GLASS ON SILICON TECHNOLOGY FOR OPTICAL INTERCONNECTIONS AND OPTOELECTRONIC HYBRID INTEGRATION

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Key words: optoelectronics, glass on silicon, optical interconnections, optoelectronic integrations, hybrid integrations, optical communications, optical telecommunications, information processing, optical guides, self aligning procedures, cost reduction

Abstract: Optoelectronic integration has been widely recognised as a very important step to further increase the competitiveness of optical technologies in communication and information processing. Despite the impressive development effort on a monolithic technology, based on semiconductor InP and GaAs substrates, which has been carried out until now with quite promising feasibility results, it is still quite far in its present implementation from being suitable for economic product development. Therefore, a less ambitious target may be set by choosing an hybrid approach, where optical interconnects can be realised on a specific substrate and active components (Lasers and PINs) are mounted on this substrate by a die attach process, eventually aligned to the optical guides with self aligning procedures. The Glass on Silicon technology developed by Italtel, which will be described in this paper, is an example of this approach, and could be applied very quickly to the development of specific components and modules for optical telecommunications system, with many clear advantages in terms of cost reduction and mass production capability, with the support of very efficient CAD tools for the design of complex, multifunctional optical subassemblies[1]

Tehnologija stekla na silicijevem substratu za izvedbo optinih povezav in optoelektronske hibridne integracije

Ključne besede: optoelektronika, steklo na siliciju, povezave optične, integracije optoelektronske, integracije hibridne, komunikacije optične, telekomunikacije optične, procesiranje informacij, vodi optični, procedure samonastavljive, zmanjšanje stroškov

Povzetek: Veliko ljudi že priznava optoelektronsko integracijo kot zelo pomemben korak k povečanju konkurenčnosti optičnih tehnologij v komunikacijah in obdelavi informacij. Navkljub prepričljivemu razvoju monolitne tehnologije na osnovi polprevodniških InP in GaAs substratov, ki je potekal do sedaj z obetajočim uspehom, je le-ta na sedanji stopnji razvoja že dokaj daleč od tega, da bi bila primerna za razvoj ekonomičnega proizvoda. To pomeni, da si v tem trenutku lahko zastavimo manj ambiciozen cilj, to je hibridni pristop, kjer optične povezave izdelamo na specifičnem substratu, dodamo pa aktivne komponente (laserje in PIN diode) v čip obliki, ki jih pritrdimo na ta substrat in poravnamo z optičnimi vodniki s samonastavljivimi poravnalnimi postopki. Tehnologija stekla na siliciju, ki jo je razvila firma ITALTEL, in ki jo opisujemo v tem prispevku, je primer takega hibridnega pristopa. To tehnologijo lahko hitro uporabimo za razvoj specifičnih komponent in modulov za optične telekomunikacijske sisteme z jasnimi prednostmi glede zmanjševanja stroškov in možnosti velikoserijske proizvodnje ob uporabi zmogljivih CAD orodij za načrtovanje zamotanih večfunkcijskih optičnih podsestavov.

1. INTRODUCTION

Packaging and assembly processes still make up a large part of the manufacturing cost in the fabrication of optoelectronic components and subsystems. Besides high cost, which is limiting the penetration of optical fibres in the distribution network, available technologies do not efficiently support the batch fabrication of complex optical interconnection schemes, which are increasingly needed for optical switching and multiwavelength networks in order to become practical applications. Monolithic integrated optics has been considered for a long time a main research and development road to overcome these difficulties, by considering the analogy with the microelectronics case. Unfortunately, until now, encouraging results are still largely confined to laboratory feasibility, due to the intrinsic complexity and low yields of the required technologies, which put the economic convenience of the huge investments needed to implement a true high volume manufacturing capability for optical integrated circuits somewhat at risk. Even from a conceptual point of view, it became clear that a fundamental difference exists between integrated optics and electronic integrated circuits: for a VLSI chip only one basic building block is required (a silicon transistor), which relies on a well known and mature substrate technology; instead, the substrate for an integrated optic device may be chosen from a large variety of options (GaAs, InP, Silicon, glass, $LiNbO_3$, to mention the most popular choices), and the building blocks may include light sources and photodetectors, optical waveguides,

[1] This paper is the second of a series, which will be presented in MIDEM during 1994, concernig advanced topics in optical technologies and systems. The first contribution has been devoted to optical amplifiers and the last one will discuss a specific application to multiwavelength transport networks

passive optical components and light modulators, each one realised with a specific design and technology, generally with very limited, or none at all, mutual process compatibility. Therefore, apart from a very limited number of cases (the PIN photodetector with integrated FET preamplifier, for instance), the performance of integrated optoelectronic devices is generally worse than their discrete assembled equivalent version. In fact, elementary optical functions integrated on a monolithic chip are far less optimised due to process compatibility reasons, with respect to the same functional result achieved with discrete devices.

