Extended Abstracts of the 1996 International Conference on Solid State Devices and Materials, Yokohama, 1996, pp. 646-648

Polyimide Optical Waveguide with Multi-Fan-Out for Multi-Chip Module Application

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The polyimide optical waveguide with multi-fan-out has been develpoed. This polyimide optical waveguide can be used as the optical intercon nection to connect many LSI chips in a multi-chip module system. The propagation direction of signal light is changed from the horizontal to the vertical and from the vertical to the horizontal by using aluminum micro-mirrors in this waveguide. We demonstrated that the light signal introduced into the waveguide impinges on the photodiode after bending the propagation direction by aluminum micro-mirror and then induces a significant increase of the photodiode current.

1. Introduction

The performance of LSIs has been dramatically improved by scaling-down the device size. A microprocessor chip with the clock frequency higher than 400MHz has been already reported. A processor chip operated at the clock frequency over 1GHz will be developed in the near future. Thus, it is prospected hereafter as well that the internal clock frequency of LSI chips continues to dramatically increase by scaling-down the device size. However, it is a big problem that such improvement in the LSI chip performance does not always lead to the improvement of the system performance due to a bus-bottle neck in the future as long as electrical buses are used to connect the LSI chips. Therefore, it is very important to develop a high performance bus with high data rate in order to dramatically improve the system performance. The optical interconnection is expected as a candidate for such high performance bus.

As an example of systems with optical interconnection, we have proposed multi-chip module (MCM) system as shown in Fig.1 where a processor chip and many memory chips (Optical RAM-bus DRAM chips) are connected by many optical interconnections which act as high speed multi-bus[1]. A block of data are simultaneously transferred from the built-in cache memories in Optical RAM-bus DRAM chips to the processor chip through the optical interconnections in this system. Therefore, very high data rate can be achieved. We have developed the polyimide optical waveguide with multi-fan-out for this system. The multi-fan-out was achieved by using aluminum micro-mirrors. A mesh type optical waveguide with multi-fan-out has been also developed for the mesh-connection type parallel processor system as shown in Fig.2

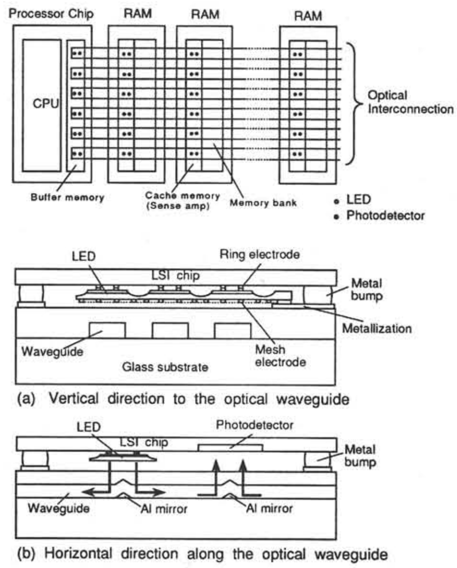


Fig.1 Multi-chip module with optical interconnection.

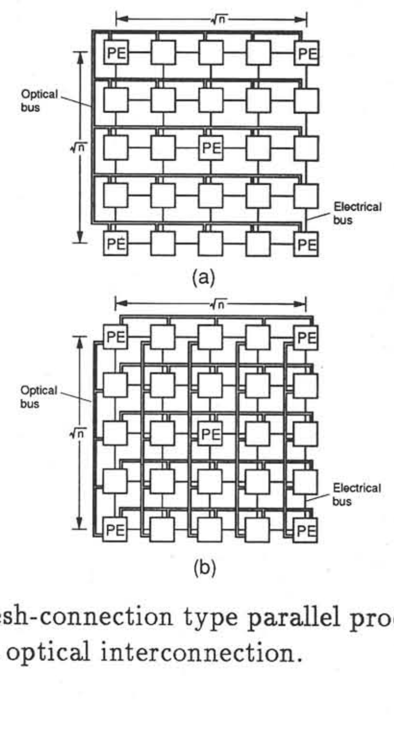


Fig.2 Mesh-connection type parallel processor system with optical interconnection.

