High-Q Microdisk Resonator on Aluminum Nitride Photonics Platform

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Abstract: A high-Q microdisk resonator is demonstrated on aluminum nitride (AlN) photonics platform on an 8-inch silicon wafer. Multiple modes are observed from spectrum response. A loaded Q of 1.3×10^5 is also reported. © 2024 The Author(s)

OCIS codes: (230.3120) Integrated optics devices; (130.3130) Integrated optics materials.

1. Introduction

Integrated silicon photonics technology has been developed in the past two decades with applications in modern communications and sensing. Compared with the traditional silicon photonics materials including silicon and silicon nitride, aluminum nitride (AlN) has wide transparency window down to the visible spectrum, significant 2^{nd} order nonlinear effect and piezoelectric effect [1,2]. These properties enable advantages for photonic application in the visible wavelength range, generation of entangled photons through nonlinear effect, and opto-mechanic multi-physics coupling. Diverse functional devices have been demonstrated on AlN photonics platform, from quantum emitter [3], Pockels modulator [4], frequency comb generator [5], to UV photodetector [6]. On photonic integrated circuit (PIC) and optomechanical systems, resonators are commonly used to enhance the field intensity in various functional devices such as laser source [7,8], modulator [9], spectrum filter [10], and nonlinear optical generator [11,12]. Microdisk resonator is a key component within PIC and optomechanical systems. Compared with microring resonator with the same size, microdisk resonator enables higher Q since it only has one etched sidewall [13]. Also, a microdisk resonator can support a large number of whispering-gallery modes [13]. AlN-based microdisk resonator with loaded Q of 2.8×10^4 at C-L band has been reported earlier [14].

In this work, we demonstrate a high-Q AlN-based microdisk resonator on an 8-inch wafer. We are leveraging on AlN photonics platform developed in house fabricated using complementary metal-oxide semiconductor (CMOS)-compatible fabrication facilities. The fabricated device is characterized at O-band with multiple modes observed. From the measured passive spectrum response of the device, the estimated loaded Q of 1.3×10^5 is reported. With further analysis on the multiple resonance modes within cavity, the microdisk resonator can be applied for nonlinear optical generation.

2. Microdisk design and wafer-scale fabrication

The microdisk is designed with a radius of 50 µm and a thickness of 500 nm. Two straight bus waveguides, each with a width of 1 µm, are used to couple light into and out of microdisk resonator through evanescent coupling. The gaps between bus waveguide and microdisk are varied between 0.2 to 0.9 µm. The device with 0.4 µm gap has been found to have enough extinction ratio at the resonance wavelength for loaded Q estimation. Therefore, this device is selected for further characterization, with setup and results presented in the coming section. The calculated transverse electric (TE) and transverse magnetic (TM) modes within the microdisk resonator are illustrated in Fig. 1(a). A note worth mentioning is that in actual device, there are multiple modes co-existing within microdisk cavity (as observed in later experiment section) rather than single mode.

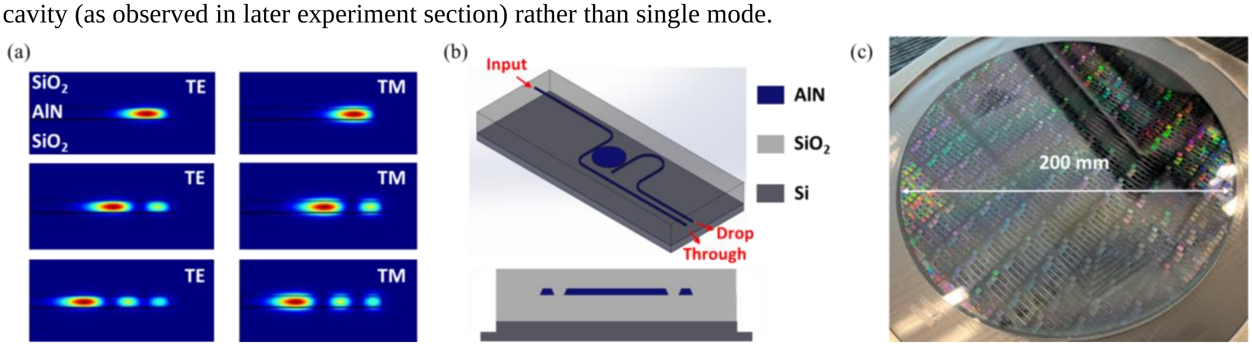

Fig. 1 (a) Calculated TE and TM modes within the designed microdisk resonator. (b) Top panel: schematic of microdisk resonator. Bottom panel: cross-sectional schematic of fabricated device including AlN microdisk, and deep trench for dicing and optical edge coupling. Drawings are not to scale. (c) Photo image of fabricated wafer for AlN photonic platform.

