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Realization of a micro-cavity via the integration of Silicon Nitride and Lithium Niobate using micro transfer printing

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Abstract: We combine Lithium Niobate and Silicon Nitride using transfer printing and realize a micro-cavity with an experimentally measured intrinsic Q-factors of 50,000. We believe this is the first realization of such type of a micro-cavity.

1. Introduction

Lithium Niobate (LN) based modulators and switches have been vital to the development of optical telecommunications. However, LN is difficult to process which typically limits applications to the use of bulk crystals. Recent advances in fabrication technologies allowed the realization of lithium niobate on Insulator (LNOI) material, which facilitates the creation of compact integrated devices such as photonic nanowires, micro-disk and micro-ring resonators, photonic crystals, and integrated grating couplers. In this paper, a thermal wafer with thin Silicon Nitride (SiN) top layer from LIONIX was combined with a transfer printed layer of LN to form strip-loaded waveguides that can take advantage of nonlinear optical coefficients of lithium niobate and of the high refractive contrast, low propagation losses and ease of processing of silicon nitride. We developed, fabricated, and characterized a Fabry-Perot (F-P) micro-cavity in such material. The F-P micro-cavity offers a high ease of fabrication, even mode spacing and excellent control over the free spectral range. Distributed Bragg Reflectors (DBR) were formed in SiN using sidewall-width modulated structures with rectangular corrugations (Fig. 1a) to provide mirrors on each side of the cavity. Fig. 1b shows simulated TE mode of the structure.

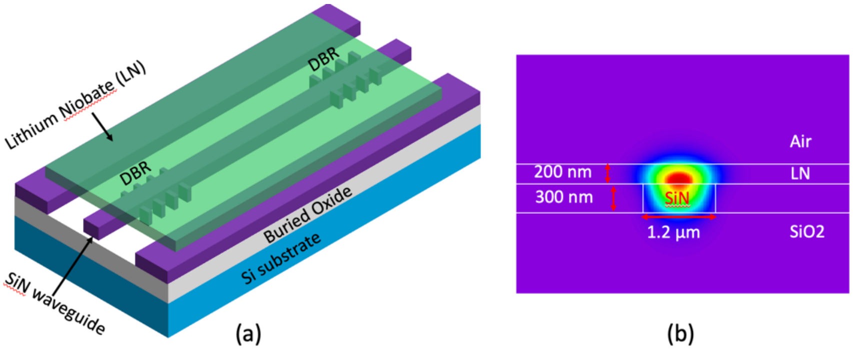

Fig. 1. a) Schematic of the microcavity with SiN and transfer-printed LN b) Simulated TE mode of the structure

2. Fabrication and characterization

The Lithium Niobate (LN) thin film was integrated with the SiN waveguide utilizing micro-transfer printing (µTP). This process involves parallel processing of two separate wafers (LN source and SiN target) before the hybrid integration. Here, the source wafer is a x cut LNOI wafer containing 200 nm LN layer on top of 2 µm buried oxide (BOx), which is used as the release layer. Fig. 2 depicts the schematic overview of our transfer printing process. First, coupons (1.2 mm long and 70 µm wide) are defined by optical lithography followed by inductively coupled plasma (ICP) etching of the LN layer and BOx layer in sequence. Photoresist thickness is chosen in such a way that it can withstand during those two etching steps. A second optical lithography is used to form thick photoresist tethers which will hold the LN coupons in place during the undercut. The sample is immersed in buffered oxide etchant (BOE) to remove the BOx layer beneath the LN device layer. After the undercut process the sample is dried by N_2 blow after DI rinse. No coupons collapsed due to capillary action of water implying that the resist tether is mechanically robust. The target wafer contains 300 nm of PCVD SiN waveguide layer on top of 3.3 µm thick buffer oxide. First, SiN is patterned using electron beam lithography. Subsequently, SiN is etched by ICP to form the ridge waveguides and DBRs in one step.

