

Optical interconnections embedded in flexible substrates

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The need for flexible electrical circuits has increased significantly over the past few years. This paper focuses on the integration of optical data interconnections in such flexible substrates. Optical waveguides, micro-mirrors and opto-electronic chips are embedded and stacked between two flexible Polyimide layers to increase the mechanical stability and the reliability. Three different optical materials (TruemodeTM Backplane Polymer,Ormocer[®] and Epoxies) have been studied as well as different schemes for applying the Polyimide layers (spin-coating and lamination). Ongoing research focuses on the embedding of opto-electronic components and the mechanical- and optical characterization of the module.

I. Introduction

The ever increasing telecommunication sector results in a continuously growing demand for higher communication speeds and data-rates, forcing the step towards optical data transmission. This step is already established for long distance communication, but the increasing density and integration of electronic components on boards forces the market to integrate optical interconnections on the boards.

Together with this trend, the demand for flexible substrates for electronic applications has doubled in the last 5 years [1]. Because of their flexible behavior, the use of these substrates can significantly lower the over-all substrate thickness and weight. Moreover they can ease the assembly, increase the module compactness and can be applied to a curved surface, and even to a dynamic one.

Both increasing trends and needs will result in applications which combine the advantages of optical interconnections and flexible substrate technologies.

This paper focuses on the fabrication of flexible substrates with embedded active opto-electronic components and passive optical interconnections based on multimode waveguides, 45°-turning mirrors and aligning structures. The definition of these structures is done by photolithography and laser ablation. Later on, the fabrication of a proof-of-principal demonstrator is intended, in means of a functional alone-standing opto-electrical flexible module.

II. Materials

The material for the optical transmission medium needs to show low light propagation losses for the common wavelengths for data communication (850 nm) and telecommunication (1.3 or 1.55 μm) and must have the right properties in means of UV-crosslinking ability, spin-coating, temperature- and chemical resistance and mechanical brittleness.

Truemode Backplane™ Polymer [2], Ormocer® [3] and Epocore are materials which meet these requirements and have shown good results when applied on rigid substrates in the past [5].

The material for the flexible substrate itself is Polyimide (PI) which is the dominant material in the flexible circuits industry because of its good electrical, chemical, temperature and mechanical behavior [4]. Precautionary steps had to be taken to assure the adhesion of the PI with the optical materials because of the chemical inertness of Polyimide (PI).

III. Stacking of optical- and Polyimide-layers

The creation of waveguides consists of the stacking of an undercladding-, core- and uppercladding layer by spin-coating. The optical materials are however not flexible and strong enough to be bended without cracking or damaging. Therefore these layers are sandwiched between two spin-coated Polyimide layers, one at the top and one at the bottom, which absorb all stress and pressure during bending, protecting the inner optical layers from breaking.

Stacking of materials with such a different chemical and mechanical behavior demands special measures like CTE (Coefficient of Thermal Expansion) matching to avoid curling and bad adhesion, and low cure-temperatures for the PI to protect the layers underneath from reaching their glass transition temperature.

As an alternative way to fabricate the stack, lamination of the optical layers between prefabricated commercially available PI-foil was proposed and studied. This method has the advantage that the PI-foil and the optical layers can be handled and cured separately since the lamination step is one of the last steps in the process flow. A semi cured adhesive, fixed on a ceramic substrate by dubbelsided tape is used as a carrier for the spincoating of the optical layers and acts as a release layer later in the process by peeling of this adhesive.

When creating the stack special care must be taken to ensure no outgassing of remaining solvents in underlying layers appears during cure steps.

IV. Fabrication of passive optical interconnections

A. Fabrication of optical waveguides

Creating a core transmission channel, isolated inside a bulk cladding material with a lower refractive index results in an optical waveguide which captures the light due to total internal reflection.

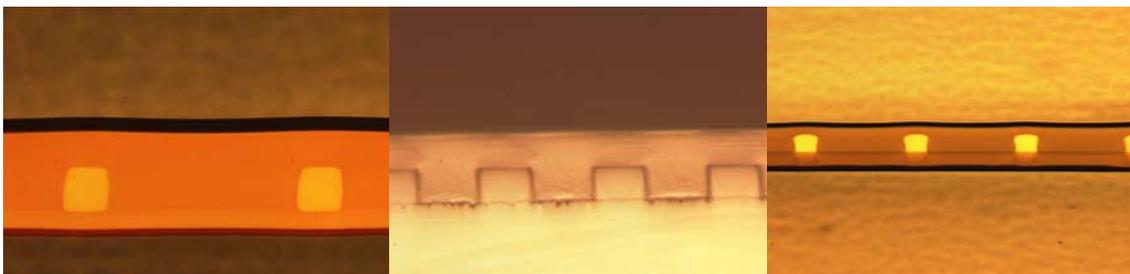


Figure 1: Complete stack with photolithographic waveguides in *left*: Ormocer®, *middle*: Epocore (on FR4-material) and *right*: Truemode Backplane Polymer™



