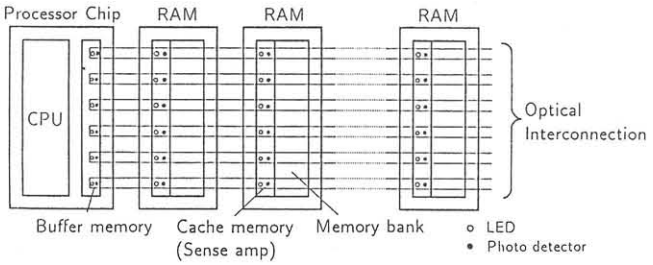

Fig.1 Configuration of ORAM-bus memory system.

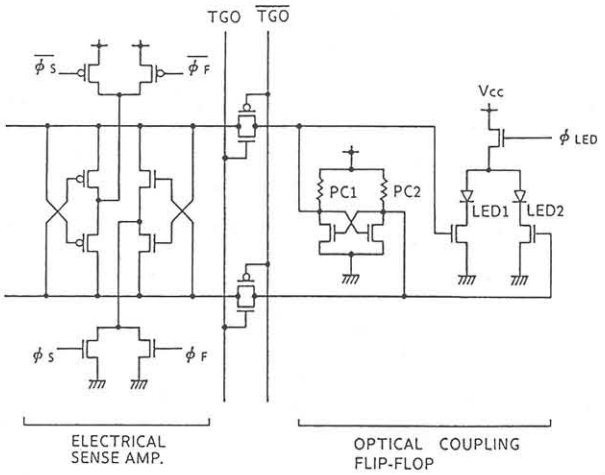

Fig.2 Optical coupling sense amplifier

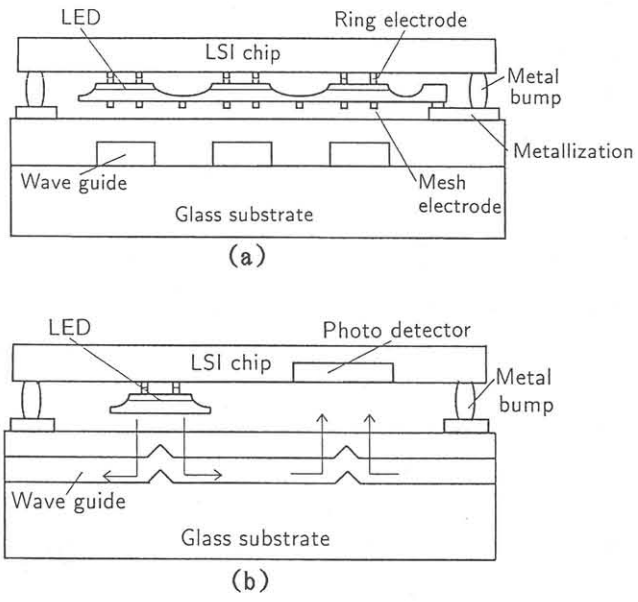

Fig.3 Cross-sectional structure of ORAM-bus memroy. (a) Vertical direction to the optical wave guides. (b) Horizontal direction along the optical wave guides.

3. FABRICATION OF ORAM-BUS MEMORY TEST CHIP

The test chips for the ORAM-bus memory were fabricated using 2um CMOS technology. Each LED was isolated with the required size by mesa etching after forming the ring electrodes and the mesh electrodes. These LED chips were bonded on the test chips using the micro metal (In/Au) bumps. A newly developed wafer aligner was used in the bonding[5]. The mesa isolated LED chips were bonded on the test chips with the alignment accruacy of 1um using the infrared light. The infrared photomicrograph of the sample after bonding is shown in Fig.4 where the LED mesa pattern, the ring electrodes and the mesh electrodes are simultaneously observed. The light emission was clearly observed in bonded LEDs as shown in Figs.5 and 6 where the LED size and the LED current are changed as parameters. The uniform light emission was obtained even when the LED size was reduced from 240um to 100um in a diameta and the LED current was increased from 0.1mA to 0.5mA. Next,the basic operation of the optical coupling sense amplifier in the ORAM-bus memory was examined using the fabricatde test chips. LED was placed on the photodetector of the optical coupling flip-flop. In order to avoid the erroneous operation caused by the stray light, the surface of test chips was covered by the aluminum mask except for the photodetector regions. The measured operation waveforms are shown in Fig.7. It is clear from the figure that the electrical read /write operation and the optical write operation are successfully performed although only writing operation for data "1" is shown for the optical writing.

