Integrated optical interconnections on printed circuit boards

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A paradigm shift in production methods for optical waveguides could make the technology more cost-competitive.

The problem of how to embed optical connections in printed circuit boards (PCBs) has been an area of intense investigation since the 1980s. Approaches to solutions include materials, process technology, integration concepts, and connecting active components to waveguides. These methods generally involve cladding/core/cladding structures and a series of processing steps, independent of the details of the waveguide configuration. Although the resulting optical performance is generally adequate, all the solutions suffer from the strong competition of electrical waveguides, which are commonplace wherever wiring is used to connect electrical components.

In view of the anticipated need for optical waveguide technology, its commercial success has so far been limited. Although the technical feasibility is undisputed, customer applications determine the critical parameters for making the right choices for one or the other solution. Aside from performance standards, one particularly critical requirement is straightforward integration of old and new technologies without the need for major or even minor changes to the existing electrical design. While this is easier said than done, it is likely to be one of the success factors for the implementation of optical PCB technology.

Several uses have been identified that call for different solutions for providing optical waveguide technology. The most important parameter in each case is the cost of manufacture and assembly.

Current work

To address these practical limitations, we came up with a new concept for manufacturing optical waveguides that might well be considered a paradigm shift in the field and could potentially allow cost-competitive optical PCBs. Essentially, we wished to avoid the high-precision assembly process for the optical component needed for efficient coupling of the waveguide to the active components. Eliminating this expensive step should increase the chances of meeting cost targets.

The idea is to embed the laser and photodiode components on inner layers of PCBs and link them with optical waveguides. The first step is to place the parts using standard precision SMT (surface mount technology) assembly equipment. The second step is to create the waveguides.

The process for writing the waveguides exploits a phenomenon from nonlinear optics called multiphoton absorption. The effect is used to initiate polymerization of material suitable for light transmission in an arbitrary volume within the bulk of the material, defined by the focus of the curing laser. In contrast, normal UV exposure permits defined structures only in the xy plane, whereas the z direction is always fully cured.

Multiphoton processing can in principle be applied to any material that can be polymerized with the use of an appropriate laser source. However, a number of challenges need to be overcome before this technology can be fully realized. These challenges include the development of suitable laser sources, the optimization of the polymerization process, and the integration of the waveguides into existing PCB designs.

Figure 1. Eye diagram of an optical waveguide made with two-photon absorption at 3Gbit/s. Photo courtesy of AT&S AG.
ate starter. In the present work, the multiphoton process uses two photons with a wavelength of 800nm, which allows an effective energy input of a single photon at $\lambda = 400$nm for triggering the polymerization reaction. This is equivalent to using UV light at $\lambda / 2 = 400$nm, and accordingly the method is known as two-photon absorption (TPA).\(^3\)\(^4\) Materials suitable for TPA structuring\(^5\)\(^6\) as well as applications using the technique, are described in the literature.\(^2\)\(^7\) A comprehensive overview is presented elsewhere.\(^8\)

Because TPA allows curing within the bulk, the optical material can be applied to the specimen and the waveguide structured without need of further development or application of cladding materials. The polymerization reaction increases the refractive index of the waveguide $n_{w}$, which is essential to achieve a functional optical waveguide. Following TPA, the optical material is thermally cured and UV flood-exposed, which results in full curing. In this process, the optical density of the surrounding cladding material, $n_{c}$, is also increased. The goal is to arrive at a situation where $n_{w} > n_{c}$ remains true by tailoring the conditions of the two processes. While the effect has been demonstrated and yields a functional waveguide configuration, as depicted in Figure 1, further optimization of the materials continues in order to increase the final difference in refractive indices of the finished product. Efforts are under way to improve the mechanical performance of the optical materials for application scenarios suited to commercialization in various fields of consumer electronics.

Part of the work described in this paper has been done within the Integrated Optical Interconnections project of ISOTEC (Integrated Organic Sensor and Optoelectronics Technologies) funded by the Austrian Nano Initiative.\(^9\)

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References