1 Introduction

1.1 Electrical Interconnect and Optical Interconnect

Although higher component cost and ease of assembly continue to be challenges for the technology to substitute copper for applications with shorter transmission distances (typically within data and telecommunication systems), data transmission through optical fiber has provided significant advantages in terms of transmission distance and bandwidth compared with copper over long distances. For shorter transmission distances, the benefits of using optical technologies have been compromised by cost and performance improvements in copper based technology. Particularly in the areas of cable connecters and printed circuit board electrical performance, they are simpler, cheaper, and reliable. However, the increasing speeds being seen for optical communications are increasing the speed and frequencies being used in telecom and datacom equipment, which is causing electrical interconnection to be pushed to its limits.

The problem with electrical interconnections at higher frequencies is that the electrical losses through the copper traces become much higher; reducing the distance that the electrical signal can travel. All transmission of electrical energy results in the loss of electrical energy as the electrical current travels along the conductor. It can be lost though several ways including:

1) The heating effect generated by the resistance of the conductor.
2) The effects of the dielectric loss of the isolating dielectric materials.
3) Electrical field skin effects on the conductor – high frequency loss

This problem is well known at a large scale for electrical power transmission, where utility companies need to carefully plan how electricity is transmitted to end users without significant amounts being lost in the distribution network.[1, 2]

Optical boards solutions have been proposed for the upcoming electrical interconnect bottleneck for over 20 years. Presently, three types of optical board technology are emerging: [3-6]

• Buried Optical Glass Fiber.

• Buried Glass Waveguides.

• Buried Polymer Waveguides

There are three basic methods for the interconnection of optical technology for a system. The most suitable will depend upon the application and how far the optical element penetrates into the system itself.

Discrete Optical Fiber Interconnect

Discrete optical fiber interconnect represents one of the most common and fundamental means of interconnecting optical signals within a system today. As the title suggests, it uses discrete optical fibers and separable optical connectors to interconnect modules and components on one daughter card to another within a rack connection. Figure 1.1 illustrates a typical configuration using this approach. [1, 5]

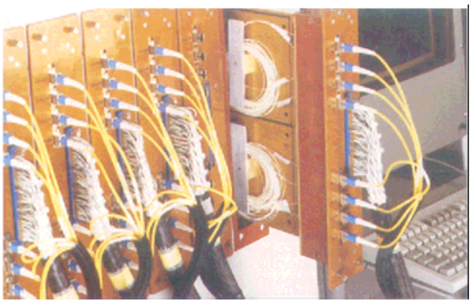

Figure 1.1 *Discrete optical fiber interconnect*

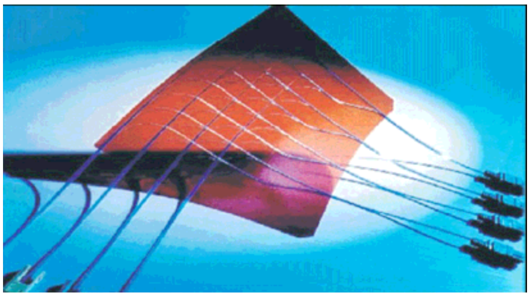

Figure 1.2 *Flexfoil optical interconnection*

A range of optical connectors is now widely available to realize such constructions. Typically MT-based multi-fiber connectors and ferrules are used including the MTP and MTRJ connector. This optical interconnect approach is simple, relatively low cost and offer high performance “point to point” interconnection for critical transmission lines within a rack system. Such an interconnection method is covered in this report, only as it represents the current interconnection point of many systems that utilize optical technology.