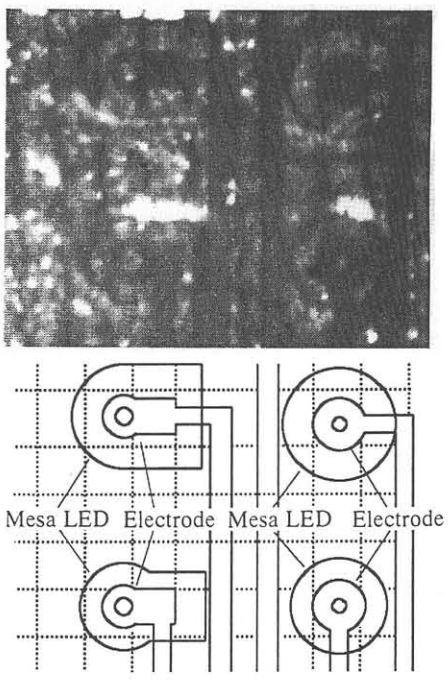

Fig.4 Infrared photomicrograph of bonded LEDs.

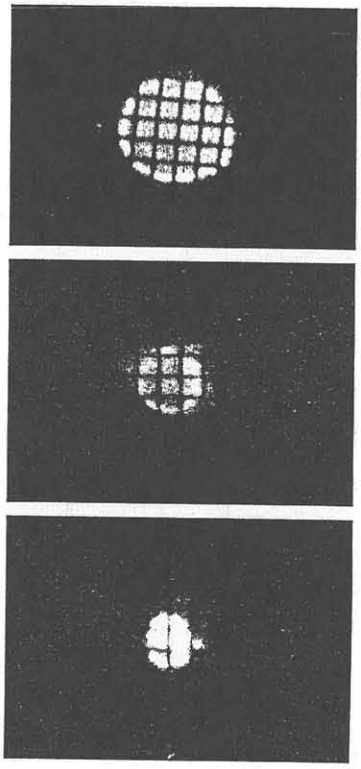

Fig.5 Observed emitted light from bonded LEDs with current of 0.1mA changing the LED size.

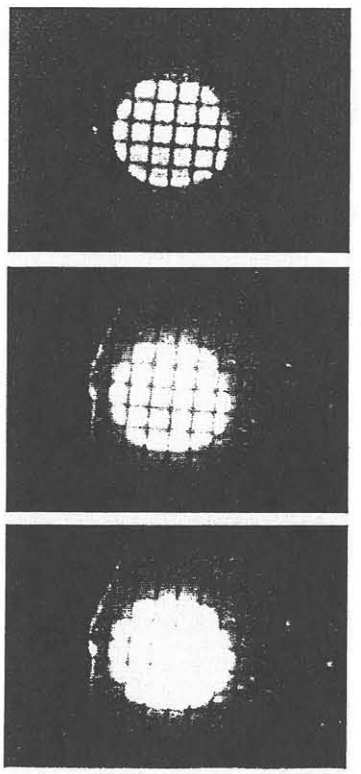

Fig.6 Observed emitted light from bonded LEDs with the diameter of 240um changing the LED current.

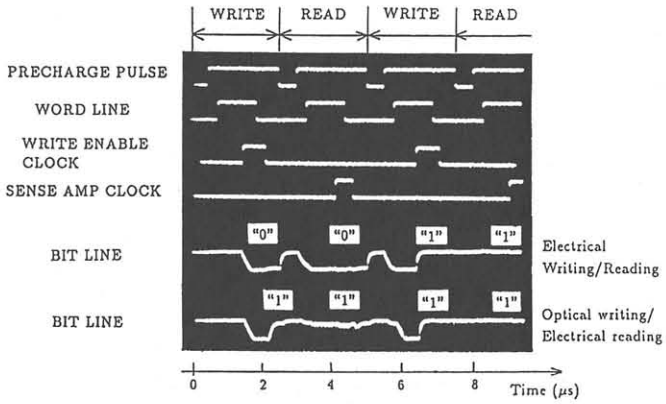

Fig.7 Measured operation waveforms in ORAM-bus memory test chip.

4. CONCLUSION

A new ORAM-bus memory system with the parallel data transfer function using the optical interconnections was proposed. It is possible in this memory system to achieve the equivalently very high data transfer speed of 100～200Gbit/s using one thousand of guided optical interconnections. The micro-bonding technique was developed to integrate the LEDs on such ORAM-bus memory chips. A very uniform light emission was obtained in the bonded LEDs. The ORAM-bus memory test chips were fabricated using 2um CMOS technology. It was confirmed in this test chips that the optical writing operation for ORAM-bus memory can be successfully performed.

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