

TriPleX™ Planar Lightwave Circuits

XiO Photonics offers solutions in passive optical components for the communication business, both in integrated optics as well as passive fiber optics technology. With over 10 years of experience, XiO Photonics' products range from current standard telecommunication components to next-generation components for the optical networks of the future.

Planar lightwave circuits

Planar lightwave circuits (PLCs) have broad application in areas ranging from space exploration to telecommunications. For example, PLC technology can be used in optical true-time delays for phased array antennas. True time delays enable simpler, less-expensive control systems. PLCs also have utility in integrated-optic communication network components, such as optical add-drop multiplexers (OADMs). These devices are the key to achieving high system functionality in the next generation of fiber-to-the-home networks. Finally, PLCs are well-suited for use in emerging sensing applications, since they enable integration of mode filters, interferometric principles, and other optical functions essential to compact and highly sensitive and selective devices.

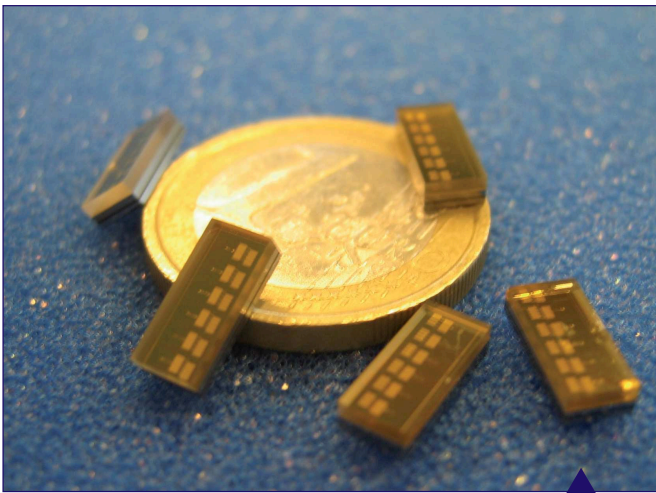


Figure 1. Example of optical integration, VLSI optics chip with six 1x4 ROADMs on a single chip

Figure 1 shows a chip that integrates different optical functions (VLSI optics) using PLC technology. Integrating multiple functions has several advantages over discrete solutions, such as lower costs, easier mass production, system stability, and small form factor (footprint area and volume).

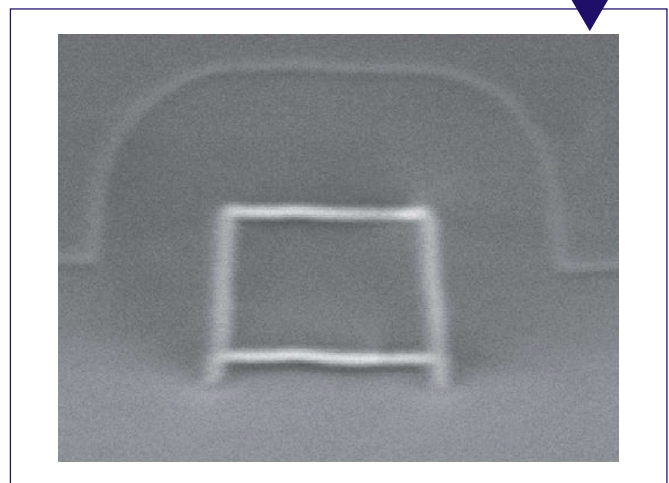
Achieving integration in the field of optics requires addressing a number of issues. First, it is desirable to achieve tight waveguide bends to enable small structures and reduce required circuit area. To achieve this, the technology must offer high refractive index contrast between the light-guiding layer and the surrounding materials. Second, increased functionality must be achieved without

incurring higher optical loss. Third, polarization dependency and polarization mode dispersion must be well-controlled. Finally, transparency over a large wavelength range is desirable to guarantee the flexibility required for an industrial standard for integration.

Design by geometry

In order to address these issues, TriPleX™ waveguide technology has been developed. This patented technology enables a new class of integrated-optic planar lightwave circuits and uses low-cost, CMOS-compatible technology. The waveguide structure consists of alternating stoichiometric layers of silicon nitride (Si_3N_4) and silicon dioxide (SiO_2) layers, which are formed using Low-Pressure Chemical Vapor Deposition (LPCVD). The silicon dioxide layer is patterned to form an inner-core, which is surrounded by an outer core that comprises the Si_3N_4 layers. TriPleX™ waveguides can be easily designed to be fully transparent for wavelengths from 400 nm up to 2 μm . In addition, TriPleX™ waveguides can be designed for operation as medium- and high-index-contrast waveguide structures.

Figure 2. SEM (Scanning Electron Microscope) image of the cross section of a box-shaped waveguide.



TriPleX™ waveguide technology has the potential to become the standard for industrial integrated optics in visible and infrared light applications.