Flexfoil/ Buried Fiber Optical Interconnection

Advanced Interconnection Technology Incorporated (AIT) of Islip, New York, USA was one of the first companies to develop a “Flexfoil” optical interconnect technology (see Fig. 1.2). The alternative variation is to carry out a similar manufacturing process but to bury the fibers in a rigid board. This then allows the optical elements to be combined with the electronic part of the backplane system, which can then be incorporated in a cabinet format. This potentially saves converting optical signals an electrical signal and then back into an optical one when it can remain optic. This can save on electronics high cost connectors and reduce losses that are inevitable by OEO conversion. Here optics is penetrating into the system itself but here only passively. [1]

Electrical and Embedded Polymer Optical Interconnects

The third technology, which has only just recently emerged, is embedded optical waveguides in conventional printed circuit board technology, which is presently very attractive because of their potential of ease, low-cost manufacture and well compatible with SMT (Surface Mounted Technique) of standard PCB production. The final product will be the Electrical-Optical-Circuit-Board (EOCB) which is illustrated in Fig. 1.3. [7-10]

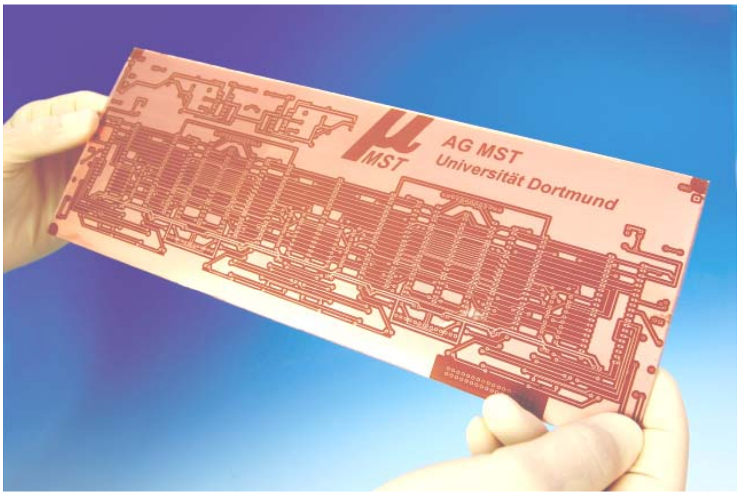

Fig. 1.3 *Electrical-Optical-Circuit-Board (AG MST)*

The basic idea of the EOCB concept is the combination of common PCB carriers with embedded polymer optical waveguides layer. But this has to be carried out with consideration of the interface processes: board fabrication and system assembling, and its basic figure are illustrated in Fig. 1.4.

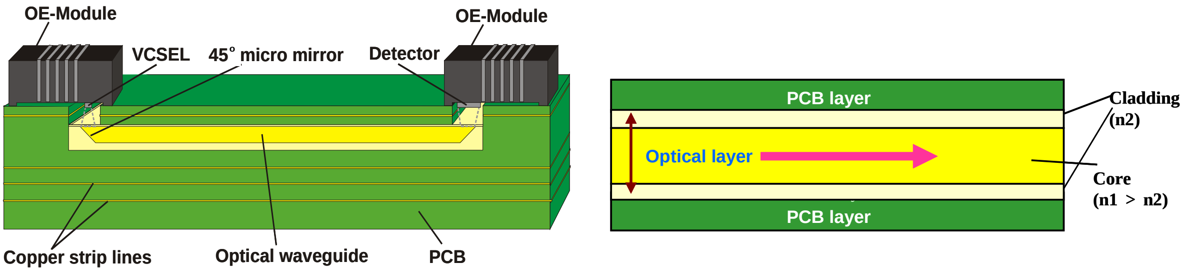

Figure 1.4 *Concept of EOCB with coupled optic-electric modules*

In the whole optical transmission system, it contains passive and active parts. The passive components involve both electrical and optical “wiring”. Then active devices like VCSELs and PINs are coupled to the waveguides through 45° high reflectance mirrors. The polymer waveguide structure consists of three layers, i.e. top cladding layer, core layer and bottom cladding layer. In order to keep the light only to be transmitted in the core optical layer, the basic condition: refractive index $n_{core}>n_{cladding}$ must be fulfilled.

1.2 State-of-Art of Polymer Optical Interconnect

As mentioned, polymers have many excellent properties over silica. However, some drawbacks exist. Most polymers are unstable under high temperature and humidity conditions. Upon thermal aging, polymers can yellowish due to the oxidation. They have greater optical losses than silica and their chemical resistance is lower. However, many of these can be modified, and this makes them attractive materials for fabricating the optics on board.