By considering the above aspects, a more realistic and practical approach than monolithic integrated optics may be based on the choice of a substrate material optimised for optical passive waveguide fabrication, on which discrete active optoelectronic devices may be mounted by a suitable hybrid assembly procedure and easily selected for a specific application. In our case, a silica layer deposited on a silicon substrate by a chemical vapour deposition technique was selected for waveguide formation; on the same silicon substrate, well known dry and wet etching, dielectric and metallic thin films deposition processes and photolithography can be used for waveguide patterning and metallic mounting pads formation. The final result is an hybrid assembly platform, suitable for a large variety of optical and electrical interconnection schemes and micromechanical alignment for efficient optical coupling, which could give to the photonic applications the same flexibility in product development, which was allowed by the introduction in the electronic design and manufacturing by the well known printed circuit board.

The Glass on Silicon technology (GoS), which will be described in the following, has been developed by Italtel in cooperation with AT&T-Bell Laboratories, during a two years joint development agreement which has been just terminated in June 1994. In the framework of this agreement, Italtel holds a full manufacturing license for products based on the glass on silicon process technology, including those processes which were originally developed by AT&T alone. Most of the work described in this paper has been carried out by a joint team from ATT and Italtel, in the ATT- Microelectronic and Bell Laboratories research facilities, in Breinigsville (PA) and Murray Hill (NJ).

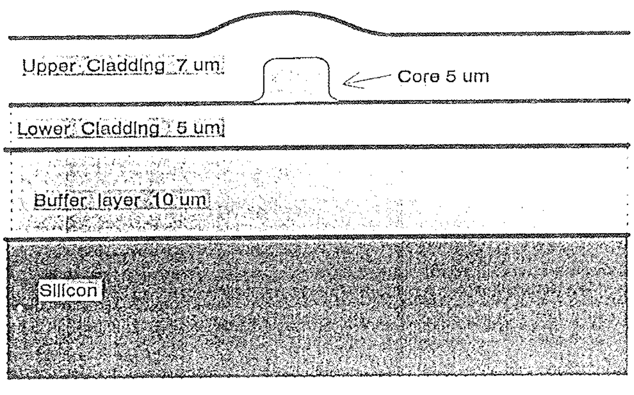

Fig. 1: *Cross-section of silica waveguide grown on Silicon substrate*

2. GLASS ON SILICON TECHNOLOGY

2.1 Waveguide deposition

A typical waveguide structure is formed on a 4" silicon substrate 0.5 mm thick; a 10 μm thick SiO_2 buffer layer is deposited first, by an high pressure oxidation process (High Pressure Oxidation, HIPOX), to avoid any optical leakage into the silicon substrate. The first cladding layer of the planar waveguide (5μm, P doped SiO_2) is deposited next, by a low pressure chemical vapour deposition, followed by a 1000°C annealing for densification and to remove the residual stress in the layer. The core waveguide layer (5μm) is then deposited by a similar process; the required refractive index for the core layer is controlled by varying the Phosphor doping and the deposition temperature. The silicon wafer is then processed through a photolithography and a dry etching process for two dimension rectangular waveguide patterning, followed by a 900°C annealing which rounds the waveguide corners and improves the layer optical characteristics. Finally, an upper cladding layer is deposited, which completes the waveguide structure (Fig. 1)

The waveguide shape is roughly a semi-circle, with a 5μm diameter; the refraction index step is of the order of 0.5 %, and intrinsic losses as low as 0.01 dB/cm have been measured; other typical waveguide parameters are reported in Table 1.

Table 1: Glass on Silicon waveguide parameters

index of refraction step, $\Delta n/n$ (%)	0.5
core size diameter (μm)	5
waveguide loss (dB/cm)	0.03
fiber coupling loss (dB)	0.1
bend radius (mm)	15
coupler excess loss (dB)	0.2
Coupling length (mm)	2 ± 0.3

2.2 Wafer processing and micromachining

In addition to the waveguide fabrication, other wafer processes have been developed, in order to obtain a number of basic building blocks for a flexible implementation of complex functionalities. Most of these processes are readily available with little or no modifications from silicon microelectronics technology, and can be implemented on high throughput processing machines. In particular, current development work is under way on 4" silicon wafers, but all the machinery is already equipped with jig adapters suitable for handling 6" wafers. In addition to the already mentioned CVD process, which will use two 4-stack BTU furnaces for doped SiO_2 and polysilicon deposition, standard processing facilities include Reactive Ion Etching, Plasma Enhanced CVD, for thick and low temperature oxide deposition, dielectric and metal thin film sputtering and metal deposition equipment.

Micromachining of the silicon substrate by using selective and anisotropic wet etching allows to reach submicron fabrication tolerances for the creation of 3D features on the substrate (steps, recesses, holes and V-grooves for instance), which may be used as mechanical references for self- alignment of various optical components (lasers, photodetectors and optical fibres) with the waveguides grown on the substrate. A few simple results already achieved in this area will be described below, as a good example of the potential of this process technology. It should be noted that, since the etching depth generally required for these applications is an order of magnitude larger than in the microelectronic case, little or no help is available from established specific silicon technology, and therefore new process development has been carried out.

