Strip-loaded horizontal slot waveguide: confinement with negligible losses

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From optical computing to data storage, from bio-sensing to quantum applications, integrated photonic nano-structures in waveguides are widely used. However, an ideal platform is still to be found to provide, at the same time, an easy fabrication, a low power consumption, low losses, and wavelength scalable devices. A promising solution is presented here.

More than forty years ago the concept of strip-loaded waveguides was proposed by Furuta *et al.* [1]. It consists of a slab waveguide and a lower refractive index material deposited on top of it. The top layer is patterned in order to create an effective index increase providing lateral confinement for the guided light. Such a channel waveguide enables low-loss waveguiding with many materials. In 2004, Almeida *et al.* impacted integrated optics by proposing the idea of a waveguide where light is mostly confined in a low index sub-wavelength gap: the slot waveguide [2]. Since then, tremendous efforts have been put on research in this field to push integration to its limit.

Both of the above mentioned waveguides have unique properties that researcher are seeking in integrated optics: the quasi-independence of the substrate and the low propagation losses of the strip-loaded waveguide, and the huge light confinement of the slot waveguide. Unfortunately, both have drawbacks that restrain their applications. A strip-loaded waveguide has a low refractive index contrast, and the slot waveguide is usually highly lossy.

We present here a novel waveguide type combining the advantages of the two structures, while minimizing their negative aspects: the strip-loaded horizontal slot waveguide [3]. Two rails of a high refractive index are separated by a few tens of nanometers thin layer of a low refractive index medium. This slab structure provides vertical confinement of light. All the materials are atomic layer deposited ensuring minimal roughness at the media interfaces. On top of the multilayer a strip is created using a polymer electron beam resist to provide a lateral confinement. A schematic of the structure is presented in Fig. 1a).

Such a channel waveguide enables localization of the quasi-TM fundamental mode, see Fig. 1b), far enough under the surface to yield a negligible effect of the surface roughness. This results in very low scattering losses. The loading strip can be pattern with any geometry leading to a possibility for a variety of functions, e.g., filters and cavities.

A first experimental demonstration has been done in order to show the response of the device at λ = 1550 nm. The high index material is titanium dioxide (n_{TiO2} = 2.23), the low index material is silicon dioxide (n_{SiO2}=1.444), and the strip is made of a homemade polymer of refractive index (1.547). The rail width is 215 nm, the slot width is 80 nm, and the strip has a thickness of 500 nm and a width of 2 μm.

An SEM picture of the fabricated structure is shown in Fig. 1c). Figure 1d) is a picture of the output optical mode observed with a x40 microscope objective.

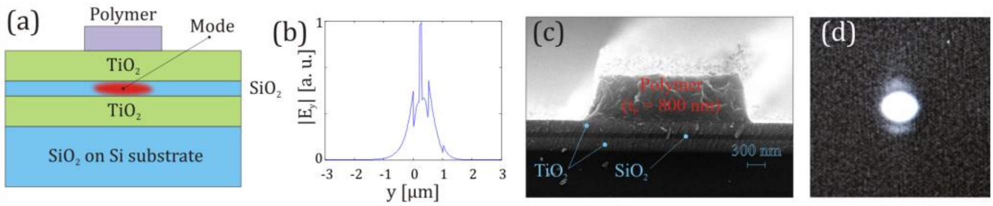

Fig. 1. a) sketch of a strip-loaded slot waveguide; b) profile along the vertical direction of the fundamental quasi-TM mode; c) SEM picture of the fabricated sample; d) picture of the output mode.

In addition to the demonstration of the existence of the waveguide mode by using several experimental techniques, we are also showing the response of a multimode interferometer, a ring resonator, and a Y-junction fabricated on this platform. The preliminary propagation loss measurements revealed losses as low as 2 ± 2 dB/cm, which is rather low compared to other slot waveguide-based structures reported in literature.

References

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