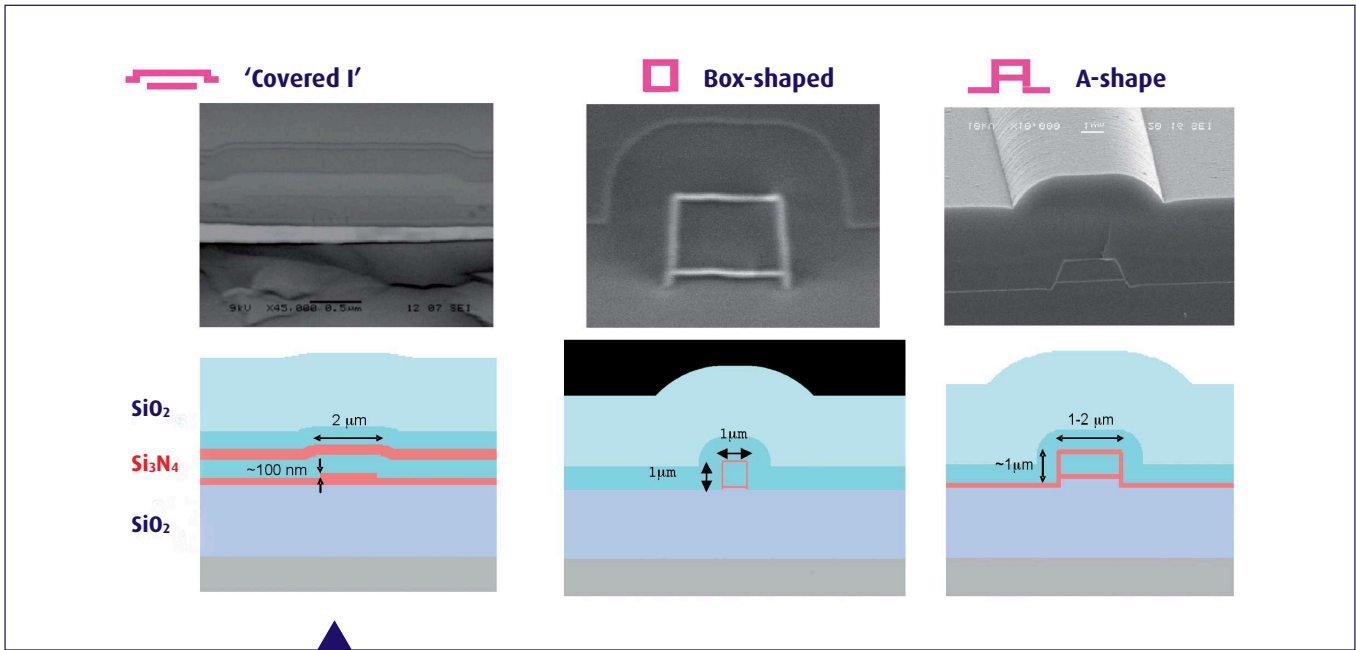


Figure 3. Cross-sectional views of three representative TriPlex™ waveguide designs demonstrating the geometrical design flexibility.

Waveguide operating characteristics, such as modal birefringence, minimum bending radius and insertion loss, depend only on the geometry of the waveguide layer structure itself. The structure is fabricated on a conventional substrate, such as thermally oxidized silicon or glass. A typical composite core has a cross-sectional area of approximately $1 \mu\text{m} \times 1 \mu\text{m}$; however, each specific design depends strongly upon its intended application, see Figure 3.

The stoichiometric nature of TriPlex™ waveguide materials leads to a vast design freedom and extremely stable performance, since the properties of stoichiometric materials are always consistent. The fabrication process is suitable for batch fabrication and highly cost-effective. In many cases, only one photolithography step is required. In addition, a proprietary tapering technology can be used to combine chip areas having high index-contrast with areas of low-index-contrast. As a result, the poor fiber coupling associated with high-contrast waveguide technologies of the past can be avoided.

Results

The Table provides characteristic operating performance data for a single-mode boxed-shaped TriPlex™ waveguide, designed for telecom applications. Optical attenuation, as well as polarization-dependent loss, can be kept to levels normally associated with

Group Birefringence (B_g)	Channel Attenuation (dB/cm)
$< 1 \times 10^{-4}$	< 0.10
Polarization Dependent Loss (PDL) (dB/cm)	Insertion Loss (IL) (no spot size converter) (dB)
< 0.10	0.15 (3.6 μm MFD)

low-contrast conventional waveguides. In addition, the coupling efficiency of a TriPlex™ waveguide to an optical fiber can be high, due to a close match of mode profiles between the waveguide and the fiber.

Conclusion and summary

TriPlex™ planar waveguide technology offers a powerful PLC platform, particularly for applications that require coupling into and out of an optical fiber network. It enables a new design approach and opens up revolutionary new application fields. TriPlex™ waveguide technology is a significant advance over conventional PLC technology in that:

- Fabrication is based on low-cost, batch-fabricable, CMOS-compatible technology and simple contact mask lithography.
- The constituent layers that form the waveguide-structure are stoichiometric in composition and stable from run to run and over time and temperature.
- Optical performance of the integrated optical circuits is controlled only by the geometry of the waveguide structures of the functional building blocks.
- Proprietary tapering technology enables efficient fiber-chip coupling combined with a small footprint.
- TriPlex™ planar waveguides are fully transparent for wavelengths from 400nm up to $2 \mu\text{m}$, thereby enabling new visible and infrared light applications.
- TriPlex™ waveguide technology has the potential to become the integration platform for not only in telecommunications but also in the newly emerging areas of data communications, medical diagnostics, health care and consumer entertainment.

[1] U.S. Patent Number: 7,146,087, "Low modal birefringent waveguides and methods of fabrication", Issued 12/5/2006.

[2] R.G. Heideman, et al, Proc. ECIO 2007 Copenhagen, p.WB0.

[3] F. Morichetti et al, Journal of Lightwave Technology, Vol 25, No 9, September 2007.

[4] W.Hoving et al, SPIE Newsroom, 10.1117.