2.3 Packaging

Packaging issues have always been a critical factor in optical and optoelectronics devices development, in particular with respect to cost targets and volume production capability. Therefore, an important long term objective for the GoS technology is to achieve complete automation in the assembly and packaging procedures, in particular without any need for active alignment for optical coupling; as a necessary condition for high production volume and low manufacturing cost. While substantial development work is still required to achieve this goal, some guidelines have already been established and tested with an encouraging degree of success; in particular:

1. a batch procedure has been defined, by a selective metallisation scheme, which allows the self-positioning of a semiconductor chip (Laser or photodetector) on the silicon substrate during the die attach, with better than 1 μm tolerance in position and less than 10 mrad misalignment of the chip edge with respect to a selected direction, starting with a relatively loose tolerance of the initial placing (20- 30μm in position, and 20° - 30° degree for the chip edge)

2. a quite complex procedure has been developed to etch a 45° degree mirror for vertical extraction of optical radiation from planar waveguides; in combination with the above process 1., then it has been possible to self-align a PIN photodetector directly with the waveguides by a batch process at the wafer level, as a good example of a truly hybrid optical integration.

3. a simple and economic lid cover technology has been developed to fabricate by etching specific recesses in Silicon to be placed in correspondance with chip positions on the substrate. The lid cover is then mounted in place by a selective die attach process on the hybrid optical circuit to achieve an high optical and electrical crosstalk immunity. The lid also allows for an hermetic seal of active devices and reduces outside electromagnetic interference. Moreover, most of the remaining work on the hybrid circuit (the fiber attachement for instance) can be carried out with delicate components on the circuit well protected and safeguarded, in such a way as to achieve high yield in testing and packaging operations.

4. the use of a plastic housing, allowed in conjunction with the hermetic silicon lid, as a final package, may further reduce the cost and increase the possibility of using different standard packages while mantaining the quality and reliability level mandatory for telecommunication applications.

The above mentioned steps clearly indicate that the glass on silicon technology holds the potential for achieving a breakthrough in optoelectronic assembly and packaging technologies; in particular, the intrinsic high yield batch process technology could be used to obtain a very low cost high volume production capability for simple devices (A packaged laser or photodetector), or to achieve an industrial standard for manufacturing complex multifunctional optoelectronic modules, with high yield and reasonable cost. A simple sketch of the potential described above is illustrated in fig. 2, which refers to a bidirectional optical transceiver, capable of using two carrier wavelengths for sending and receiving data signals simultaneously on the same optical fibre; all the functions described in fig.2, with the exception of the integral mounting of the laser source, are already available as engineered building blocks for the implementation of GoS hybrid integrated optic devices.

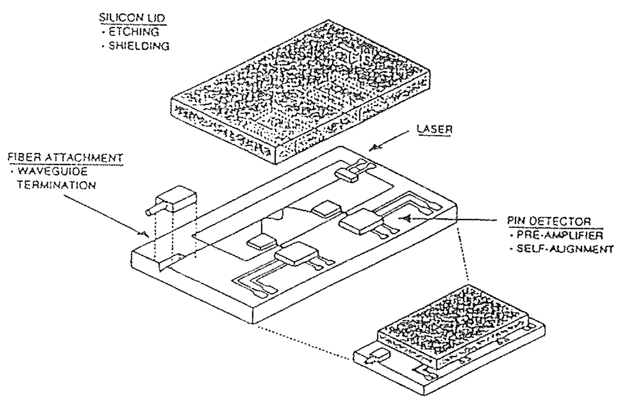

Fig. 2: Example of a Glass on Silicon integrated optoelectronic module

3. PASSIVE COMPONENTS DESIGN

Key functions in integrated optic devices are supported by passive optical components; in fig. 2 for instance the wavelength demultiplexing function, by which the incoming wavelength is sent to the photodetector, is implemented by the use of a planar waveguide structure well known in classical optics as a Mach-Zehnder interferometer. Complex passive components may be realised starting from several elementary optical elements: the straight and curved waveguide are the simplest examples of elementary passive optical component together with 3 db Y couplers and splitters. It should be noted that the bending radius of a curved waveguide is a critical design parameter /1/,/2/, since (for a fixed refractive index step between core and cladding in the waveguide) the radiation losses increase exponentially with decreasing bend radius. Therefore a compromise should be found between the optical circuit dimensions and the acceptable radiation losses; in our case, a bend radius of 15 mm is sufficient to keep radiation losses below 0.1 dB/cm. An important development issue therefore is how to increase the refractive index step in the guiding structure. Typical measured losses as a function of the bending radius for a curved waveguide are reported in fig.3, and the advantage of a higher index step may be clearly seen.

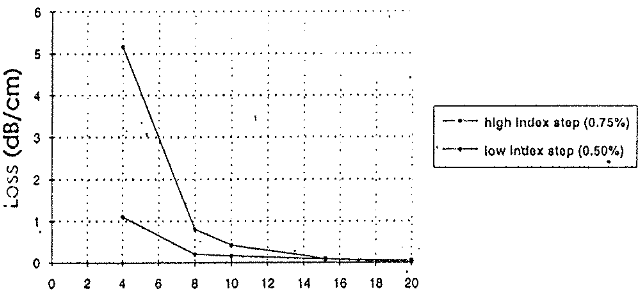

Fig. 3: *Bend losses of curved waveguides measured at the 1550 nm wavelength (TM mode)*

Even with simple elements it is possible to design quite complex optical interconnection schemes, which may offer relevant advantages in terms of quick design, simple manufacturing, reliable operation and very low cost. An example is shown in fig 4, which illustrates a 2 X 4 splitter for four fibre ribbon cable, designed and developed by Italtel for the Italian Public Operator TELECOM Italia, to be used in Passive Optical Network field trials, currently under way in Turin and Rome.