Key parameters affecting the optical polymer waveguide are the core material and the waveguide index profile. The core material determines the attenuation characteristics and operating temperature, whereas the index profile limits to the maximum bandwidth (bit rate). Some of the key qualitative properties for waveguide materials are listed below. [10]

- Good refractive index control and low birefringence
- Intrinsic absorption loss, low optical scattering loss and low polarization dependent loss
- Low cost and environmental friendly material and low material processing loss
- High thermal stability, good environmental stability and good mechanical

strength

- Similar coefficient of thermal expansion (CTE) value as the other materials in use.

Nowadays in world-wide scale multiplicities of research groups at universities, institutes and in the industry are partly commercial developing optical materials (see Table. 1.1) for polymer waveguide fabrication, identifying respective fabrication procedures and are converting them into the manufacturing processes as well. In Tab. 1.2 it is listed about the results of the most important groups working in the area of the electrical-optical printed circuit board as well as the introduction of their research progress and solution which are embodied mainly on. e.g. fabrication methods, the optical propagation loss of EOCB products, temperature stability and products sizes etc.

Tab. 1.1 *Commercial optical waveguides materials*

Company/ Groups	***Material***	***Optical loss @850nm [dB/ cm]***
Exxelis Ltd./ Terahertz, GB[11, 12]	*Truemode Backplane* ™	0,04
Zen Photonics Co. Ltd., Korea[13]	*WIR30-470/WIR30-450, ZPU12-455/ZPU12-450*	0,16
Optical Crosslinks, Inc./ DuPont, USA[14]	*GuideLink*™/ *Polyguide*™	0,08
Dow Corning Corp., USA[13, 15]	Polysiloxane	0,04
Rohm & Haas Co./ Shipley, USA[16]	*LightLink*™ (Siloxane/ Silsesquioxane)	0,03
Micro resist technology, De[17]	*EpoCore/ EpoClad*	0,1-0,2
Micro resist technology, De[18]	*ORMOCER*™	0,10
MicroChem, USA[19]	*SU-8*	0,36
Luvantix Co., Ltd., Korea[20]	*EFIRON WR*-Series	0,20

Tab. 1.2 *Overview of EOCB research group*[21]

Group	***Fabrication***	***Core material***	***Size [cm]***	***Optical loss @850nm [dB/ cm]***

Group	*Fabrication*	*Core material*	*Size [cm]*	*Optical loss @850nm [dB/ cm]*
IBM[21]	UV-ML, Laser-Writting	Acrylate, Polysiloxane	50×50	0,04
DChr[22]	Laser-Writting	N. A.	103	0,04
Gemfire[23]	Laser-Writting	Polysiloxane	10	0,05
Intel[24]	Photo-Bleaching	Acrylate	20	0,10
ETRI (1) [25]	Hot Embossing	COC	8	0,10
NTT[26]	UV-ML	Epoxy	1	0,10
OPERA[27]	UV-Embossing	UV-Glue	N.A.	0,10
ITRI (2) [28]	Injection	Opt. Glue	17	0,12
TUDD[29]	Injection	Acrylate-Glue	6	0,12
IMEC[30]	Laser-Ablation	Truemode™	7	0,13
Hitachi[31]	UV-ML	Epoxy	6	0,15
UTex (1)[13]	Softlithography	Fluor. Acrylate, ZenPhotonics	N.A.	0,16
Fujitsu[32]	UV-ML	Epoxy, Nippon Steel Chem.	15	0,20
Gatech (1) [33]	UV-ML	Epoxy-Siloxane	14	0,24[1]
IZM[34]	Hot Embossing	UV-Glue in COC	12	0,30
KAIST[35]	UV-ML	SU-8™	5	0,36
Gatech (2) [36]	UV-ML	BCB	N.A.	0,36[1]
ETRI (2) [37]	UV-Embossing	ZPU, ZenPhotonics	N.A.	0,40[2]
ULin[38]	UV-ML	Omocer™	10×10, 60×60	0,50
VTT[39]	UV-ML	SU-8™	10	0,60
UTex (2) [40]	Softlithography	SU-8™	4	0,60
ITRI (1) [41]	UV-ML	SU-8™	10	N.A.
GE[42]	UV-ML	Epoxy-Polysulfone	N.A.	N.A.