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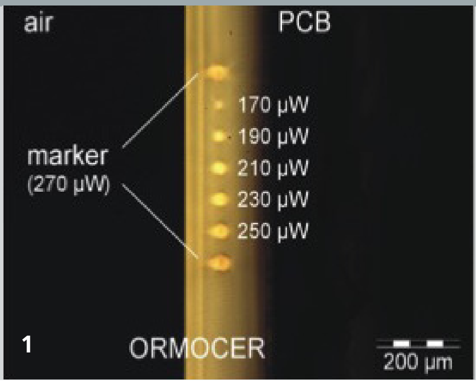

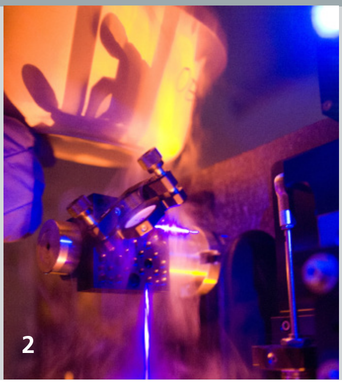

1 *Cross-section of waveguides written with TPA technology in ORMOCER® photoresist (Source: Proc. SPIE 7053, Organic 3D Photonics Materials and Devices II, 70530B (August 27, 2008); doi:10.1117/12.798817)*

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TWO-PHOTON POLYMERIZATION

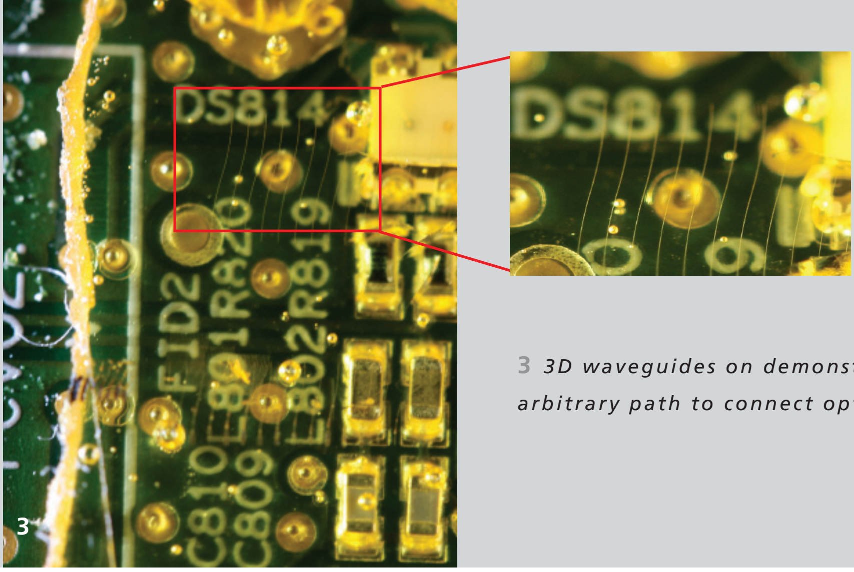
FOR APPLICATIONS IN OPTICAL DATA TRANSFER

As the processing power and consequently the desired bandwidth in PCs, data centers, high performance computing systems as well as in mobile applications increases according to Moore's law, the data transfer between components on different length scales might soon become a bottleneck for future applications. This is due to strong crosstalk and attenuation of electrical interconnects (copper) which can no longer keep pace with Moore's law. While optical data transfer nowadays is well-established in long distance datacom like in the submarine cables or fiber-to-the home, electrical interconnects still dominate at on-chip or chip-to-chip levels. Obviously, it is necessary to shift to optical interconnects even at shorter length scales, such as the board-to-board, the chip-to-chip or even the on-chip level.

However, optical integration is more complicated than electrical interconnection: Accurate alignment is a critical parameter as in conventional processes the waveguides are manufactured before the assembly of the electro-optical components. The conventional process chain to manufacture polymeric waveguides is cumbersome as it requires up to 20 individual steps for material application, illumination, development, baking etc. This comes along with substantial economical as well as ecological impact. Two-Photon Processing on the other hand, can circumvent these processing constraints by entirely remodeling waveguide processing.