The integrated splitter will replace a bulky and fragile distribution box using fused fibre couplers and fusion splices manually assembled. It is interesting to note the use of waveguide intersections, which does not causes any measurable signal cross-talk, provided that the intersection angle is higher than a minimum value, which

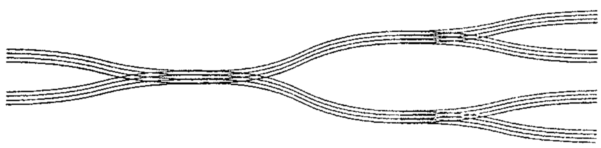

Fig. 4: *2X4 splitter for ribbon cable*

depends on waveguide parameters (around 30° degrees for this specific example)

3.1 Directional couplers

When two waveguides come into close proximity (at a distance of the order of magnitude of the guided wavelength) for a certain length, an energy transfer takes place between the waveguides; the effect is the optical equivalent of the directional coupling well known to microwave engineers, and is controlled (Fig. 5) by the operating wavelength, the coupling length L, and the waveguides spacing d. In a directional coupler the input and output waveguides should be single mode while the central zone should be bimodal at the wavelengths of

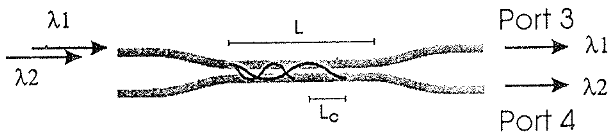

Fig. 5: *Schematic of a directional coupler*

interest. Due to the small branching angle, light is adiabatically coupled from the input branch into the double waveguide section. The two modes excited at a particular wavelength have different effective refractive indices and thus propagate at different velocities in this section. As these two modes interfere with one another the energy in the central zone oscillates from one waveguide to the other as the resulting phase difference between the two modes changes. Taking account of the distributed coupling in the input and output sections, this phase difference is given by:

$$\Delta\phi = \Delta\phi_{\text{central zone}} + \Delta\phi_{\text{branching zones}} = \Delta\beta L + \int \Delta\beta \, dz \qquad (1)$$

By ignoring the second term in this equation we can derive an expression for the coupling length in the central zone:

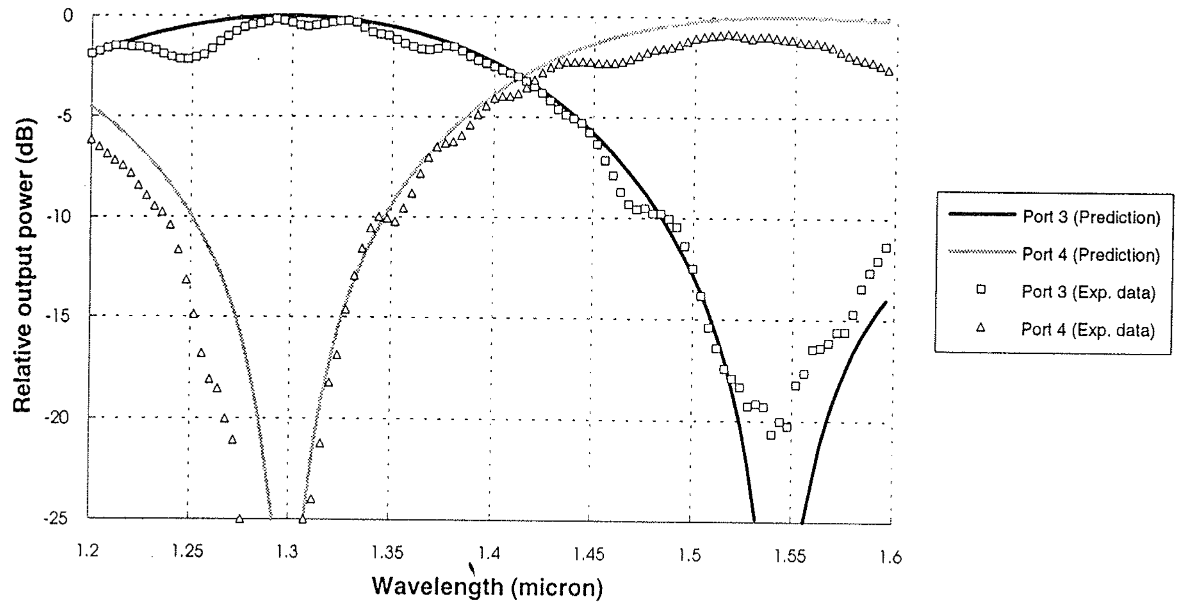

Fig. 6: Design prediction and experimental results of a WDM

$$L_c(\lambda) = \frac{\lambda}{2\left(n_{00} - n_{01}\right)} \qquad (2)$$

Multi/demultiplexing between two wavelengths may be achieved by choosing the length of the two waveguide section to be an even multiple of L_c at one wavelength and an odd multiple of L_c at the other.

The spectral characteristics of a directional coupler WDM are shown in fig.6, where excellent agreement is obtained between design prediction and experimental results.