Figure 2: Complete stack with laser ablated waveguides in Truemode Backplane™ Polymer, using a 248 nm wavelength Kr-F Excimer laser, bended with a radius of 1cm.

This isolation can be done by patterning the core-layer with a standard photolithographic process with selective exposure of the waveguides to UV-light (Figure 1) and in an alternative way by laser ablation, removing the core-material at both sides of the waveguide (Figure 2).

B. Fabrication of 45 degrees out of plane turning mirror

The data-carrying light can be vertically coupled in- and out of the waveguides with 45 degrees out of plane deflecting micro-mirrors, terminating the waveguides and connecting them with laser diodes, receivers, optical fibers, open air or optical elements. These mirrors are realized by laser ablation with a Kr-F Excimer laser (248 nm wavelength) [5].

C. Fabrication of alignment structures for a proof-of-principle demonstrator

This research not only focuses on the optical assembly of flexible circuits but the combination of optical and electronic assembly on the same module. This means that the positioning of the VCSEL's and receivers on one hand and optical fiber-arrays, optical elements and deflecting micro-mirrors on the other hand is crucial. Alignment structures like alignment holes, mechanical stand-offs and fiducials are therefore needed and fabricated using the laser ablation technique .

A proof-of-principle demonstrator will be fabricated in the future, including all the elements which have been discussed in this paper to create a standalone flexible module with embedded optical interconnections and electrical assembly on top of the Polyimide.

V. Embedding of active optoelectronic devices

Experiments have been done with success to embed ultra thin dummy chips into the optical layers by implementing a cavity with photolithography. Later in the research functional opto-electronic chips, thinned down to 30 μm thickness [6], will be embedded. Micro-via's will be ablated using a frequency tripled Nd:YAG laser (355 nm wavelength) and metallized by sputtering and plating to fan out the contacts on the top PI layer where all other electrical assembly can be done with standard flex assembly processes. The optical layers have proven to stand the temperature cycles during these procedures.

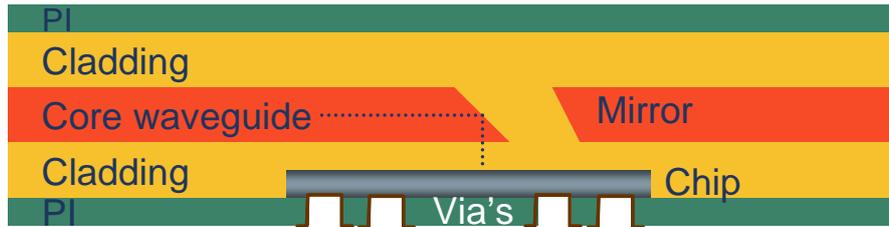


Figure 3: Schematic representation of the embedding, alignment and electrical connection of active components and waveguides in the optical layers.

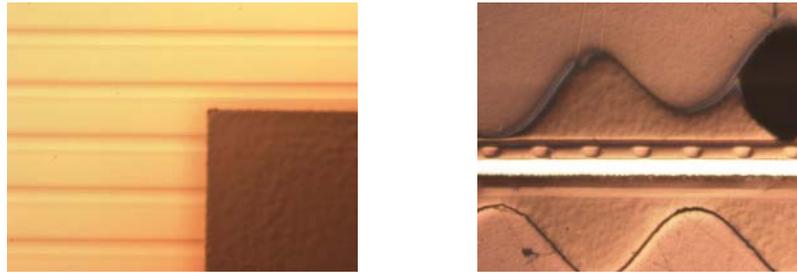


Figure 4: Embedded 5x5 cm² dummy chip and waveguides in Ormocer® material. *left*: Top view *right*: Cross section.

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VII. Conclusion

The increasing need for flexible modules and the integration of photonics on boards results in a challenging and competitive research which combines both needs by embedding passive optical interconnections and active optoelectronic devices on flexible Polyimide substrates.

A complete autonomous opto-electrical and flexible module will be demonstrated.

References

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