Concept of TPA waveguide fabrication

In Two-Photon Absorption (TPA) waveguide fabrication, tightly focused femtosecond laser pulses are used to locally boost the refractive index of the polymer. This modification of refractive index is confined to the focal volume which can be moved in 3D space in order to create waveguides and consequently optical interconnects between arbitrary trajectories. The induced contrast in refractive index is permanent – when



3 *3D waveguides on demonstrator PCB. Optical links can follow an arbitrary path to connect opto-elec-tronic components*

appropriate materials – such as specially developed ORMOCER®s – are employed. TPA waveguide processing offers a variety of advantages over conventional patterning technologies:

- Few process steps needed:
  - ⇨ application of material
  - ⇨ pretreatment
  - ⇨ femtosecond laser inscription of waveguide
  - ⇨ final temperature treatment
- Only one material is used for planarization, core and cladding (+ dielectrics)
- Different active and passive electronic/optical (EO) components, such as laser diodes, photodiodes, fibers, gratings etc., can be connected easily
- Fabrication of waveguides after assembly of electro-optical components ⇨ arbitrary positioning of the electro-optical components in 3D space
- Cross-section of the waveguide can be adjusted
- High bandwidth
- The waveguides fabrication process is compatible to the PCB process chain
- Apart from waveguide even more complex index structures are possible
- GREEN process: Not only because optical data transfer is less power consuming than electrical data transfer, but also because TPA processing saves huge amounts of energy and chemicals due to the low number of necessary process steps

Using TPA technology, the processing of waveguides creates benefits in terms of ecological and economical aspects.

ORMOCER®

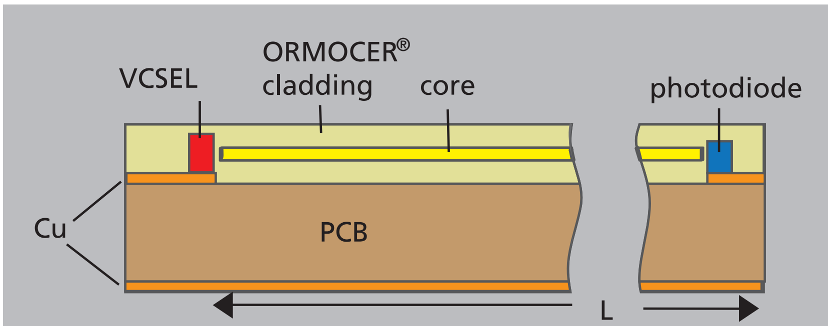
ORMOCER®s – inorganic-organic hybrid polymers – are used as waveguide material. This material class shows superior optical properties in terms of low absorption at datacom wavelength and adjustable refractive index. Moreover, the material excels by a very high reliability with respect to aging effects. The material can be designed to show no yellowing or mechanical degradation even at elevated temperature or harsh conditions due to the fact that the inorganic and the organic network chemically strengthen one to each other.

ORMOCER®s are synthesized by hydrolysis and polycondensation reactions of alcoxysilane precursors. The synthesis products is an organically functionalized inorganic network which is responsible for the glass-like properties of the material. This liquid resin can be processed similar to purely organic photo resists by UV lithography, TPA processing, or thermal treatment. Mainly the choice of precursors but also the synthesis and processing conditions determine the ORMOCER® properties.

Consequently, ORMOCER®s are a material class of high performance photoresists which can be tailored to application-specific needs.

We offer

- Studies on waveguide fabrication for the formation of optical interconnects
  - ⇨ Optimization of processing parameters
  - ⇨ Adjustable waveguide geometries
  - ⇨ Acceleration of throughput
- Material formulation
  - ⇨ Materials ready for permanent index patterning
  - ⇨ Adjustable optical and mechanical properties
  - ⇨ Characterization of materials by optical and spectroscopic methods
  - ⇨ Aging studies



Schematic illustration of TPA waveguide process