3.2 Wavelength Division Multiplexers

The directional coupler principle can be used in a more complex structure (Fig. 7) based on two input ports, two 3-dB directional couplers, and a central section where one of the waveguide is longer by ΔL, in order to give a wavelength dependent phase shift between the two arms, and two output ports. The resonance conditions required for the multi/demultiplexing of two specific wavelengths are (at the output of the interferometer):

$$n(\lambda 1).\ \Delta L = m.\ \lambda 1$$

$$n(\lambda 2).\ \Delta L = (m \pm 0.5).\ \lambda 1$$

where $n(\lambda)$ is the refractive index and m is an integer.(the order of the interferometer).

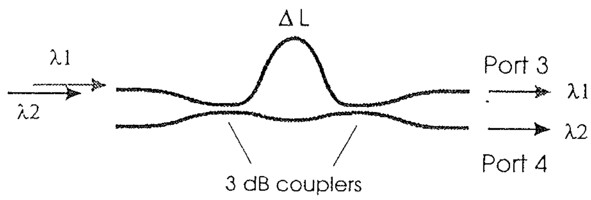

Fig. 7: Mach-Zehnder interferometer

The power from the input port divides between the two output ports in such a way that a specific wavelength can be adressed to each port. Therefore, the transmission characteristic of the Mach Zehnder interferometer allows the realisation of a wavelength division multiplexer or demultiplexer (WDM) where many optical carriers are being transmitted on a single fibre in a transmission network. While this principle was well known and applied for quite a long time, the new opportunity offered by the glass on Silicon technology is the full support from a computer aided design capability, which directly generates the photolitographic masks needed to implement the required design, with high accuracy and reproducibility. Moreover, the use of CAD tools would make it relatively easy to implement complex structure starting from more simple building blocks already designed and tested; for example, a four channel multiplexer, shown

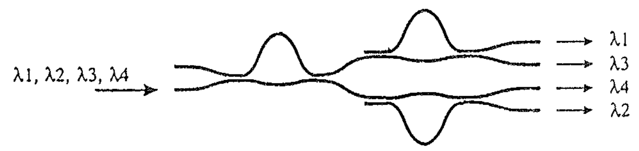

Fig. 8: Four channel WDM schematic

in fig. 8, is composed of three Mach Zehnder interferometer elements. The power from the input port divides among the four output ports, as a function of the selected wavelengths. the spectral characteristic of the four channels WDM is shown in fig.9.

The precise differences in path length required for the multiplexer design is easily controlled by the the mask fabrication process. With normal tolerances available in microelectronic masks, it would be possible to design multi channel WDM with channel spacing as low as 0.1 nm, the only limitation in channel number being the available wafer size.

The Mach-Zehnder interferometer is a basic building block in the design of a variety of optical control functions based on the splitting and combining of optical beams, normally as a function of their wavelength, which is controlled by the different optical length of the two interferometer arms. If this difference could be varied externally, a tuning capability would be added to the interferometer. In the case of devices built on an electrooptic material such as $LiNbO_3$, this effect is achieved by applying an electric field. In the GoS case, similar results has been experimentally demonstrated by NTT by using a thermo-optic effect /3/. In practice, a thin film NiCr strip heather is metallised on top of one interferometer arm, whose optical path length can be controlled by a thermorefractive effect due to current heating of the NiCr strip. Even if this effect is relatively slow, with response time of the order of milliseconds, it can be very useful in the development of complex multiwavelength networks as it would provide an economic solution to many wavelength control and routing problems, where only low speed processing capability is generally needed.

3.3 Multifunctional devices

More complex passive optical devices are at present under study to be implemented in the GoS technology; two examples will be shortly described here in order to give a simple demonstration of the potential of the approach. Both devices have already been tested in terms of feasibility in the ATT and NTT Laboratories.

With glass on silicon technology it is possible to implement waveguide patterns of NxM star couplers /4/,/5/,/6/ (N and M up to 256) as shown in fig 10. The input power from any one of the 256 channel waveguides in the input array is radiated to a slab region and received by the output array. The uniformity of the optical power distri-

