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Low-loss amorphous silicon carbide photonics and its heterogeneous integration with existing high performance active/passive platforms

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Abstract: In this work, we fabricate and characterize ring resonators on ICPCVD-deposited a-SiC films at a low temperature of 150°C, demonstrating exceptional intrinsic quality factors and low waveguide propagation losses, thus highlighting the potential for a-SiC as a valuable platform for future hybrid photonic technologies.

1. Introduction

The field of integrated photonics has rapidly expanded in recent years, and revolutionized the use of light in computing, communication, and sensing. Impressive performance, for various photonic components, have been demonstrated in platforms such as Silicon-On-Insulator and Silicon Nitride, but the demand for materials that offer tunability, non-linearity and compatibility in integration with III-V devices has led to the exploration of new platforms. One such platform is Lithium Niobate-on-insulator (LNOI), known for its electro-optic properties along with the Pockels effect and high second-order non-linearity [1]. Over the past few years, several research groups have demonstrated tunable linear and non-linear circuits in LNOI platform with remarkable performance metrics. As anew emerging material, Silicon Carbide (SiC), is also gaining attention for its unique characteristics, including a high refractive index, strong second- and third-order optical non-linearities, and a broad transparency window from visible to the mid-infrared range [2]. Amorphous silicon carbide (a-SiC), even though not exhibiting a second-order nonlinearity, has the potential for hybrid integration with lithium niobate, which has a strong third-order nonlinearities, is compatible with CMOS (Complementary Metal Oxide Semiconductor) fabrication processes [3], and can be deposited at low-temperatures via Inductively Coupled Plasma-Enhanced Chemical Vapor Deposition (ICPCVD). An additional benefit of these techniques is the possibility of nitrogen incorporation, making the films conductive and gives the possibility to employ the thermo-optic effect directly within the optical components. The latter makes a-SiC:N thin films a very promising candidate for optical switches, multi-mode interferometers (MMIs), and transistors for on-chip signal processing [4].

2. Low-loss amorphous Silicon Carbide

In recent years, a wide range of deposition techniques has been optimized for high-quality films to meet the requirements of demanding applications such as biological sensing, micro-electronics, and micro-electro-mechanical system (MEMS) devices. To deposit amorphous Silicon Carbide thin films, Low Pressure CVD (LPCVD), PECVD, and ICPCVD techniques have been used, among which PECVD and ICPCVD have been proven to be effective in producing high-quality films for diverse materials used in photonic devices.

In this study, a variety of fabricated devices using ICPCVD a-SiC films at different deposition temperatures were characterized thoroughly to generate statistical data and ensure the repeatability of the results. The highest loaded quality factors were obtained for a deposition with ICPVCD at a temperature of 150°C with devices showing values of $4x10^5$, making it more than three times higher than previous reported results with half the deposition temperature.

3. Hybrid integration with current platforms

The low temperature deposition of a-SiC films, gives high flexibility for integration with other platforms and hence hybrid photonics as well as the possibility to achieve deposition and lift-off as an additive step to existing photonic circuits. Here we show a simple lift-off method and successfully demonstrate fabrication of some of the photonic components (waveguides and ring resonators) using this method.

To achieve low-loss routing of photons in photonic schemes, it is essential to use material platforms that offer high optical quality. Ultralow loss photonics have been demonstrated on thin LPCVD Silicon Nitride platform [5]. We argue that in future combination of a-SiC with SiN thin-films can be utilized to achieve dense integration (offered by a-SiC) as well as ultralow loss large components such as delay-lines in SiN platform. Furthermore, high opto-thermal tuning of SiC and low thermal sensitivity of SiN can be combined on a single chip, offering novel and unique possibilities for sensing application. We demonstrate that tapered waveguides can be used to avoid coupling losses between a-SiC and SiN films. In addition, we will present and discuss our latest progress with SiC/SiN platform.

The combination of amorphous silicon carbide and lithium niobate3is a very promising platform for the development of high-performance tunable photonic integrated devices. Both a-SiC and $LiNbO_3$ possess unique optical properties that can be tailored for specific applications, and their combination offers several advantages such as low insertion loss, high extinction ratio, and high-speed modulation. Furthermore, the amorphous nature of a-SiC allows for easy fabrication and integration with other materials, while the electro-optic properties of LiNbO3 enable efficient modulation of light. We will present our efforts in co-integration of SiC and Lithium niobate photonics.

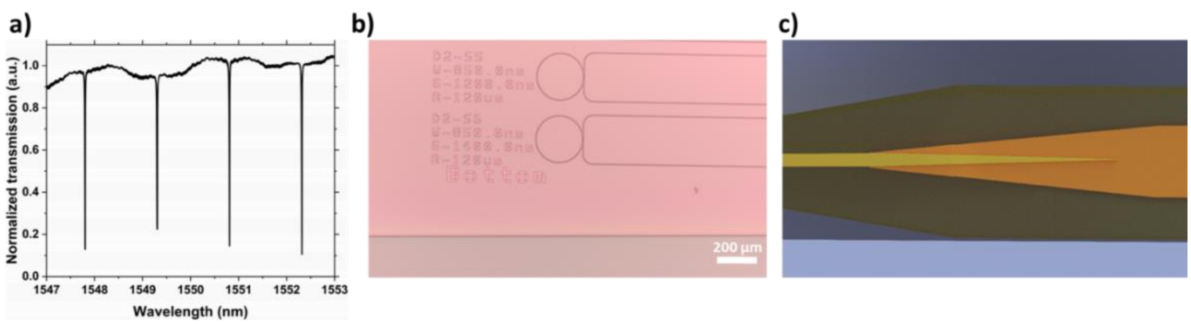

Figure 1. a) Transmission spectrum of a ring resonator with ring radius 100 µm and 0.85 µm gap, b) ring resonators fabricated on a-SiC after lift-off and c) taper design for high coupling efficiency between a-SiC (yellow) and SiN (orange) embedded in a tapered Silicon Dioxide cladding (brown).

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