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Abstract of PhD Thesis

INTEGRATED OPTICAL INTERCONNECTIONS ON CERAMIC SUBSTRATES

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My PhD Thesis consists of six chapters. In chapter 1, the rapid development of electronics over the last 60 years is described. Development of electronic components including transistors, allows the production of smaller and smaller components that occupy less space and consume less energy. As a result, the density of transistors, their number on the same surface of the semiconductor structure, increases rapidly. The number of transistors on a chip grows exponentially, as fast as the demand for power delivered to the processor, despite the fact that a single transistor consumes less energy. In addition, the development of integrated digital systems requires the processors to have faster clock rate and the current development of technology allows its annual growth by 10-13%. However, it is estimated that the real annual increase will not exceed 5-8% due to significant increase in the generated thermal power. Increasing the frequency of the electrical signal transmitted in a metal conduit, in addition to the growth of thermal power, causes other undesirable implications: the skin effect, crosstalk and electromagnetic interference. Those problems caused more and more companies and research centers to conduct research into finding a new concept for development of integrated circuits.

The optical interconnections, compared to the electrical connections, have a number of advantages related to the transmission of signals at high frequencies. The most important are: the lack of generation and resistance to electromagnetic interference, extremely high bandwidth, lack of power problems and high temperature of the system. All these advantages have made a lot of people working on the introduction of optical connections to the commercial electronic integrated circuits. Optical interconnection can be divided into 3 parts. The first part is the control and power supply circuit with a light source. The second part includes an optical detector system with the possible amplifier. The last part is a transmission medium. Typically, this is a cylindrical optical fiber made of glass or polymer, planar waveguide and, less frequently, the air.

In the second chapter of this work, active and passive components are described in detail.

The third chapter of my PhD thesis contains a review of literature illustrating the development of concepts and various solutions of optical interconnections introduced into the electronics. Various methods are described for the coupling of active elements with different types of optical fibers: standard glass optical fibers, the planar optical fibers and optical fibers made of polymers and silicon. Described coupling techniques differ from each other. The simplest method is the direct coupling called butt coupling. More advanced methods involve wedge couplers, tapered couplers or optical systems built with microlenses or micro-mirrors.

There are many types of optical fibers that differ in shape, size or material from which they are constructed. Each of them has different mechanical and optical parameters. To correctly choose a fiber for an application, the conditions under which the optical fiber will operate must be determined first. In the fourth chapter of this dissertation, the research that made it possible to find the best optical fiber for integrated optical interconnects on ceramic substrates is presented. The best candidate turned out to be the multimode optical fiber defined in 2010 by the ITU -T and IEC SC86A G.561.B3 WG1 standards. This optical fiber belongs to a group of optical fibers resistant to bending of OM4 class. Its numerous advantages: a relatively large core diameter, the possibility of using micro-lenses to couple active elements to optical fiber, low cost, resistance to high temperature and the ability to bend it without significant power losses of the transmitted signal, determined the choice.

The fifth chapter presents the research related to the integration of optical fiber lines in ceramic substrates. Different types of glass multimode optical fibers were integrated in the grooves of different shapes, to determine the most optimal configuration of the fiber and the substrate. In the fifth chapter the research related to the transmission of signals through integrated in the ceramic substrate optical fiber lines was described.

Choice of the appropriate light source and detector, as well as work related to the integration of active and passive elements on ceramic substrates are presented in the sixth chapter of my dissertation. Three different methods for coupling optical fibers with active elements were tested. During the integration of optical interconnection to ceramic substrates the angled-ball-lensed optical fibers has been chosen to couple active elements to optical fibers. Their application has two main advantages: they allow to change the direction of the light beam and allow, thanks to the knowledge of their focal, to precisely indicate the distance between the coupled active elements and optical fiber.

The work related to the design and realization of integrated optical interconnects on ceramic substrates was successful. Active and passive elements were integrated into ceramic. An innovative method of coupling active elements to optical fiber was developed as well. 2GHz signals were sent through integrated optical lines. The obtained results prove the correctness of the posed thesis of my PhD dissertation.