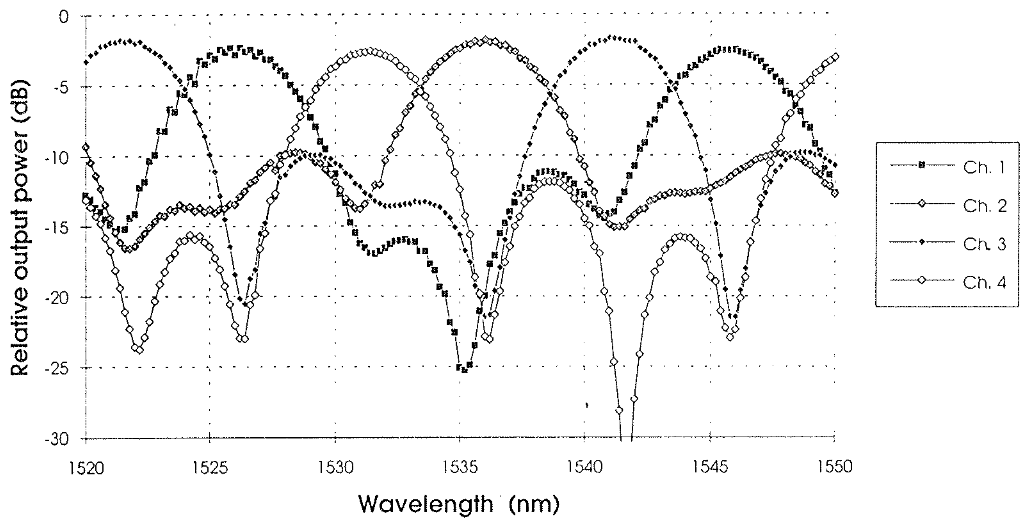

Fig. 9: Measurement of a 4 channel WDM with 5 nm channel spacing

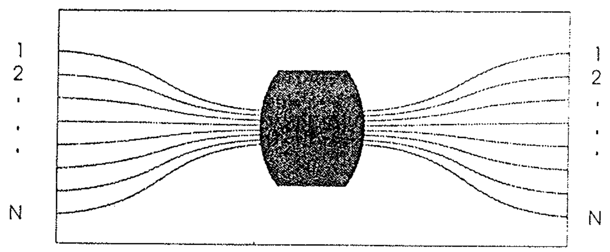

Fig. 10: *NxN star coupler*

bution was obtained by optimising the coupling conditions between adjacent waveguides in the input waveguide array. This device has the added advantage of being wavelength independent if properly designed.

Another complex device which has been realized using this technology is the NxN (N ≤ 8)switching matrix, as developed by NTT [7] and illustrated in fig 11.

This device allows the routing of an optical signal to any one of N output fibres. The routing is realised using a composition of N^2 elementary switches each of which is based on a symmetric Mach-Zehnder interferometer thermally tuned by an electrode. Both arms of the interferometer are of equal length (no geometrical path difference) and the optical path difference is varied by modifying the effective refractive index in one of the two arms by means of the thermooptic effect. This effect is generally slow (≈ 1 ms) but still quick enough for most routing applications.

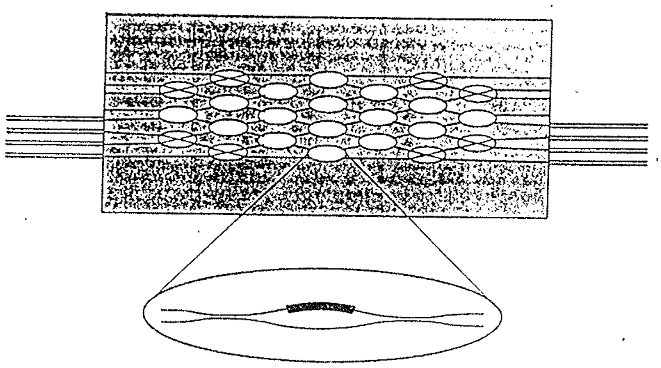

Fig. 11: *NxN switching matrix*

4. HYBRID ACTIVE INTEGRATED COMPONENTS

Assembly of active devices, such as lasers and photodetectors, on the Silicon substrate, with self alignement features with respect to passive elements (Fibres and planar waveguides) is another critical step to achieving a practical optical integration capability. Therefore, two basic processes have been established to develop the elementary building blocks for such functions.

4.1 Integrated photodetector (PIN-PAC)

The basic version of the integrated photodetector consists of a PIN photodiode mounted on a silicon submount and coupled to an optical fibre pig-tail (fig. 12).

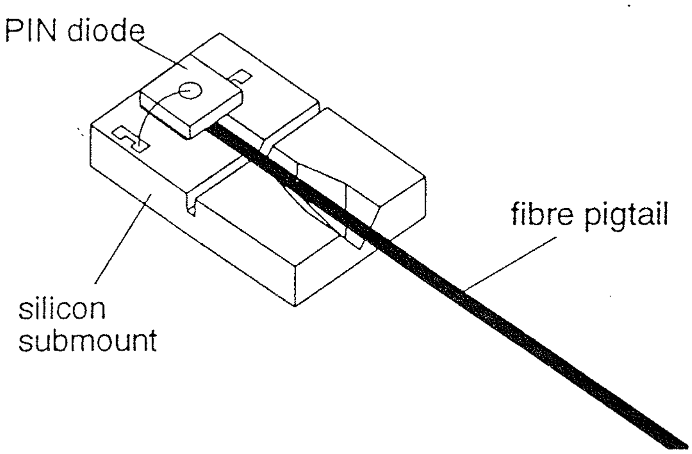

Fig. 12: *PIN-PAC integrated photodetector*

The basic characteristics of the PIN-PAC are:

1. the use of a 45° degree mirror to reflect the incoming light from the fiber pig-tail to the bottom illuminated photodetector soldered above it .

2. the use of anisotropic etching through a thick SiN or SiO_2 mask to form deep "V-grooves" in the Silicon substrate to house and fix the fibre pig-tail, with process reproducibility capable of achieving a 1µm tolerance in the position of the fibre, without any active alignement procedure.

3. the use of a particular metalisation pattern on the Silicon substrate and on the photodiode which makes possible the self-centering of the photodiode die with respect to the turning mirror position during the die-attach soldering process. This process can be done in a single step at the wafer level for hundreds of PIN devices simultaneously.