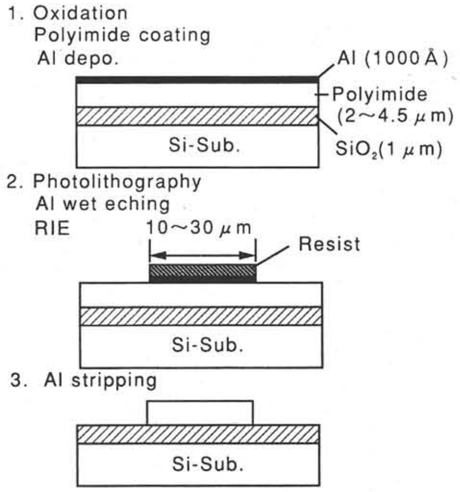


Fig.3 Fabrication sequence of polyimide optical waveguide.

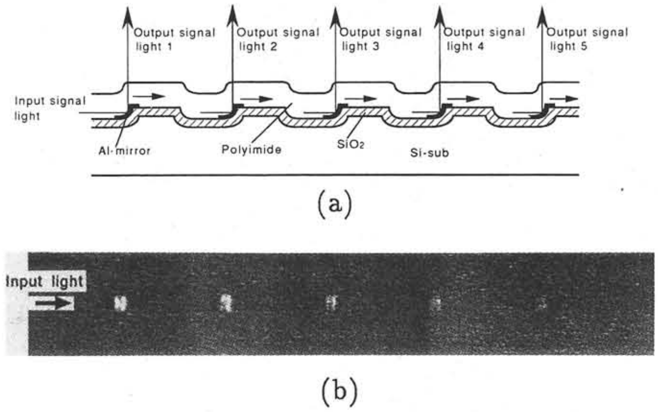


Fig.4 Polyimide optical waveguide with micro-mirrors (a) and photomicrograph of output signal lights vertically reflected by micro-mirrors (b).

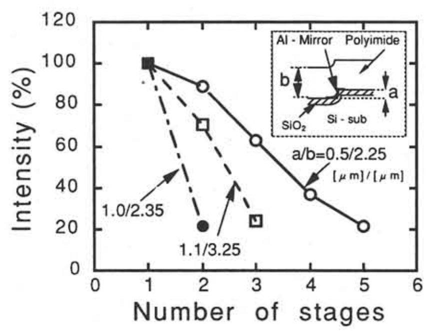
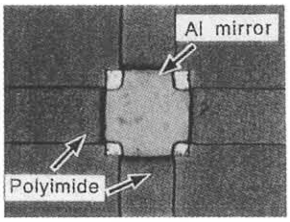


Fig.5 Output light intensity as a function of the number of the mirror stage in multi-stage micro-mirrors.

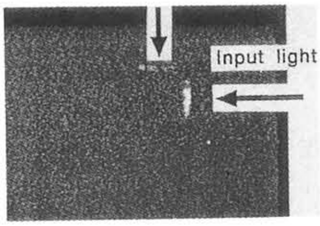
where the optical interconnection is employed as the global bus. In this paper, we describe a new polyimide optical waveguide with multi-fan-out developed for the multi-chip module system.

2. Experimental Results

In order to fabricate the polyimide optical waveguide, a polyimide film (refractive index n=1.65) with the thickness of 2 to 4.5μm spin-coated on the oxidized silicon wafer is patterned using O_2-RIE method as shown in Fig.3. Such polyimide optical waveguide is formed onto the oxidized silicon wafer with several steps on its surface. The step is formed by chemical etching. Aluminum micro-mirrors with the thickness of 150nm are formed on the steps. The propagation direction of signal light is changed from the horizontal to the vertical or the vertical to the horizontal by these aluminum micro-mirrors. In the case of Fig.4, the horizontal signal light is bent to the vertical direction. It is clear in Fig.4(b) that five output signals are obtained from one input signal. Thus, the optical waveguide with multi-fan-out can be easily achieved by using the polyimide and the aluminum micro-mirror. It will be possible to obtain more than 10 fan-outs by optimizing the step height of micro-mirror and the polyimide thickness although the maximum fan-out at present is 5 because they are not optimized yet as shown in Fig.5 where it is shown that the output signal intensity decreases after passing through the micro-mirrors. The polyimide optical waveguide with micro-mirrors for the mesh-connection type parallel processor system is also fabricated as shown in Fig.6 where two optical waveguides are crossing each other. As is obvious in the figure, the vertical output signals are obtained for two horizontal input light signals (2 fan-ins) which are simultaneously introduced into the waveguides from the right-hand side and the upper-side. Two horizontal light signals are crossing and then passing through each other after parts of signals are reflected to the vertical direction by aluminum micro-mirror. The test circuits and test systems as shown in Figs.7 and 8 are fabricated in order to confirm the basic operation of the system which uses the polyimide optical waveguide with multi-fan-out. LSI chip is bonded onto the optical plate with the the polyimide optical waveguide with multi-fan-out using the micro-bonding technique in the test system shown in Fig.8. A wafer aligner , which has been newly developed, is used to precisely align the LSI chip to the optical plate[2]. Infra-red light is used for the alignment in this wafer aligner. The changes of the photodiode I-V characteristics when the signal lights impinge on the photodiodes through the polyimide waveguide with multi-fan-out are shown in Fig.9. A significant increase of the reverse photodiode current is observed even for the fourth fan-out. Thus, it