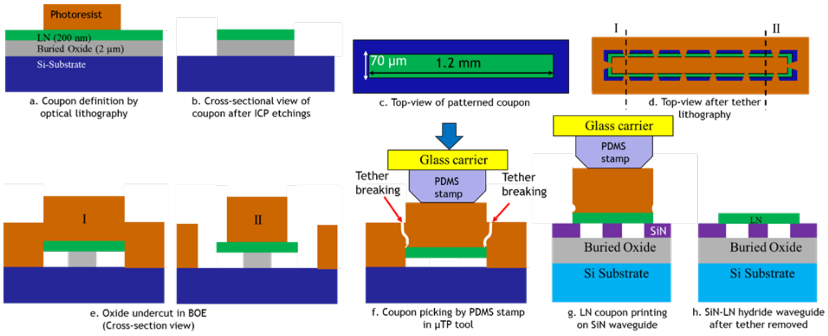

Fig. 2. Process flow of the transfer printing step for the integration of SiN platform with LN

The hybrid integration was realized by transfer printer source coupons on top of the SiN target wafer. As no adhesive layer is used here, the target needs to be cleaned and to present a smooth surface. The target wafer was cleaned in RCA-I solution (NH_4OH: H_2O_2: DI = 1:1:5) at 70ºC followed by DI rinse and oxygen plasma treatment prior to print. The wafers were aligned, and a suitable elastomeric stamp (PDMS) is used to pick and place the LN coupons on top of SiN waveguide. The physics of transfer printing is based on viscoelastic effect of elastomeric stamp [1], which essentially means that the coupon picking speed should be higher than the coupon printing speed. Accurate alignment is not a stringent requirement since waveguide dimension is much smaller than the LN coupon. After printing, the tether resist is removed by oxygen plasma. The optical image of the final devices is in Fig 3a.

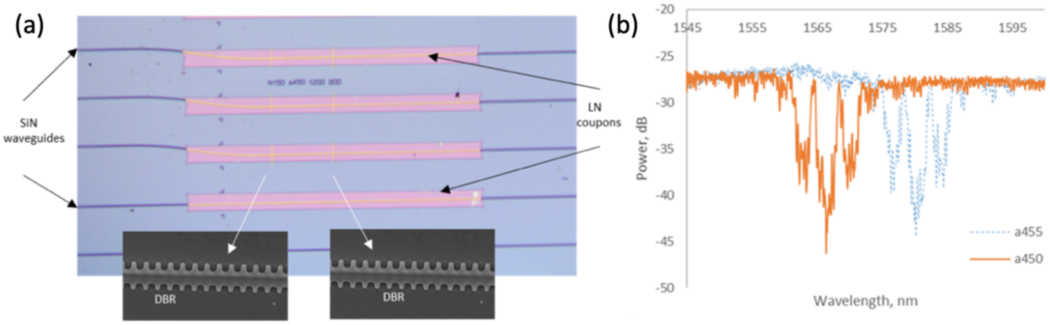

Fig. 3. a) Optical image of the transfer printed LN coupon on SiN waveguide containing the microcavity (inset SEM image showing the DBR structures), b) Transmission spectrum for DBRs consisting of 150 periods (N).

Light with Transverse Electric (TE) polarization from a broad-band source operating between 1520 and 1620 nm was launched into the input waveguide using a lens, another lens collected the light at the output of the device and sent it into a detector. The single bend of radius 100 μm of the input waveguides was also introduced for preventing the direct light from the source from entering the objective lens located in front of the detector. An optical spectrum analyzer was used to record the transmission spectra of devices for different DBR periods with N= 150 mirrors. These are presented in Fig. 3b on a logarithmic scale. Calculated intrinsic quality factor of tested cavities is 52,200, which is at least twice larger of previously reported [2]. The quality factors could be improved further by optimizing fabrication process to minimize scattering losses between LN coupons and SiN waveguides as well as scattering losses of DBRs. In conclusion, we have demonstrated the transfer printing of LN on SiN and demonstrated a high Q-factor micro-cavity. The transfer printing integration strategy allows both materials to be combined without compromises on performance.

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3. References

[1] Meitl, M., Zhu, ZT., Kumar, V. et al., "*Transfer printing by kinetic control of adhesion to an elastomeric stamp*," Nature Materials 5, 33–38 (2006).
[2] M. V. Kotlyar, S. Iadanza, L. O'Faolain, "*Lithium Niobate Fabry-Perot microcavity based on strip loaded waveguides*", Photonics and Nanostructures - Fundamentals and Applications, Volume 43 (100886), 2021.