Therefore the PIN-PAC device is made without the need for individual optical alignement; the process is suitable to achieve both high production volume and very low cost. The assembly shown in fig 12 is a discrete device, which offers a very competitive trade-off between performance, cost and overall quality, with respect to currently available standard alternatives. In the case of an integratable photodetector, a similar but somewhat more complex process technology has been developed, in which the turning mirror is directly etched in the glass waveguide. In conclusion, the optical receiver function can be considered fully available for an hybrid integration in a Glass on Silicon optical IC.

4.2 Integrated photoemitter (Laser-PAC)

Intermediate results have been achieved so far in the case of the optical transmitter. A similar structure for a discrete device (Laser-PAC) (Fig. 13) has been developed, which already offers distinct advantages in terms of performance and manufacturing procedures with respect to standard laser modules, (the use of an integral microheather for the soldering of a metallized fibre pig-tail to the silicon submount, for instance) but still requires an active alignement procedure. Moreover, the Laser-PAC structure is not suitable for hybrid integration, even if a very simple coupling procedure can be used to join a fibre pig-tail of a few millimeters from the Laser-PAC to a "V-groove" on a separate Silicon substrate.

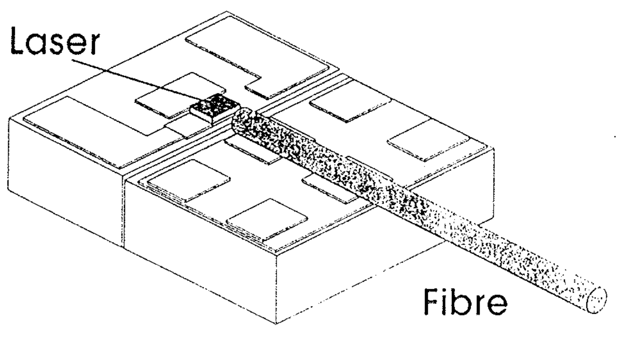

Fig. 13: Laser PAC

5. OPTOELECTRONIC MODULES APPLICATIONS

While most of the effort under way on the Glass on Silicon program is still focused on implementing process technology, and on achieving a good control of design tools and characterisation of basic building blocks described above, a few optoelectronic module prototypes have already been developed for specific applications, by using a combinations of available active and passive optical functions

5.1 Integrated optical transmitter and front-end receivers

The compact and reliable structure of PIN-PAC and Laser-PAC is ideally suited for realising an hybrid optoelectronic IC, by mounting on the same substrate, or on a ceramic support, the required electronic circuits. In the case of the receiver, the structure (fig.14) includes a PIN-PAC photodetector and a custom IC for preamplifier, AGC and clock recovery functions:

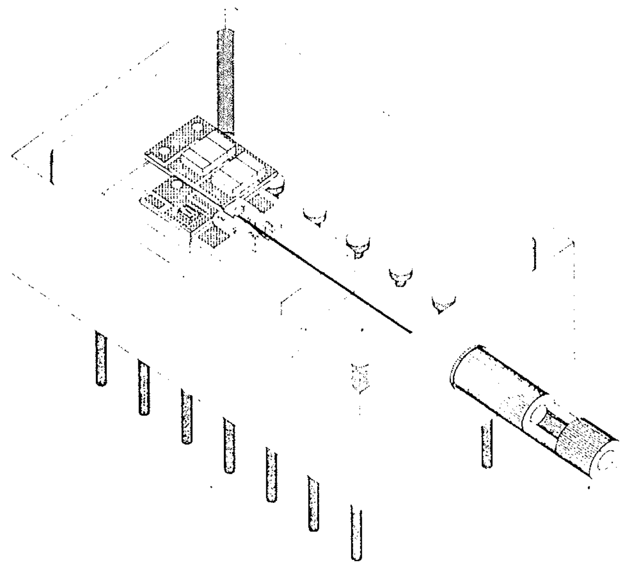

Fig. 14: SDH receiver

Housing is provided by a 2 x 1 cm package with a pig-tail. The transmitter includes a Laser-PAC mounted on a ceramic substrate with a custom IC for laser driver and supervisory and control functions, in the same housing as above. Both units' specifications are compatible with STM1 Synchronous Digital Hierarchy standard for 155 Mbit/s operation. For stand alone PIN- PAC and Laser-