(a)



(b)

Fig.6 Photomicrograph of mech type polyimide optical waveguide with aluminum micro-mirror (a) and the vertical signal output for two input light signals (2 fan-ins) (b).

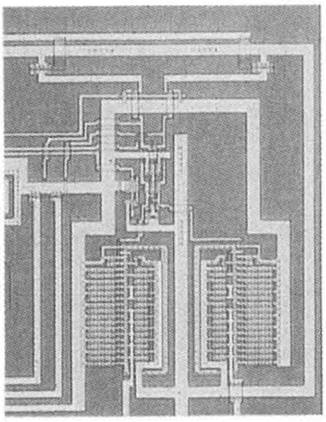


Fig.7 Test circuit with SOI phototransistors for optical interconnection.

was confirmed that the polyimide optical waveguide with aluminum micro-mirrors is very suitable as the optical interconnection to connect many LSI chips in multi-chip module system.

3. Conclusion

We developed the polyimide optical waveguide with multi-fan-out which can be used as the optical interconnection to connect many LSI chips in a multi-chip module system. The propagation direction of signal light is changed from the horizontal to the vertical and from the vertical to the horizontal by using aluminum micro-mirrors in this waveguide. A mesh type optical waveguide with multi-fan-out also developed for the mesh-connection type parallel processor system where the optical interconnection is employed as the global bus. Furthermore, we demonstrated that the light signal introduced into the waveguide impinges on the photodiode after bending the propagation direction by aluminum micro-mirror and then induces a significant increase of the photodiode current.

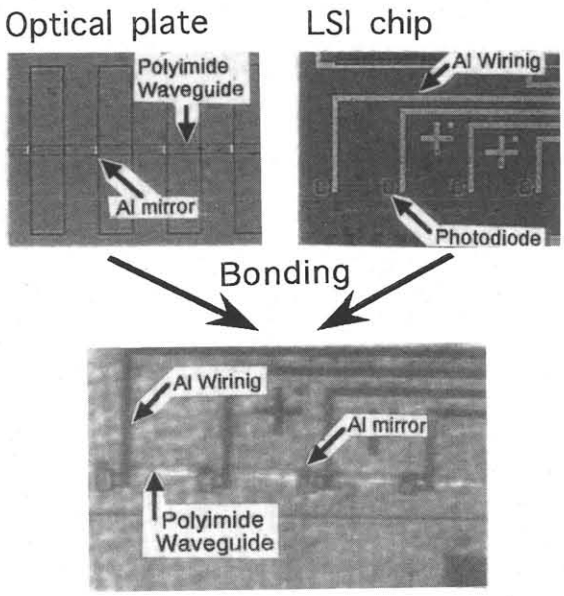


Fig.8 Infrared light image of test system after bonding LSI chip onto the optical plate.

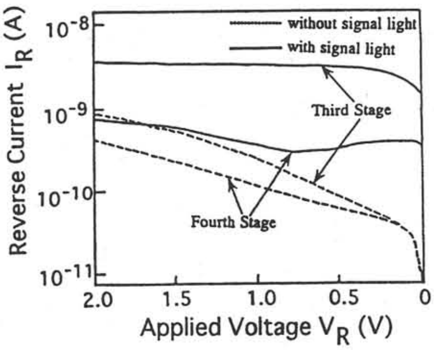


Fig.9 Changes of photodiode I-V characteristics caused by light signal which impinges onto the photodiode.

Acknowledgment

Authors would like to thank to Mr. N. Satoh of Hitachi Chemicals Ltd. for supplying polyimide samples.

References

[1] T. Matsumoto et al., Ext. Abstr. SSDM'95, p.1037 (1995)

[2] T. Matsumoto et al., Ext. Abstr. SSDM'95, p.1073 (1995)