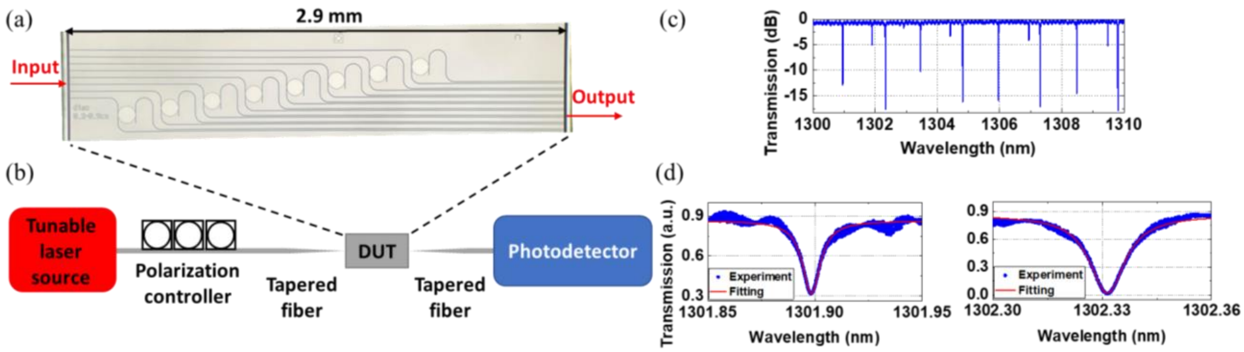

Fig. 2 (a) Microscopic image of microdisk devices with design variations. (b) Schematic of device characterization setup. DUT: device under test. (c) Passive response of microdisk resonator under TM polarization input, measured from the through port. (d) Typical resonance plots in linear scale with Lorentzian curve fitting.

The wafer-scale fabrication process is similar to our earlier report [15]. The wafer is fabricated in CMOS-compatible 8-inch fabrication line. The AlN layer is deposited and patterned. The 3D schematic and cross-sectional schematic of fabricated device including AlN microdisk and deep trench for dicing and optical edge coupling are illustrated in Fig. 1(b) top and bottom panel, respectively. The 8-inch wafer is diced into coupon size for further testing. A photo image of fabricated 8-inch wafer after dicing is presented in Fig. 1(c).

3. Characterization results and discussion

A chip is selected from the central part of the wafer for further characterization. The microscopic image of the device and the characterization setup are shown in Fig. 2(a) and 2(b), respectively. A tunable laser source (Keysight N7776C) in O-band is used as light source. A polarization controller is used to ensure either TM or TE mode is coupled onto the device under test (DUT). To ensure the mode polarization from lensed fiber, a linear polarizer cascaded with a powermeter is utilized before the experiment for calibration. The plot in Fig. 2(c) shows passive response from the through port of DUT under TM input light. Multiple resonance modes can be observed from the optical spectrum. These resonance modes are distinguished based on their free-spectral range (FSR). The resonance modes with lower FSR have the highest extinction ratio of >15 dB. Lorentzian fittings for the resonance modes (around 1302 nm) are plotted in Fig. 2(d) left and right panels, showing loaded Q-factor of 1.3×10^5.

4. Conclusion

In summary, we have demonstrated a high-Q microdisk resonator on AlN photonic platform. The device is fabricated using CMOS-compatible fabrication facilities on 8-inch silicon wafer substrate. The loaded Q of the microdisk resonator is estimated to be 1.3×10^5 based on the experimental characterization under TM mode input light at O-band. With further analysis of multiple resonance modes from the microdisk resonator as future work, the device can be applied for nonlinear optical generation.

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