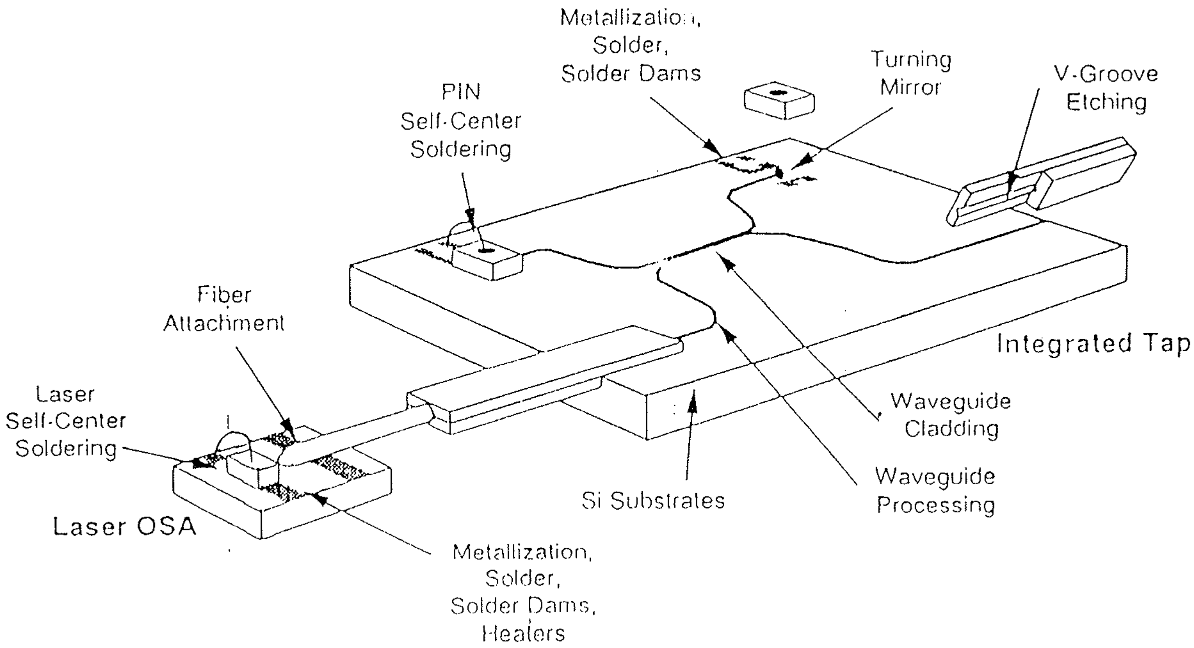

Fig. 15: Bidirectional operating module

PAC devices bandwidths in excess of 1 GHz have been measured, essentially identical to the laser and PIN original bandwidth characteristics.

5.2 Bidirectional optical transceiver

Bidirectional transmission of two carrier wavelengths on the same optical fibre has been considered by several RACE projects to be a viable solution for reducing cost in the implementation of the Broadband Access Network. Bidirectional transmission may be considered as a specific case of WDM principle, and therefore the development of an integrated bidirectional module has been chosen as a significant test vehicle to validate the Glass on Silicon technology with respect to the process capability of hybrid integration of several functions. At present, these functions are the wavelength demultiplexing, the monitor photodiode, the line receiver photodiode, the "V-groove" coupling of the output/input optical fibre and do not include the laser transmitter. A Laser-PAC equipped with a very short (a few mm) pig-tail can be coupled to a "V-Groove" etched into the module. The structure of the bidirectional module (apart from the transmitter side), is very similar to the scheme illustrated in fig. 2, and it is shown in fig. 15.

The optical bidirectional link is equipped with two complementary transceivers for each line termination. In particular data from the network (upstream) side should be transmitted at 1300 nm wavelength and data from the customer access (Downstream) side at 1500 nm wavelength. Also the data rate may be asymmetrical. (622 MBit/s upstream and 155 MBit/s downstream)

The WDM function is realised by a Mach-Zehnder interferometer, which provides enough isolation from optical cross-talk (>20 dB) to achieve the required Bit Error Rate on the line terminal; one of the WDM branches also provides the signal for the monitor photodiode. Electronics functions (Laser driver, PIN preamplifier and control circuitry) are realised with bare IC chips, mounted near the optoelectronic module on a ceramic thin film substrate. Layout design to mount these ICs directly on the Glass on Silicon substrate is under study, in particular to evaluate electrical cross-talk problems. The hybrid integrated circuit, including electronic functions, is housed in a 24 pin Dual in Line package.

6. CONCLUSIONS

Features of a new approach to the development of hybrid integrated optical circuits have been presented, taking into account material deposition processes, packaging and assembly aspects, and preliminary results on prototype design and characterisation. Main achievements reported to date include the simulation and design of several passive optical components, whose performance has been experimentally tested with good overall results. A sufficient set of CAD rules and basic building blocks have been established and experimentally assessed to make possible quick end efficient design of more complex functionalities. On the other hand, the high degree of process reproducibility, tested with good statistical accuracy, makes us confident that the technology is sufficiently stable and controlled to allow a pilot production line deployment, which would be in full operation by mid 1995. To our knowledge, this is the first industrial initiative in Europe for a product development which may lead to a significant breakthrough in the field of optoelectronic component manufacturing and optical communication system technology.

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REFERENCES

/1/ "New technology for reduction in cost and size of silica guided wave component", K.Imoto and A.Hori, Electronics Letters Vol.28 No.17, 13th August 1992.

/2/ "Optimum planar bends", C.Dragone, Electronics Letters Vol.29 No.12, 10th June 1993.

/3/ "A four channel optical waveguide multi/demultiplexer for 5 GHz spaced optical FDM transmission", Kyo Inoue et al, Journal of Lightwave Technology Vol.6 No.2, February 1988.

/4/ "Efficient multichannel integrated optics star coupler on silicon", C.Dragone et al, IEEE Photonics Technology Letters Vol.1 No.8, August 1989.

/5/ "Efficient NxN star couplers using Fourier optics", C.Dragone, Journal of Lightwave Technology Vol.7 No.3, March 1989.

/6/ "Efficient NxN star couplers based on Fourier optics", C.Dragone, Electronics Letters Vol.24 No.15, 21st July 1988.

/7/ "Silica based optical matrix switch with intersecting Mach-Zehnder waveguides for larger fabrication tolerances", M.Kawachi et al, OFC/IOOC '93.

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